Innovation Funding Incentive
Annual Report 2008/09
Section 2

Electricity Transmission
R&D Programme Detailed Reports

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National Grid Electricity Transmission (NGET)
R&D Programme Detailed Report

During the financial year 2008/2009 National Grid Electricity Transmission utilised the Innovation Funding Incentive across a number of projects. In accordance with Innovation Good Practice Guide for Energy Networks (ENA Engineering Recommendation G85 Issue2) projects with an annual spend of under £80,000 have been combined with other projects to form programme areas. These programme areas can be seen below and the progress reports can be seen over the next few pages.

National Grid Electricity Transmission R&D Programme areas	
1	Network Design - New Generation
2	Network Design - System Stability
3	New Technology to Enable the Connection of Low carbon Generation
4	Infrastructure development for the electricity transmission network for 2020-30
5	Future Energy Use and Assets
6	Flexnet
7	Efficient Incorporation of Intermittent generation considerations in network design.
8	Condition and Life Extension of Substation Assets
9	Improved Life Cycle Costing Methods
10	Efficient Incorporation of Intermittent generation considerations in network design.
11	On line Monitoring Integration
12	Strategic Asset Management Capability
13	EPRI
14	Substation Compaction
15	Substation Design
16	OMU Top Up tanks
17	Earthing
18	Understanding Conduction Mechanisms in Earthing Systems and Optimisation of Earth Electrode Geometries
19	Transformer Lifetime Modelling
20	Transformer Management
21	Sulphur in Oil Trial
22	Developments in Protection and Control
23	WAMPAC
24	Collapse Prediction on Transmission Networks
25	Digital Control System Upgrade
26	Architecture for Substation Secondary System (AS3) Project
27	Remote Access to POC
28	Cable Asset Life project
29	Cable Development/Protection and Recovery
30	Cable Oil/Ratings and Thermal Data Analysis
31	SODA
32	Tower and Conductor Design, Capability and Maintenance
33	Understanding and mitigation of hazards related to TT bases
34	Terrestrial Laser survey
35	River Crossing Dampers
36	Scheme 20448 Development of a Live Wrap Replacement techniques for OHLs Using a Modified SCC System

37	Composite Cross Arms study
38	Long Term Performance of Silicone Based Composite.
39	Lubricant Rationalisation
40	Design and Development of Maintenance Delivery Tools
41	Reduction of Asset Based Safety Incidents
42	EMF
43	Environmental Improvement/Remediation
44	Environmentally Acceptable alternatives to SF6
45	Flooding Risk Analysis Pluvial Flooding Risk
46	Flooding Risk and Severe Weather Reduction
47	Vegetation Growth Model
48	Automatic Risk Based Handling of Plant Enquiries

1) Network Design - New Generation

Programme title	**Network Design – New Generation** This programme of work consists of the following projects: • Impact of Offshore Networks on the Insulation Coordination and Operation of the NG Transmission System • Generic Compliance Development for Renewable Generation • Improve reliability of future system by enabling integration of new generation • Wind Power Management System • 2020 Renewable Black Start Asset Research			
Project engineers	Mark Osborne, Jonathon Horne, Tarek Ismail, Nilton Green, Shanti Majithia			
Description of programme	This programme of work is concentrated on minimising and mitigating any negative impacts of connecting new types of power generation (including large scale offshore wind and supercritical coal) to the transmission system. There are several areas under consideration. The first of these seeks to identify and assess the impact of large offshore transmission system connections on the levels of electromagnetic transients likely at the points of connection to the onshore network. There are several projects in the programme that are concerned with ensuring that future generation (renewable, thermal and nuclear) will comply with the technical requirements required of them under UK licence conditions. There is also a project in the programme that addresses the fact in the future Black Start capability will need to be supplied by a diverse mix of generation which will include renewable sources that until now are unable to provide this service.			
Expenditure for financial year	Internal £26k External £64k Total **£90k**	Expenditure in previous (IFI) financial years	**£0**	
Total programme costs (collaborative + external + internal)	**£348k**	Projected 2009/10 costs for National Grid	£164k	
Technological area and/or issue addressed by programme	This programme seeks to ensure that future generation technologies are compatible with, and do not have an adverse affect on, current and future transmission assets.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		9 to 16	-1 to -4	10 to 17
Expected benefits of programme	The major benefits of this programme are the avoidance of capital cost of possibly unnecessary system reinforcements. The work also provides National Grid with information with which to inform policy and strategic investment decisions. This will help to ensure that low carbon generation technologies are utilised successfully. The benefits of the projects within the programme are outlined below. Insulation Coordination • The key benefit of this project is to identify whether			

	existing policy is suitable for the development of the transmission architecture. If the levels of transients are lower or within existing policy then no additional protection is required, however if the converse is true then we need to reinforce our protective measures to prevent damage to equipment. A modest investment of upfront R&D to avoid switchgear failure and possible injury would offset major replacement cost and claims (~£2m). Compliance Development • Benefits of this project include developing a direct relationship with the equipment manufacturer in order to help shape development of future plant to provide a more GB grid friendly solution. In addition the project will result in a more streamlined project specific compliance process for developers and National Grid. Enabling Integration of New Generation • NGET will be provided with a timely and efficient means of understanding new generation technology limitation and reduce the impact of the new generation technology on power system security by the timely development of necessary codes and standards evolved from technical knowledge. Wind Power Management System • If the performance of wind power forecasting can be improved by 20-30%, constraint costs in Scotland can be reduced by around £100K per year. In addition it is likely that reduced levels of uncertainty will translate into reduced levels of reserve and greater levels of confidence. WPMS use more sophisticated modelling methods than the current WindyMiller spreadsheet and is likely to achieve greater performance and be demonstrably scaleable to large numbers (thousands) of windfarms. Experience gained from the project would also benefit our rollout of a full production system in the UK or elsewhere. 2020 Renewable Black Start Asset Research • It is in keeping with Government and National Grid's objectives for environmental and corporate responsibility to seek out methods of utilising more environmentally sustainable methods of conducting its business. Looking at how the transmission system could be restarted using environmentally friendly generation supports these goals. • Recent government driven Black Start exercises (Phoenix & Longshadow) have emphasised the importance of a robust and effective Black Start restoration to the GB economy. Failure to develop new methods of black start could result in an inadequate, or even non existent plan, as the majority of coal based black start stations decline in line with the Large

	Combustion Plant Directive. This would of course significantly increase the cost to the all relevant consumers during a system blackout potentially amounting to many £millions. • National Grid can help to shape the overall development of renewable technology and associated system design and asset design issues through projects like this. The wider industry, including other utilities and manufacturers of plant, will therefore see benefits from this project.		
Expected timescale of project	5 Years	Duration of benefit once achieved	Ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£129k
Potential for achieving expected benefits	There is confidence that this programme will deliver the benefits expected from the work. Projects are largely on track and have shown promising results to date.		
Project progress as of March 2009	Insulation Coordination • There has been a delay in recruiting a suitable student. This is now secured and due to start on the 1st July 2009 Compliance Development • To date the project has aided the development of multiple initiatives for dealing with the large volume of wind based generation planned for the GB electricity system. These include; o Development and clarification of the GB Grid Code (pending consultation) to explicitly include the compliance process focusing on i. Generic compliance process. With the aim of streamlining the connection process by allowing a flow of 'generic' information direct from the manufacturers to National Grid. ii. Wind farm testing. This is essential for determining the performance and Grid Code compliance of the plant. This has now been streamlined as much as possible and explicitly clarified for the Grid Code, including some aspects of 'generic' test information. • Development of relationships directly with the major wind turbine manufacturers. This has progressed well, and with regular dialogue the issues are discussed and solutions found to the extent where some performance aspects of the most modern wind turbine equipment now exceed that of conventional plant. • Wind turbine model development has resulted in better dialogue with model development departments in the		

	main wind turbine manufacturing companies. We are now delivering National Grid customised models for the most common plant in GB. Further simplification and improvement is thought to be possible throughout the remainder of this project. Enabling Integration of New Generation • Performance issues associated with CCGT plant load rejection capability with two main manufacturers have been identified. Both manufacturers have submitted proposals for how this can be addressed. One manufacturer has provided NG with control system models of the proposed solution to verify the solution independently. NG is working with the manufacturer to optimise the functionality of the new controls to deliver the required performance. • For super critical coal technology, to-date both 2 manufacturers have independently confirmed that their reference plants has the potential to be modified to and re-optimised to increase frequency response capability and the potential for meeting Grid Code requirements. Work has also started with a manufacturer to identify requirements for a Black Start capable super critical coal plant. • For nuclear technology, discussions are ongoing with 3 companies to identify some of the performance issues associated with the new generation of nuclear plant including the EPR and potential shortfalls when compared with current Grid Code requirements. Wind Power Management System • So far a prototype has been delivered and tested. A few enhancements have been suggested but at this stage it is uncertain that we will go ahead with that work. 2020 Renewable Black Start Asset Research • So far the Phase 1 report has completed. • Initial indications are that it will be feasible to Black Start a Wind Turbine Generator. The start-up power requirements can either be met by a diesel or UPS. Solutions have been offered to maintain stability of the wind turbines at low loads and control of the switching transients when energising parts of the Transmission System. • We also have an indication of the outline costs to provide Black Start capability on a 300MW wind farm.
Collaborative partners	Alstom, GE, AREVA, Siemens
R&D provider	Cardiff University, National Grid, ISET, Converteam UK Ltd

2) Network Design - System Stability

Programme title	Network Design - System Stability This programme of work consists of the following projects: • Review of Voltage Dependency of Load • Impact of series capacitors on transmission system performance • Review of low voltage demand disconnection schemes • Assessment of SVCs for use in Constant MVAr mode (CMM).			
Project Engineer	Mark Perry			
Description of programme	This programme of work investigates National Grid's policy and asset capability in order to better understand and ensure optimum network design and operation. The programme is made up of several projects. A review of the voltage dependency of load will review current assumptions regarding composite load models at GSP and BSP locations based on an updated breakdown of load classes. It will also investigate the impact of distributed generation or other voltage control schemes/devices connected at voltages below that of the GSP and investigate the potential impact of new load types such as energy efficient lighting and the further use of switched mode power supplies. National Grid is involved in a project with manufacturers to explore the use of series capacitors to maximise the transfer capability of the available transmission system. An assessment of the effectiveness of low voltage demand disconnection schemes to minimise the spread of voltage collapse under severe system disturbance conditions is also being carried out. The final project in the programme looks at the use of SVCs in an alternative control mode that potentially reduces the noise generated and the amount of control room action needed.			
Expenditure for financial year	Internal £14k External £58k Total **£72k**	Expenditure in previous (IFI) financial years	**£18k**	
Total project costs (collaborative + external + internal)	**£122k**	Projected 2009/10 costs for National Grid	£53k	
Technological area and/or issue addressed by project	This programme addresses issues relating to system stability by ensuring assets such as SVCs are utilised effectively and that policy regarding demand disconnection and the use of series capacitors is up to date.			
Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating 5 to 13	Project Residual Risk -1 to -5	**Overall Project Score** 6 to 16
Expected benefits of project	The benefits of the individual projects are listed below. Review of Voltage Dependency of Load • The benefit of this project is that an accurate model of the voltage dependency of load is essential to accurate fault level and transmission system voltage performance assessment. Significant investment is based on fault level			

	and voltage analysis, often in cases where system performance is expected to be only marginally outside of capabilities and / or standards. Where load models are not known pessimistic assumptions are made. Better modelling of loads is likely to result in a reduced requirement for reactive compensation plant (ranging in cost between £5million and £20million per compensation device) and lower requirements on switchgear. • The accurate calculation of fault levels operationally is essential to the safe operation of substations. Overstressed equipment may fail destructively and substation running arrangements have to take account of fault levels to ensure safety. In some cases substation splits, which are less desirable for security but help reduce fault levels, may be unnecessary, based on fault level calculations using pessimistic load assumptions. • Improving knowledge of the composition of loads, and the development of accurate models, is likely to reduce transmission system investment and increase levels of system security. Impact of series capacitors on transmission system performance • The expected benefits are that the use of series capacitors will allow increased transfers from Scotland without the need to build additional interconnecting circuits. This will reduce constraint costs and require less investment and have less environmental impact than alternatives such as the construction of new lines. Should their use result in damage to generation plant National Grid would suffer a loss of reputation and may be held liable for any costs to the Generator. This project will therefore establish whether the benefits of series capacitors can be gained without introducing potentially high costs. The costs of enhancing the network could be in the range of £100m/100km and this project could contribute 10% towards avoiding costs through increased knowledge in this area. Review of low voltage demand disconnection schemes • The main benefit to NGET will be the enhancement of reputation as a prudent system owner / operator. • The cost of a total GB blackout could be over £1billion and if the knowledge gained through this project helps to reduce the black out cost risk by 1%, corresponding to £10m. Assessment of SVCs for use in Constant MVAr mode • Should operation of SVCs in CMM be possible NGET will benefit from more effective use of the network and improved environmental performance benefiting NGET's reputation. Although the first stage of the work will concentrate on one site where noise complaints have been received, the development of the models and analysis techniques will allow rapid assessment of SVCs at other sites should noise issues arise.

Expected timescale of project	4 Years	Duration of benefit once achieved	Ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£406k
Potential for achieving expected benefits	Overall it is anticipated that the expected benefits of this programme will be achieved.		
Project progress as of March 2009	Review of Voltage Dependency of Load • The start of this project has been delayed. It is expected to begin in July 2009. Impact of series capacitors on transmission system performance • The second phase of the work has been completed and a report delivered. This report highlights some potential for Sub Synchronous Resonance with the use of series capacitors, further work will be required. Review of low voltage demand disconnection schemes • A report from a GCRP working group was submitted to OFGEM in November 2007. No decision has yet been reached. It is unlikely that this work will be progressed this year. Assessment of SVCs for use in Constant MVAr mode • The initially assessed site, Mannington, has been operating in CMM for several months and has seen reduced noise levels. Work has not yet started on further sites.		
Collaborative partners	Siemens		
R&D provider	University of Strathclyde, Siemens, National Grid		

3) New Technology to Enable the Connection of Low carbon Generation

Programme title	**New Technology to Enable the Connection of Low Carbon Generation** This programme of work consists of the following projects • SuperGUM • Control System Model Development for existing stations to avoid system reinforcement • Model development for new HVDC plant • Risk Managed Corrective Control of Electricity Transmission • Harmonic Data Gathering • Voltage transducers for power quality measurements • Impact of future generation plant on system stability and frequency control
Project engineers	Derek Young, Mark Horley, Mark Perry, Forooz Ghassemi
Description of programme	The overall objective of this programme of work is to ensure the smooth integration of large scale renewable and low carbon generation into the GB power system. This includes the development of various models to assist in planning and designing the system. *SuperGUM* is being developed by Strathclyde University. This is a development of the existing Generator Uncertainty Model (GUM) for probabilistic generation planning. The development of validated excitation system models for existing power stations for use in power system analysis and the development of dynamic models for new HVDC plant aim to facilitate the future integration of HVDC connections to the system. A further project researching risk managed corrective control aims to deepen the understanding of the risk of major loss of supply to NGET as well as improve understanding of those investments that promise to be most effective in managing these risks. It will also help to identify an appropriate means of efficiently utilising quadrature booster transformers and other series control devices, taking due account of risks of major loss of supply. National Grid in collaboration with DNO companies is involved in a project organised by the Energy Network Association (ENA) that will conduct a system wide survey on the existing harmonic distortion on the electricity supply system in the U.K. The project has the following objectives: • to determine the harmonic voltage levels during the defined 5 years, • to obtain the trend of harmonic distortion for the period of survey, • to investigate any correlation in harmonic voltages on transmission and distribution systems at the measured sites, and • to verify whether or not the existing control measures are sufficient to meet the needs of a society with an ever appetites for equipment that generates harmonic current. The use of voltage transducers for power quality measurements will

	verify the power quality measurement performance of voltage transducers currently in use in National Grid's electricity network and examine and validate the performance and possible use of less costly transducers introduced as a result of recent technology developments. The final project is trying to look at the various scenarios to establish any stability issues with large generation plant that may be part of future nuclear or any other power plant.			
Expenditure for financial year	Internal £30.5k External £78.5k Total **£109k**		Expenditure in previous (IFI) financial years	**£97k**
Total project costs (collaborative + external + internal)	**£465k**		Projected 2009/10 costs for National Grid	£215k
Technological area and/or issue addressed by project	The issue addressed by this programme is the connection over the coming years of large scale renewable and low carbon generation and ensuring any possible technical barriers are overcome in good time.			
Type(s) of innovation involved	Modelling and simulation methodologies, generation planning models	Project Benefits Rating 6 to 11	Project Residual Risk -1 to -9	**Overall Project Score** 7 to 15
Expected benefits of project	The benefits of this programme are listed below. SuperGUM • The software developed by this project will be available as an analysis tool, and National Grid will benefit form the knowledge gained during the project. The software could be used to develop a greater understanding of the generation market, and in the assessment of risk in load-related capital planning. Control System Model Development • The project hopes to improve accuracy of Power System dynamic modelling allowing more efficient system design decisions. Model development for new HVDC plant • This project aims to save almost £500k by the year 2011 considering just wind farm connections and HVDC schemes planned for then. Risk Managed Corrective Control of Electricity Transmission • This project addresses the fact that transmission system supply interruption events originating and impacting upon the main interconnected system are both rare and severe (as opposed to those on demand connections, which are both more frequent and considerably less severe). While rare, such events have a major impact both on customers and a transmission company's reputation. (This much is immediately apparent from a number of major interruption			

	events that have occurred in recent years in, for example the north eastern US, Italy, Sweden, Greece and the western UCTE system). One major consequence of an electricity supply interruption is the impact of health and safety of the general public. Appropriate infrastructure 'defence measures' and IT systems can (a) Reduce the risk of such events occurring and (b) Reduced their extent, in terms of both magnitude and duration. However, these measures require investment that must be justified. This project will provide knowledge based on international experience on the most effective such methods and how they may be justified to regulators and other stakeholders. This will then permit National Grid to identify investments appropriate to GB and to justify them with the benefit of reducing the risk and impact of major interruptions to electricity supply. Major events, though infrequent, cost many £millions, if successful this project is estimated to reduce likelihood of a severe event (estimated cost £10m) by 5% (£500k). Harmonic Data Gathering • With uncertainties of background system harmonic voltages, larger design margin of harmonic equipment will be required and the additional cost could be up to million pounds in an EHV project. For example, it had caused an addition of 3 million pounds on HVDC filters on the Chandrapur (Indian) project as the harmonic problem at the design stage of the project was not identified. A similar cost impact could apply in the UK. If a life time of a 240MVA 40011 32kV transformer is reduced to 30 years from 40 years due to the electrical overstress of harmonics, it is equivalent to f 750,000 approximately at today's price. Voltage transducers for power quality measurements • The expected benefits of the voltage transducers project are that given the uncertainties of their impact on the future system, accurate dynamic models are critical for system security and operational assessment. This will help to minimise the future cost on both the design and operation. Accurate modelling could reduce the need for system reinforcement costing up to an estimated £100m against the 2020 scenarios. Impact of future generation plant on system stability and frequency control • This will enable National Grid to know whether it is safe in terms of stability to connect large generation plant to the system.		
Expected timescale of project	5 Years	Duration of benefit once achieved: could be used over a 5-year regulatory review period and possibly beyond	Ongoing

Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£123k
Potential for achieving expected benefits	There is a very good chance that this programme of work will deliver the expected benefits.		

Project progress as of **March 2009**	The progress of the individual projects is as follows.
	
	SuperGUM
	• The student attended a week long discussion and workshop period with interested parties at the National Grid Warwick office.
	• The student has produced a first year technical progress report.
	• Suitable novelties in modelling methodology and software architecture have been identified, and a software prototype is under development to illustrate these principles. The prototype is initially applied to the existing GUM model.
	
	Control System Model Development
	• Excitation system models have been developed in Powerfactory and validated against on-site testing for the following stations:
	  ○ Foyers
	  ○ South Humber Bank
	  ○ Fawley
	  ○ Torness U1
	  ○ Tilbury B
	  ○ Cowes U2
	  ○ Peterhead U2
	
	• Prototype excitation system models have been developed in powerfactory for the following stations but have not yet been validated against site test results:
	  ○ Clunie
	  ○ Fiddlers Ferry
	  ○ Aberthaw
	  ○ Littlebrook OCGT
	  ○ Kingsnorth
	  ○ Eggborough
	  ○ Cruachan
	  ○ Ryehouse
	  ○ Ratcliffe
	
	Model development for new HVDC plant
	• This work is being considered as part of the Strategic Investment work that is being separately funded.
	
	Risk Managed Corrective Control
	• The project has not started properly due to difficulties in securing a suitable researcher.		

	Harmonic Data Gathering • To date the project is on track. Measurements up to winter 2008-2009 and measurements for Summer 2009 are in progress. • Coordination with different DNOs has been done. Voltage transducers for power quality measurements • Work is in progress on this project. An automated, multi-frequency source has been designed and built for testing devices up to 25kV. • Lack of test samples has been a problem. Quotes have been obtained from instrument voltage transformer manufacturers for further tests. Problems have resulted from long lead times. • All DNOs have been requested to provide 11kV and 33kV instrument transformers, as samples, to be tested. • Work is in progress to increase the source voltage capability to 80kV. Impact of future generation plant on system stability and frequency control • The project comprises building a model and simulating various scenarios and producing a report. To date, the model has been built and tested and its operation is verified. Part of the studies were run and completed as reported previously. No further progress has been made due to resource constraints.
Collaborative partners	
R&D provider	Strathclyde University, National Grid, ENA, University of Manchester,

4) Infrastructure development for the electricity transmission network for 2020-30

Project title	Infrastructure development for the electricity transmission network for 2020-30			
Project Engineer	Andy Hiorns			
Description of project	To develop novel/innovative solutions (including use of series compensation / integration AC/DC solutions and the development of smart transmission system) focussed on designing and delivering an economic and efficient transmission system in a coordinated manner to meet the government's renewable target challenges. The key areas of this work involve identifying technology barriers to transmission delivery and developing strategies to address them based on predictive, credible long term scenarios. The overall objective is to ensure short / medium term technical engineering developments are consistent with long term objectives up to 2020 -2030.			
Expenditure for financial year	Internal £44k External £118k Total **£162k**	Expenditure in previous (IFI) financial years	**£2k**	
Total project costs (collaborative + external + internal)	**£307k**	Projected 2009/10 costs for National Grid	£145k	
Technological area and/or issue addressed by project	The project will develop solutions for increasing the transmission capacity of the GB transmission system through the use of new or previously unused technologies. The project will also examine the potential to design optimised control systems for devices such as series capacitors and HVDC links which maximise the benefits delivered to the network.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	4	6
Expected benefits of project	It is critical that National Grid studies, develops and implements new technologies to develop an efficient and economic transmission system in a coordinated manner and to ensure long term stability of the electricity transmission system and therefore security of supply to our customers under a very different supply mix. Developing the engineering understanding will influence a robust long term strategy to ensure that we continue to meet our licence obligations wile delivering the government targets in the best possible way without unduly increasing the overall cost to the consumers. The development of series compensation and integrated HV DC networks is likely to be the most economical solution which is availed to enable in timescales to meet government targets. An alternative is to build overheadlines, which is likely to need significant cables sections which could increase costs by £500M - £1B.			

Expected timescale of project	2 Years	Duration of benefit once achieved	Ongoing
Probability of success	80%	Project NPV = (PV benefits – PV costs) x probability of success	£17m
Potential for achieving expected benefits	The project has met all deadlines to this point and has the support of both internal and external stakeholders. Continued support from Ofgem, in the form of funding, indicates that there is a high possibility that this project will progress to the procurement and construction phase.		
Project progress as of March 2009	High level designs for network reinforcements have been proposed and preliminary cost benefit and system study work carried out. Through examining alternative options for reinforcing the transmission system economic and environmental benefits have been achieved. Good relationships have been established with equipment manufacturers to support the project and provide technical information and indicative costs. A report to the Electricity Networks Strategy Group (ENSG) was completed in December 2008 which detailed National Grid's proposals and work to date. http://www.ensg.gov.uk/index.php?article=126 Negotiations have begun to set up a collaborative working arrangement with other UK Transmission Owners to carry out detailed study work for proposed network reinforcements. Funding has been secured from Ofgem to carry out detailed pre-construction engineering work.		
Collaborative partners	Ofgem, Scottish Power Transmission, ABB, Siemens, Areva		
R&D provider	N/A		

5) Future Energy Use and Assets

Project title	Future Energy Use and Assets This programme of work consists of the following projects: • Demand Response • Demonstration of Distributed Demand-side Management as a service to the UK grid operator		
Project Engineer	Shanti Majithia, William Hung		
Description of project	The first project is proposed collaboration in a collaborative project under the International Energy Agency's Implementing Agreement on Demand Side Management. The principal deliverables will be two reports, covering both the information collated from the UK participants and the International partners. The first of these will define the requirements for the implementation of Micro demand Response and Energy Saving schemes, along with options for effective delivery. The second will build on the first to assess how such facilities might be deployed by users. The second project will demonstrate the operation of distributed demand side management, providing fast response in order to reduce reliance on conventional generation for grid balancing and security and thus permit much greater penetration of renewables and aid in maximising the use of existing assets. The demonstration will focus on the control of commercial air conditioning to provide an aggregated service of some tens of MW. The value and scope for wide scale application of the technology across the UK, and with regard to transmission constraints will be demonstrated through software modelling based on the results of the practical trial.		
Expenditure for financial year	Internal £4k External £0 Total **£4k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£300k**	Projected 2009/10 costs for National Grid	£11.5k
Technological area and/or issue addressed by project	The first project assesses the potential for and likely business case/s to support the delivery of Micro Demand Response and Energy Saving projects to Residential and SME customers. The three techniques for demand side management that will be focused on are Time Of Use pricing, remote/automatic demand switching and End Use Monitoring and Feedback (EUMF). Whilst the primary interest is in relation to developments within the UK market, the project is coordinated under the International Energy Agency's Implementing Agreement on Demand Side Management. This provides an opportunity to look at the impact for National Grid in a broader context, and to understand developments within the other participating countries, and specifically to help understand its impact on the assets and the secure operation of the Transmission network; The second project seeks to improve demand side management technology to allow the commercial building demand in particular air		

<table>
<tr><td></td><td colspan="4">conditioning load to be effectively control to minimise CO2 emissions from power stations and also help to reduce the impact of intermittency of wind generation on system performance.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>5</td><td>-5</td><td>10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The anticipated benefits of participating in the first project are as follows:
An opportunity to influence Residential & SME DR terminology and understanding within the UK and help understand its impact on the assets and the secure operation of the Transmission network;
Gain an independent view of the technology and techniques available for the largely untapped Residential & SME market;
Knowledge of international approaches and opportunity to learn with others to develop ‘best practice’ approach to small consumers;
Understand the role of demand side in energy markets through the use of DR programmes and mechanisms;
Evaluate the advantages and disadvantages of different technologies and techniques;
Quantify infrastructure needs for load control and energy saving options;
Assess the potential of time of use or developed profile metering in achieving objectives; and
Opportunity to work with a number of UK stakeholders and gain an awareness of current developments in this area.
Given air conditioning load is becoming more significant in recent years (eg summer demand in London is higher than that in Winter), the appropriate management of this type of demand in commercial buildings will also help to level out some of the peaks and hence reducing the technical and financial impacts on National Grid.</td></tr>
<tr><td>Expected timescale of project</td><td>2 -3 Years</td><td>Duration of benefit once achieved</td><td colspan="2">Ongoing</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">-£35k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">The potential for achieving the expected benefits is of the first project are high subject to contractual agreements. As it is a collaborative project, there is a potential risk of limited contribution by other members of the UK team.

Significant ground work has been initiated and good progress made</td></tr>
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	in each work stream to contribute to the success of the second project. There is a good potential for achieving the objectives set out in the project.
Project progress as of March 2009	The first project commenced in January 2009 and consisted of an initial phase of confirming what would be required to deliver the project. The majority of the data collection for Subtask 1 has been completed and is in the process of being compiled and used to identify types of Demand Response &/or Energy Saving products. The information requirements for Subtasks 2 and 3 have been scoped and data collection is in progress for these subtasks. The information from these three subtasks will be collated, analysed and reported on by October 2009. The second project commenced in January 2009 and five Work Packages were established with work plans agreed to meet the overall project objectives. As the demonstration project is to establish Demand Side Management type of Balancing Services and possibly energy trading, National Grid's role has been making sure the services need by the system are clearly defined to ensure the service to be developed will serve the network in a efficient and cost effective way. Close involvement on the modelling of the system dynamic, response scheduling and load dynamic is critical as accurate modelling is important for the correct assessment of the facility.
Collaborative partners	British Gas New Energy Department for Energy & Climate Change EdF Energy E.ON Engineering – Innovation team Scottish & Southern Energy . **International partners – France, India, Finland, Spain, Greece, Netherlands** Eon, SpaceAir, Daikin, Horstmann, Viessmann, IC, LUT, National Grid
R&D provider	EA Technology Ltd, IC and LUT

6) Flexnet

Description of project	FlexNet will put in place a substantial body of work that will build on the achievements of FutureNet and lay out the major steps, technical, economic, market design, public acceptance and others, that will lead to flexible networks, including starting to showcase these so that they can be taken up by the commercial sector, Government and Regulators for practical implementation.			
Expenditure for 08/09 financial year	Internal £8k External £63k **Total £71k**			
Expenditure in previous (IFI) financial years	The programme started in this regulatory year.			
Total Project Costs (Collaborative + external + internal)	**£ 7.6M**	Projected costs for next financial year	**£30k**	
Technological area and / or issue addressed by project	Some key questions to be addressed are: • How can we judge the degree of flexibility needed? • How can flexibility be achieved? • How much flexibility should come from primary plant giving margin and how much from secondary plant giving enhanced controllability? • What constrains or encourages flexibility, what technologies are acceptable and what economic frameworks and public policies provide flexibility at the least overall long term cost?			
Type(s) of innovation involved	Significant, Technological substitution and Radical innovations	Project Benefits Rating 7.2	Project Residual Risk -2	Overall Project Score 9.2
Expected Benefits of Project	**Each work stream is expected to deliver benefits.** Shape & Size of Future Electricity Networks will continue to build on the FutureNet scenarios. Markets & Investments will investigate some of the economic issues of the electricity market. Power System Electronics will investigate why capital cost, cost of power losses and concerns over local network integration result in power electronic systems currently being restricted to voltage control. Smart, Flexible Controls will help network operators to understand the benefits of changing the network operation philosophy and the requirements for its implementation. Customers, Citizens & Loads will analyse potential contributions that customers and responsive demand can make towards enabling a more flexible energy system, to identify barriers to this participation and their possible remedies, and to analyse the place-related factors shaping public acceptance of a more flexible network infrastructure. Validation and Showcase will provide the basis for testing the research outcomes in a representative environment and demonstrating their effectiveness in addressing problems central to the realisation of flexible power			

	networks. Future Energy Mix will consider possible changes in (UK) energy systems to 2050 and examine the impact of these changes on energy transportation networks. Future LV Networks will investigate losses through auditing and analysing the relative impact of load-profile, sharing, imbalance and sag on losses. Education, Deliberative Engagement and Public Acceptance of Future Network will inform many of the social issues and engagement.		
Expected Timescale to adoption	Year 2012 onwards	Duration of benefit once achieved	20 Years
Probability of Success	25%	Project NPV (Present Benefits – Present Costs) x Probability of Success	£2M
Potential for achieving expected benefits	The new researchers are now integrated in the consortium and working well. Industrial partners have been providing case studies and data to allow researchers to make specific assessments of technologies. The "validation and showcase" workstream is now producing detailed plans for its crucial role in promoting the benefits. Research topics within FlexNet have been identified as directly supportive of the ENSG 2020 Vision and efforts are underway to create some focused studies on this vision. Similarly, we expect benefits for future distribution network design based analysis of the evolution of demand in the electricity sector and demand side management.		
Project progress as of March 2009	The Management Executive meets quarterly and receives detailed progress reports. Thirty PhD projects and 20 research assistants have started although slow recruitment means detailed plans have been adjusted in some cases. Good progress has been made on various forms of modelling: energy resource models, transmission system models and distribution planning models. On top of these there are now outputs to support transmission access review and the security and quality of supply standards. Generic approaches to distribution planning for high DG penetration are being advanced and new technologies such as soft normally-open points are being evaluated. Work on demand-side control has reviewed European experience and proposed operational and settlement options for the UK. Researchers on the Future Energy Mix workstream supported the LENS report with techno-economic appraisals and that work is now disseminated.		
Collaborative Partners	EPSRC, National Grid, Scottish and Southern Energy, Central Networks, EDF Energy Networks, ScottishPower Energy Networks, CE Electric UK, and Electricity North West.		
R&D Provider	Universities of Bath, Birmingham, Cambridge, Cardiff, Edinburgh, Manchester, Strathclyde and Imperial College London.		

7) Efficient Incorporation of Intermittent generation considerations in network design.

Project title	Efficient incorporation of intermittent generation considerations in network design			
Project Engineer	Noel McGoldrick			
Description of project	Development of a methodology for determining the optimum required capability for the main interconnected transmission system with significant intermittent generation.			
Expenditure for financial year	Internal £66k External £125k Total **£191k**	Expenditure in previous (IFI) financial years	**£106k**	
Total project costs (collaborative + external + internal)	**£460k**	Projected 2009/10 costs for National Grid	£164k	
Technological area and/or issue addressed by project	Integration of renewable generation into the grid Reliability of electricity supply Network investment			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	3	7
Expected benefits of project	An efficient methodology to determine transmission capability requirements with significant intermittent generation will address the following: (a) Optimum balance between investment costs, operational costs and reliability of supply (b) Promotion of integration of renewable generation into the grid hence reducing CO_2 emissions			
Expected timescale of project	1 – 2 Years (originally estimated to be 1 year)	Duration of benefit once achieved	10+ Years (methodology developed from scenarios up to 2020)	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£28k	
Potential for achieving expected benefits	High. Key approaches have been identified from the work done so far. The approaches are based on sound engineering principles and further work has been identified to further develop the principles Feedback from industry indicates a significant interest in the outcome.			
Project progress as of March 2009	We are working on the development of a cost benefit tool for assessing the required boundary capabilities on the transmission system. Several iterations of the tool have now been implemented for the Transmission organisations to use. We are in the process of developing a tool to allow a fundamental assessment of transmission planning and operation based on a probabilistic, reliability assessment model. The model will be used to review the existing design and operation standards of the			

	transmission system. A version of the model is currently being tested by the Transmission companies. We are reviewing the historical incidence of faults on the transmission system and determining statistics for the actual level of security supplied to a sample of transmission connect substations. We are reviewing the detailed criteria for assessing power system stability to examine the potential the increase power flows across the system.
Collaborative partners	ScottishPower Transmission Limited and Scottish Hydro Electric Transmission Limited.
R&D provider	TNEI Consultancy in collaboration with Strathclyde University

8) Condition and Life Extension of Substation Assets

Project title	Condition and Life Extension of Substation Assets This programme of work includes the following projects: • Oil Level Monitor • Grading capacitor condition evaluation • Bus Transfer Capability • Frame 'r' Circuit Breaker Refurbishment and Maintenance Reduction. • Charge development of GIS spacers • Vacuum Tapchanger • Uneven dynamic voltages
Project Engineer	Dan Morrice, Paul Coventry, Andrew Taylor, Kevin Mockridge, Dave Woodcock
Description of project	An oil level monitoring (OLM) system will be developed and trialled that can be retrofitted to substation plant in non-outage conditions. The trial will be based at the Oil Management Unit in Thorpe Marsh and involve attaching a sensor to two transformer oil storage tanks. By artificially imposing a leak on either or both of the tanks the sensitivity of the monitoring equipment can be evaluated. The effects of environmental changes on oil level will also be evaluated. The key objective of the second project is to establish the correlation between diagnostic measurements on circuit breaker voltage grading capacitors that have been in service and the actual condition of the capacitor. The knowledge obtained will be used to decide whether the capacitors of circuit breakers undergoing refurbishment are fit for a further 20 years service without risk of disruptive failure or whether they require replacing. The effects of bus transfer duty on the Committee design of disconnectors will be investigated together with a solution to modify/retro-fit Committee design disconnectors to provide them with a Bus Transfer rating as per current IEC/National Grid standards. The objective of the fourth project is to resolve two design and performance issues associated with the mechanism trip latch & D shaft and the interrupter head trip valve. The mechanism(s) by which charge accumulates on the surfaces of solid support insulators in GIS are to be investigated to recognise the design factors that confer immunity or susceptibility to trapped charge, to eliminate at identified sites the requirement for special switching procedures for GIS and to incorporate appropriate clauses in specifications to eliminate susceptible designs. The vacuum tapchanger project will attempt to fit a new technology tapchanger (Vacutap) to an existing asset which has a worn out tapchanger on a healthy transformer. The installation will be monitored on completion to assess the success of the project to aid future strategy on this type of problem. Cost savings will be delivered through achievement of extended asset lives with a reduced maintenance requirement.

	Uneven dynamic voltage distribution between circuit-breaker interrupters is believed to be the cause of a number of in-service failures of devices switching shunt reactors. Successful demonstration of the phenomenon will allow design and type test requirements for circuit-breakers and their voltage grading capacitors to be specified, so that in service failures may be eliminated by design.		
Expenditure for financial year	Internal £26k External £41k Total **£67k**	Expenditure in previous (IFI) financial years	**£128k**
Total project costs (collaborative + external + internal)	**£279k**	Projected 2009/10 costs for National Grid	£37k
Technological area and/or issue addressed by project	The Condition and Life Extension of Substation Assets programme addresses the following areas/issues: • The development of low cost adaptable Oil Level monitors to detect leaks. • Internal examination of circuit-breaker voltage grading capacitors removed from service has revealed incipient faults that would certainly have lead to failure but which were not revealed by existing diagnostic checks. The present work is concerned with applying a range of diagnostic techniques to capacitors that have been in service and correlating the indications obtained with the results of internal inspections to identify the techniques most effective in detecting incipient fault conditions. The knowledge obtained will be used to decide whether the capacitors of circuit-breakers undergoing refurbishment are fit for a further 20 years service without risk of disruptive failure or whether they require replacing. • Committee designed disconnectors do not have any on-load bus transfer rating but they are expected to perform this duty in their locations on the electrical transmission system. Their design is based on requirements dating back 30-40years and they do not fulfil the performance requirements of having an on-load bus transfer capability when compared to modern day specifications. In some cases operation of the assets leads to damage to the equipment and therefore attracts associated OMGS costs for repairs and significant work has been required to repair the damage. These disconnectors will be on the system for a considerable number of years to come and are being re-used in Capital schemes, albeit without having a rated bus transfer duty. As a result National Grid will continue to operate and maintain this equipment with the operational inflexibility and continued damage to the equipment unless a modification/retro-fit option can be developed. • Circuit breaker mechanism trip latch and D shaft have a history of slow trip response due to material hardness variations and resultant poor lubrication performance. The objective is to redesign, re-manufacture and test alternative designs with a view to resolving the performance issues. The interrupter trip valves have a history of sticking in the open		

position, causing severe air loss, potentially leading to 'flash through' in the interrupters. This problem is caused by a poor valve design and the drying out of the lubricating grease. The objective is to redesign, re-manufacture and test alternatives designs with a view to resolving the performance issues.

Trip latch & D shaft

Interrupter Trip Valve

- It is known from experience that gas-insulated switchgear (GIS) substations are susceptible to the effects of charge trapped on isolated sections after switching. The DC electric field associated with trapped charge can lead to migration of charge onto insulator surfaces and a reduction in the withstand performance. Since the mechanism by which charge migrates onto the insulators has not been identified, it is difficult to eliminate the problem at the design stage and, at present, the effects of trapped charge are managed by adopting special switching procedures for GIS. The present work aims to understand migration of charge onto GIS insulators by applying modern measurement techniques so that the issue may be eliminated by appropriate design.

- The sixth project addresses replacing worn out tapchangers with new technology.

- A number of in-service failures of circuit-breakers switching shunt reactors have occurred both in the UK and elsewhere. A theoretical explanation for the cause of failure has been proposed in collaboration with CIGRE Working Group A3.18 'Operating environment of circuit-breaker voltage grading capacitors'. Due to considerable practical difficulties in performing suitable measurements, it has not been possible to prove the theory experimentally. British Columbia Transmission Corporation (BCTC) has invited National Grid to participate in the proposed research project which aims to address the above shortcoming by performing tests in BCTC's high power laboratory.

		Project Benefits Rating	Project Residual Risk	**Overall Project Score**
Type(s) of innovation involved	Significant	7 to 11	-2 to -5	9 to 16

Expected benefits of project	Oil Level Monitor: This development should play a major role in the risk management of oil containment, removing the need for 'bunding' of at least 450 single-phase oil units. An example case presented by Network Design is for a 6 Bay site, and is approximately £350k. This includes 'bunding' interceptors, project management, etc. The estimated cost of an equivalent monitoring system at a 6 bay substation is estimated to be in the region of £37k. This does not include economy of scales given the larger scheme. If the monitoring scheme proves viable, the stated values could contribute to a saving of £7m over a bunded scheme. Fitting Oil Level Monitors to potentially leaking plant would also enable the issue of oil leaks to be managed in a far more efficient manner. Earlier detection would enable faster response and resolution. Evaluating the leak rate would provide a "line of site" that enables resources to be managed in a proactive rather than a reactive manner. Low oil level alarms triggered by cold snaps could also be assessed and evaluated by the OMU without the need for the reactionary use of manpower and resources. National Grid is exploring the feasibility of refurbishing some of its air-blast circuit-breakers with the intention of achieving an additional 20 years life beyond anticipated asset life. It is known that some of the voltage grading capacitors in the population to be refurbished may be exhibiting incipient failure and will not be capable of achieving a further 20 years life. If the capacitors exhibiting incipient failure cannot be identified with confidence, it will be necessary to replace all capacitors irrespective of their condition at a cost of around £1 - £1.5 k per capacitor. A reliable diagnostic technique would minimise the risk of in service failures while avoiding the unnecessary replacement of healthy capacitors. If it was found that, say, 50% of the capacitors need not be replaced, savings of the order of £2.5 m could be accrued in the period to 2020. Operational inflexibility will be removed by allowing the Committee design disconnectors to be operated in the on-load bus transfer mode which in itself will remove existing longstanding Technical Limitations on some of the disconnectors. By modifying the design of these disconnectors, this should improve their remaining service life and ensure they are used to their full potential when they are retained/reused in Capital schemes. There is a population of approx. 2800 disconnectors (across the 400kV and the 275kV Transmission system) that may be candidates for this solution although it is not expected all disconnectors will be modified/retro-fitted as the cost/benefit will need to be assessed based on remaining useful life. Frame 'r' circuit breaker reliability will be improved for the proposed life extension period of 20 years. Both design modifications will also reduce the maintenance requirements. Currently the trip valves require greasing at 6 yearly maintenance intervals and refurbishment/exchange on a 9 yearly interval. The redesigned trip valve requires no greasing and it is expected to be maintenance free for the remaining life of the circuit breaker 20 years. The work of the fifth project will allow GIS designs that are more resistant to charge migration to be identified and the special switching procedures for these sites to be relaxed. The special

	switching procedures add complexity to the switching programme and extend outage times. Savings of around £180k per year in opex avoidance are estimated. The switching procedures cannot always be adhered to and occasional trapped charge flashovers can still occur. The ability to intercept designs susceptible to trapped charge at the Type Registration stage would allow future trapped charge flashovers to be avoided, saving around £100k in a 10 year period. The expected benefits of the vacuum tapchanger project are: • A major reduction in maintenance requirements for the NE1 team (120K saving over 12 years) • A future strategy on this type of asset problem. • Minimal disruption of supplier's steelworks by not having to replace a transformer. Experimental proof of the cause of failures associated with shunt reactor switching would allow such failures to be eliminated through the adoption of appropriate specifications and type test procedures. The costs of failures, including consequential damage to equipment and repair costs, will be avoided, the impact on the system of non availability of the plant will be minimised and safety risk to personnel will be reduced. A single failure requiring replacement of a circuit breaker can result in direct costs exceeding £500k and indirect costs of several £100k if additional generation is required while the shunt reactor is not available.		
Expected timescale of project	3 Years	Duration of benefit once achieved	Ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£660k
Potential for achieving expected benefits	The potential for achieving the expected benefits of this programme of work is good based on the good progress to date in the majority of projects in this programme.		
Project progress as of March 2009	Oil Level Monitor. The contractor has conducted an initial off-line feasibility study to ensure that the theory to be employed is sound and repeatable. The feasibility study was successful and the contractor is confident that they will be able to detect oil level changes whilst being able to correct for Weather induced fluctuations. Grading capacitor condition evaluation: An order has been placed but laboratory testing has not yet been performed. Bus Transfer Capability: The equipment to be tested is being sourced for shipment to supplier to begin the development work and subsequent type testing of the designs. This is expected to take place during the summer of 2009 and a solution to be fitted to an in-service disconnect as a trial during 2010.		

	Frame 'r' Circuit Breaker Refurbishment and Maintenance Reduction: Significant progress ihas been made in the following areas: **Trip Valve.** The trip valve was redesigned to incorporate self lubricating bearings and seals. The piston stem was replaced with a high tensile steel shaft and the piston assembly was chrome plated and ground to the required size and surface finish to mate with the dry lubricated seals. The valve body was machine to incorporate the new seal and self lubricating bearing. This negates the need for greasing at 6 yearly intervals. Four prototype valves were manufactured and type tested to 2000 mechanical operations on a specially manufactured test rig. A further test rig was manufactured to measure the speed of valve operation. The valves were fitted to a test circuit breaker and circuit breaker timing tests were completed to establish the valves function correctly. All tests were successful and a programme of valve modification has begun, fitting the new 'lubricant free' valves to all refurbished circuit breakers. **Trip Latch & D shaft.** The trip latch & D shaft was redesigned to use materials with similar hardness. A prototype D shaft was remanufactured, made from EN40B Nitride case hardened and Tuftride QP-dry lubricating/surface toughening coating. The trip latch was modified by inserting a sintered fine grain tungsten carbide tip coated titanium nitride dry lubrication and silver soldered into the latch as a mating surface for the D shaft. The trip latch & D shaft will be type tested to 2000 mechanical operations on a test rig in June 2009 and the materials examined for wear performance and tip adhesion in the latch. On confirmation of successful performance the redesign trip latch & D shaft will be installed in all refurbished circuit breakers. Charge development of GIS spacers. The electro-optic Pockels experiment has been developed further to measure the surface discharge distributions under different voltage waveforms (positive/negative square pulse of different durations, triangular waveform etc.). Further post-processing analysis has also been performed in which the total surface charge is integrated and shows a correlation to the applied voltage. An accurate measurement circuit of the discharge current has been constructed. This is of importance as the integration of the current waveform provides the total charge in time and gives a good comparison with the post-processing results. An improvement to the spatial resolution has also been attempted by moving the transparent earth electrode closer to the discharge surface but saturation occurs; this requires further investigation. Improved electro-optic crystals have been tested, which show fewer fringes on the images and less noisy results after processing. Simulations of a positive discharge have been applied to different gases and pressures. Modelling of a negative discharge is being investigated. Initial simulation results on negative corona discharges show good agreement with the literature. Two conference papers have been written and a journal paper is in draft. The Vacuum Tapchanger project has been terminated. The credit crunch has resulted in the commercial arrangements and the reduction in manufacturing changing the strategy for transformers at the proposed site where the refurbishment was going to take place.

	The project has been terminated as there is now no long term benefit. Uneven dynamic voltages. Since initiating the project, the estimated project costs have risen significantly and the supplier has been unable to secure the support initially anticipated. The project was therefore cancelled in December 2008. In view of the cancellation, National Grid is proposing to adopt an alternative approach that tests the grading capacitors against the worst case conditions predicted by the theoretical model. These tests will be performed in the high voltage laboratory at the University of Manchester.
Collaborative partners	-
R&D provider	IDLS, The University of Manchester, Ruhrtal-Hochspannungsgerate GmbH & Co. OHG, Cobham (ERA) Engineering Consultancy Services, University of Southampton, Areva, British Columbia Transmission Corporation

9) Improved Life Cycle Costing Methods

Project title	Improved Life Cycle Costing Methods			
Project Engineer	Paul Coventry			
Description of project	To establish a methodology for evaluating the life cycle costs of transmission system assets and to account for the potential health and safety performance of such assets across their life cycle. The methodology will be used to support the development of asset investment and management policy and will allow optimum solutions to be identified taking into account economic, environmental and social costs. It will also inform health and safety policy and the cost-benefit assessment of risk reduction and improved risk management strategies			
Expenditure for financial year	Internal £9k External £39k Total **£48k**	Expenditure in previous (IFI) financial years	**£0**	
Total project costs (collaborative + external + internal)	**£45k**	Projected 2009/10 costs for National Grid	£0	
Technological area and/or issue addressed by project	Traditionally, investment decisions have been made on the basis of capital costs of equipment only. This approach has been accepted since the capital costs for electricity transmission assets are large compared to annual operating costs and, being incurred up-front, are dominant in the discounted cash flow. However, it is becoming increasingly important that the whole life cycle be considered when evaluating options, including costs of obtaining raw materials, manufacturing, maintenance, losses and decommissioning/disposal of equipment. The use of more holistic life cycle costing (LCC) methods are an imperative for companies based on capital intensive assets having long asset lifetimes where the true current and future costs of ownership and operation are to be critically assessed with investment decision criteria that are searching and meaningful. Although the importance of this approach is recognised, its complexity and a lack of meaningful data and appropriate techniques have hindered its implementation. While health and safety risk assessment is a well established discipline, very little has been done on life cycle assessment of human hazards and risks from plant manufacture, to scheme construction and commissioning, to operation and maintenance through to end of life management. There are significant potential benefits to being able to carry out such assessments in order to quantify the most effective ways to reduce hazards and risks and how to assess the effort and cost required to achieve safety by design for both new and current schemes.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		11	1	10

Expected benefits of project	This research will provide a platform for policy decision making to reduce overall project costs while delivering National Grid's stated health and safety and environment performance aspirations in the context of asset investment and design related decisions. It will assist in enumerating potential long term liabilities and provide a rational and transparent assessment of whole life cycle costs. It will enable informed justifiable decisions on health and safety and environmental management to be made and enable the trade-offs between competing and often conflicting criteria to be better and more formally managed. It will provide a knowledge base for improved asset policy and management. The framework will facilitate consistency in asset investment and design related decisions. It will provide a platform to manage proactively the health and safety and environment challenges facing the network.		
Expected timescale of project	1 Year	Duration of benefit once achieved	Ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£230k
Potential for achieving expected benefits	The methodology developed in the course of this R&D project will be used to evaluate the economic, environmental, health and safety and social impacts of the options considered when making decisions on which asset to use, which design to choose and what intervention to undertake for assets on the transmission system. In the event of a successful outcome, there will be significant potential for achieving the expected benefits.		
Project progress as of March 2009	A review of previous work on life cycle costing methods has been completed. Academic and commercial information sources have been reviewed to identify and critique life cycle costing methods and related tools. Of the methodologies reviewed, the American Institute of Chemical Engineers (AIChE) method is the most advanced and well developed and it is proposed that it be adapted for use in the present work. A draft report has also been produced on health and safety related economic impacts. Three workshop meetings have been held to identify all the primary economic, environmental and social cost elements relevant to substation and overhead line case studies. These workshops have been held with experts from within National Grid and a fourth one to identify cost elements relevant to cables co-located in cable tunnels has been scheduled. A catalogue of cost elements appropriate for National Grid's business is being compiled and a review of hazard and risk assessment approached relevant to transmission assets and schemes is in progress.		
Collaborative partners			
R&D provider	Gnosys UK Ltd, University of Surrey		

10) Smart Asset Management

Project title	Smart Asset Management This programme of work includes the following projects: • Smartlife Workgroup • Full site trial of CM • Remote Mass Flow Meters • Data Visualization • Condition Monitoring of Circuit Breakers • Air System Conditioning Monitoring • Bi-Directional R.F Intra-Substation Communications System • Noise Recorder GPRS Interface to Provide on-line data logging facility • ARMADA • Remote Connection to PD Monitoring • Energy Scavenging Technology			
Project Engineer	Jenny Cooper, Carl Johnstone, Mike Hannon, Martin Dimmock, Graham Moss, Mark Winters, John Fitch			
Description of project	This research and development programme covers the area of Smart Asset Management (SAM) and involves extensive research into condition monitoring, data analysis and data collection techniques. The purpose of SAM is to provide National Grid with safer, more efficient systems that will allow improved planning of maintenance and greater real time knowledge of asset conditions. Research is being carried out on methods for condition monitoring and methods of data collection and visualisation for a wide range of transmission assets.			
Expenditure for financial year	Internal £33k External £161k Total **£194k**	Expenditure in previous (IFI) financial years	**£22k**	
Total project costs (collaborative + external + internal)	**£700k**	Projected 2009/10 costs for National Grid	£108k	
Technological area and/or issue addressed by project	In order to ensure that National Grid manages its assets as effectively and efficiently as possible it is important that the business enters a regime of proactive asset management where appropriate. Large scale integrated condition monitoring of transmission assets will allow failures to be predicted and/or mitigated, maintenance to be planned more efficiently and will improve the safety of staff by providing up to date knowledge of the condition of assets to which they are within a close proximity.			
Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating 4 to 12	Project Residual Risk -1 to -9	**Overall Project Score** 3 to 17

Expected benefits of project	The expected benefits of the projects within the programme are as follows:
	
	Smartlife
	As a European network to develop asset management improvements, the outcomes from this project are proposed ultimately to be included in future asset management policies.
	
	Full site trial of CM
	• Reduction in OPEX:
	• Risk management - more information means better targeted risk management, and increased sensitivity
	  ○ Maintenance regimes (RCM, CBM, R&C, PBM, etc).
	  ○ Reduction in cost of retro fitting of CM.
	  ○ Reduced/ released resource from increased visibility of planning requirements.
	  ○ Increased value from PDSAs.
	• Reduction in CAPEX
	  ○ Dynamic asset replacement.
	  ○ Clearer Policy for implementing CM into plant (Embedded/retrofit-able sensors, when to fit 'black boxes', frequency of monitoring (online/ /base/annual/five yearly/etc).
	• Operational
	  ○ Increased capability of Dynamic rating of equipment.
	  ○ Increased availability of the network.
	  ○ Faster RTS – Automated Post fault analysis.
	  ○ Risk management.
	• General
	  ○ The 'Virtual' substation will enable external parties (international bodies/Utilities) to see a demonstration of the application while not exposing real information. This will be a quantifiable demonstration of a global asset manager meeting the business challenges.
	  ○ Clearer accessible information to a wide audience.
	  ○ Audit trail of changes and traceable measurements.
	  ○ Provide a means for realising capability of existing CM solutions.
	  ○ Making CM more viable by utilising data recorded in existing applications.
	  ○ Reduction in cost of CM due to economy of scale.
	  ○ Softer benefits – better 'buy-in' and ownership.
	  ○ Business benefits not directly related to Asset management. (Electronic T-cards, security recognition, easy communication-local or centralised).
	These benefits combined give a potential business benefits of up to £700 to £1M in savings, these figures will be clarified by stage 1 of this study.
	
	Remote Mass Flow Meters
	• Reduced risk of misreporting of data (undefined corporate fine, potential of >£1m).

- Simple and easy validation recording of SF6 usage.
- Minimised time spent locating test equipment (reduced travel and worktime).
- Effective use of test equipment by increasing availability.
- Reporting can be aligned with online density monitoring. Single viewing platform for online and offline top-ups.
- Offer an alternative where it is not viable to fit online monitoring.
- Trial of a technology that could be transferred to others technologies (CB timing, SF6 gas Sampling, etc).

Data Visualization

- This solution would allow for quick access to key asset information, and provide a geographical view of where the route lies. This is particularly critical in emergency situations. In addition it would have the potential to layer onto that information, population densities, weather feeds (or any other information that is publicly available). This is of benefit in assisting with risk assessments during incidents. It will also enable better understanding of overall overhead line asset condition and a useful tool for OHL project leads during their work planning process.

Condition Monitoring of Circuit Breakers

- The monitoring kit will be beneficial for reactive maintenance. It could potentially help to carry out planned maintenance in a cost beneficial, risk managed and outage controlled manner. It should also raise confidence in new technology. Monitoring applied at the appropriate time gives engineers more knowledge and information of the asset and enable longer lead times and clear assessment of management decisions. Using data currently held, as well as new data it will allow enhanced performance and maximum efficiency. In effect it's the drive towards a cost effective, optimum timing device to enable National Grid to move towards condition/risk base maintenance.

- CB timing incurs a cost in time and resources that could be mitigated using a real time online methodology. It takes 2 people 1 day to perform timing tests on a single Circuit Breaker and approximately 60 Circuit Breakers are timed each year. Also, it takes one person one day every month to download the data from CB watch equipment on site. Consequently, over a five year period 660 man days are spent timing circuit breakers and retrieving the data which equates to manpower costs of £165k.

Air System Conditioning Monitoring

- Following a successful trial and national roll out, the following potential cost savings could be made.
  - Lowered operational expenditure via improvements in reliability and lowered spares consumption - £100K per year.
  - WSE legal compliance (TGN 77) & (TGN 14) via DEW point monitoring - £60K per year.
  - CO2 & Energy cost reduction - £100K per year.
  - Proactive maintenance and oil top up prediction - £50K per year.

Bi-Directional R.F Intra-Substation Communications System

- **A Single Uplink Gateway.** Currently each monitoring type can have its own uplink gateway, which is rapidly leading to multiple uplinks on a single site. Each uplink requires a pre-paid GPRS cellular link. This raises some difficult issues with managing accounts with many systems of differing ages. The system to be researched is designed to remove this requirement, allowing a single data collection point, thus future proofing the site for any further monitoring need.
- **Increased reliability.** By reducing the number of variants (types of bespoke interface systems) and replacing the architecture with a standard model platform which is expandable and modular in design, the number of problems with 'uniqueness' in respect to connection errors and protocol conversion will be minimised. All systems will be future proof, backwardly compatible and critically, all the same in technical design.
- **Reduced Installation and Maintenance Costs.** A standardised data recovery platform reduces many of the common problems seen with integration to the physical monitoring equipment and the substation environment. The single point uplink and downlink (bidirectional system) allows remote firmware revision, error correction, instrument interrogation and servicing with remote reset capability, thus much lowering the site access time required currently.
- **Improved Asset Management.** The new architecture will provide a design 'basic' to which all future monitoring applications will be engineered towards, enabling a simple and easy to manage interface to be rolled out to every substation with monitoring requirement . All existing comms systems will be compatible with the new standard ensuring no compatibility issues.

	Noise Recorder GPRS Interface to Provide on-line data logging facility • To be able to access [via the web] live noise and meteorological data without the need to visit what are often remote sites allows more timely and better quality decision making about costly asset management options, allows the integrity of the monitoring equipment [and in some instances the integrity of the plant itself] to be continually monitored, and allows a whole raft of interested parties who may have little or no noise expertise, to easily share the information without reference to noise specialists. Interested parties might include Environmental Engineering's own internal clients, Environmental Health Officers and even complainants themselves in certain instances. Although there is a general need to visit sites to download other high resolution data and to maintain and calibrate equipment [perhaps quarterly], the number of site visits by specialist operatives will be reduced. ARMADA • This work further leverages National Grid's involvement in the Supergen 5 programme; by offering these transformers as a trial facility National Grid gains directly from the outputs of WP6. The knowledge gained from this work will also allow National Grid's monitoring policies to be further developed and implemented. Key benefits from the work will include: • The extent to which data from one transformer can be used to infer condition information about a similar unit. • Understanding how data fusion from several simple sensors can give additional information beyond treating each individually. • Test the transformer thermal model previously developed by Liverpool university. • Look for correlations in the data that have not been previously observed due to never having had such a heavily instrumented transformer. • In addition to the Supergen work at Ocker Hill it is proposed to undertake a test of wireless sensor networks in collaboration with the National Physical Laboratory (NPL). This work will only require the provision of some manpower since NPL already have funding for the sensors. However the knowledge gained from trialling these new advanced data communication systems within a substation environment will allow National Grid to (1) understand the influence of electromagnetic interference on performance, (2) assess the battery performance and (3) evaluate the embedded intelligence within the motes. Remote Connection to PD Monitoring • The solution will remove travel time for specialist from Italy to the UK to down load the data and review settings and

	alarms, as this will be needed to initially tune the pd system to match the unique characteristic design on this cable to reduce false alarms and optimise the pd signal to noise ratio. • This system will also remove the need to provide site access in London substation where resource is a constraint. • The availability of the system to be monitored will reduce any PDSA costs, as a large proportion of the budget will be allocated to travel and accommodation. More importantly it will greatly improve the lead-time from identifying a problem to failure. Energy Scavenging Technology • This project is likely to have medium-term payback (5-10 years). The technology to be developed will enable the deployment of more advanced sensors and monitoring techniques within the electricity transmission system, enabling National Grid to take a world leading position in the management of its plant and capital assets. • The research will contribute to the reduction of DC battery and cabling requirements for plant sensors and facilitate the monitoring of hitherto inaccessible information on plant condition. Consequently this will avoid unnecessary site engineering work, minimise the impact of electromagnetic interference, and ultimately enable more efficient operation of the network and give greater confidence in the health of plant in operation. As such, it should eventually lead to reductions in costs associated with unanticipated plant failure and consequent detrimental effects on industrial and domestic consumers. • It would be rather difficult to use money term to value the benefit of this research on reducing the risk of electromagnetic interference and improve reliability of substation secondary systems. However, the potential saving on reduction of battery usage and site cabling is estimated in region of £50 – 100 k per annual. In addition, the outcome of this research will also have huge impact on the environment due to reduction of the usage and disposal of DC batteries at substations.		
Expected timescale of project	4+ Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£530k
Potential for achieving expected benefits	Overall this programme fully expects to realise the benefits expected of it. Projects are largely on track and producing results that indicate a positive outcome. Many examples exist where this web based live data access has proved extremely useful. A facility was established at Mannington for instance to bring back live data about the operating status of SVCs.		

	This data has been key in identifying business drivers to justify modifications to the SVC to improve noise performance to help to resolve a 10-year old noise complaint scenario. The concept aligns with the Smart Asset Management initiatives already being implemented within Asset Engineering.
Project progress as of March 2009	The progress of the individual projects is as follows: Smartlife Workgroup • Smartlife is a self-funding European Collaborative Project consisting of 26 organisations, and led by Electricité de France SA, ERDF, SINTEF, Cesi Ricerca, KEMA, Iberdrola, ENEL Distribuzione, and RTE. The project started in January 2009 and partners are still joining; the latest being Wien Energie Stromnetz. Activities are broken into 5 User Groups: Underground cables, Overhead lines, Transformers, DSO Asset Management, TSO Asset Management. Prof Rowland of Manchester University represents National Grid's interests on the Overhead Lines groups. He has also attended Underground Cable meetings on National Grid's behalf. Each of the groups is charged with drawing together best practice and asset failure data, and using this to determine necessary research paths to be followed for filling-in knowledge gaps identified. Full site trial of CM • Investigation to equipment and system historically installed on site, now requirement to scope work. Intended to be delivered in next two months. Remote Mass Flow Meters • Hardware and most of the software delivered. Now require a scope and budgetary extension to make amendments to firmware on modems to meet IS security requirements. • Intended to be delivered in next two months. Data Visualization • To date we have come up against an issue regarding a visual map provider. Although we have undertaken a considerable amount of research on the mapping side, we await a business decision as to what mapping platform is to be adopted. • Running in parallel, we have been looking into how we collect and capture data. We are investigating the possibilities of moving to a PDA device with GPS capability. This would allow the use of real time mapping to match assets to data. • To accommodate the above we are putting considerable effort into verifying our asset data, making it more accessible and easier to manipulate Condition Monitoring of Circuit Breakers • Due to delays and resource issues, programme has started later than programmed. The deliverables and scope has not changed Air System Conditioning Monitoring

- Contracts have been raised and all the collaborating parties are working on their agreed specifications. The project web based management tool (Base camp) is operational and all parties are managing their respective action / targets via this platform. C3 software is in production and the trial version is viewable over the internet. The two test trial sites are planned and are on target to be complete by the end of July 2009.
- The wireless data equipment is in transit and test data will be uploaded during June 2009.
- Trial site data will be viewable on the internet by July 2009.

Bi-Directional R.F Intra-Substation Communications System

- Invisible Systems LTD (ISL) have now finished the main component of the system, which is the ISL012 gateway unit. This is the transmitter/receiver hub which will sit at each device and act as the central collection node.
- Work is commencing on the protocol converters which will be the interface between the bespoke field measurement devices and our intra-substation wireless network.
- This firmware will allow the transmittal of commands out from the central node to the device hub, which will then convert the command to a local protocol string the instrument understands.
- The reason we do this is due to the low data rates that are offered at this frequency of radio bridging.
- We are expecting the first trial deployment to allow a command to be sent from a web server down to the device to effect a sampling frequency change to be rolled out by the first week of September 09.

Noise Recorder GPRS Interface to Provide on-line data logging facility

- The trial logger device is successfully extracting data from the proprietary sound level meter [and weather station] on loan from National Grid. The supplier is just at the stage of porting this test data [via GPRS] to his server, where the data will be made available to NG via a web site running on the suppliers own server. The GPRS enabled logger is shown below;

	ARMADA • All the hardware has been installed for this project, but was finally completed and made live to the data servers in November 08. The delays in getting the core project work installed were mainly down to the year's extremely poor weather which seriously hampered the installation plan. • As of last November, all the main sensor systems on the two test transformers plus some additional sensing systems (Laser Acoustic, Transfix, Hydran) are all operational and recording data. • Strathclyde University have server access to all the online data and are begin to model the information into the chromatic maps under the AMPerES project. Remote Connection to PD Monitoring • No longer required, alternative solution impleamented. Energy Scavenging Technology • Project was delayed to start Sept 2008 and two project meetings have been held to date (Sept 2008 and Feb 2009). Initial research has commenced and the possible energy scavenging techniques to be evaluated have been identified. • Research into existing measured field strength data has been completed with typical substation plant field strength measured data provided by the EMF team at National Grid. A mock up of a capacitive scavenging unit has been manufactured, • Both Inductive and Capacitive energy scavenging techniques to be investigated and a power budget matrix to be prepared to match the scavenging technique with potential application.
Collaborative partners	Smartlife is a self-funding European Collaborative Project consisting of 26 organisations, and led by Electricité de France SA, ERDF, SINTEF, Cesi Ricerca, KEMA, Iberdrola, ENEL Distribuzione, and RTE Other partners include Power Link, Areva, Adaptive Solutions, C3 AMULET, CompAir, Gardner Denver
R&D provider	University of Strathclyde, C3 Amulet, A1Predicta, C3Global, Elimpse, IDLS, Ruggedcom, Kelman, IDLS, Siemens, EPRI, Adaptive Solutions, compare, Gardner Denver, Invisible Systems LTD

11) On line Monitoring Integration

Project title	On line Monitoring Integration			
Project Engineer	Carl Johnstone			
Description of project	To trial and implement a full on line monitoring system external of the business network, by the involvement of key stakeholders across the business. To retro install an online density system on GIS substation were current monitoring in manual checking of gauges and a new GIS Substation where there is a stand alone online density system installed through construction, and then evaluate the benefit case for running a scheme to roll out to other substations.			
Expenditure for financial year	Internal £3k External £184k Total **£187k**	Expenditure in previous (IFI) financial years	**£0**	
Total project costs (collaborative + external + internal)	**£212k**	Projected 2009/10 costs for National Grid	£25,000	
Technological area and/or issue addressed by project	More efficient management of GIS and SF6 filled equipment to move from reactive to proactive planning of resource, by applying modern monitoring techniques to order equipment where bigger benefits would be delivered			
Type(s) of innovation involved	Tech Transfer	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		11	2	9
Expected benefits of project	The benefits are itemised for SF6 but the business process benefits could apply to any online condition based measuring systems such as Drallim (cable oil pressure), Gas in Oil analysers (Hydra< Kelman) Partial Discharge (AIS and GIS). :- • Process • To predict the time to intervene and action required. Then record and make information available to a wide audience and to other systems (Planning, Reporting to the regulator, ranking of leaks -maximising benefit by focusing on highest leaks, automated instruction to site staff on action required cost avoidance to deferred maintenance for resource constraint. • Maximise expenditure by matching level of leak, to level of repair. Regulator incentive £10m over 5 year period. • Carbon equivalent (£25/ton carbon x 23,000)cost if applied £837,411 (at Littlebrook 07- 08) • £14k/annum spent on SF6 gas for top-ups (at Littlebrook 07-08) • Man hours for top up and gauge survey (£3.5k/annum with travel time Littlebrook) • Reduce call outs diverted resource to respond to gas alarms (£70k/annum to GIS sites) • Reduced alarms to the NOC • Better Visibility			

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- Easier to view current status (on-site or remote) to reduction of emissions, site targets, reduces need to attend site (travel time/carbon footprint)
- better 'buy-in' for site staff and other business users due to clarity of drivers and contribution to the overall target
- Reduced training requirements and understanding of proprietary software from different suppliers.
-
- Affiance
- Better use of resource in areas where constraints (GIS and cables are generally based in London and South East) reducing deferred work.
- Opportunity cost benefit for released resource - 25 man-days for sub routines for the four sites
- Avoidance of inefficiencies associated with diverted resource
- Maximise benefit of system already installed, currently under utilised.
- Calculate volume of gas used in each gas zone removing need for weighing and mass flow meters.



</td></tr>
<tr><td>Expected timescale of project</td><td>2 Years</td><td>Duration of benefit once achieved</td><td>5+ Years</td></tr>
<tr><td>Probability of success</td><td>60%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td>-£26k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="3">Success has been achieved on a small scale trial and now the scaling issues will be addressed in this phase</td></tr>
<tr><td>Project progress as of March 2009</td><td colspan="3">System (hardware and software) has designed, developed and fully factory tested. Awaiting resource and planning to meet construction regulations to install on the live substation without requirement for outages, making the application viable.</td></tr>
<tr><td>Collaborative partners</td><td colspan="3">Siemens have participating with the development of the system and knowledge of the primary assets.</td></tr>
<tr><td>R&D provider</td><td colspan="3">Siemens/ C3 Amulet</td></tr>
</table>

12) Strategic Asset Management Capability

Project title	Strategic Asset Management Capability
Project Engineers	Jenny Cooper, Mark Osborne, Lewis Dale, Paul Auckland
Description of project	This project is a combination of strategic projects being carried out largely by university groups as part of major strategic collaborations. Projects are supported under EU funding, Electricity Supply Research (ESR) network funding and Engineering and Physical Sciences Research Council (EPSRC) funding in conjunction with contributions from international utilities. The projects focus on understanding the potential of techniques or technologies to impact the electricity Transmission network. The Power Networks Research Academy (PNRA) has been established through a strategic partnership agreement between; EPSRC, electricity transmission and distribution companies, related manufacturers and consultants, that will fund and support PhD researchers in power industry related projects and help maintain and improve the research and teaching capacity in power engineering subjects. Supergen is an EPSRC strategic partnership programme incorporating a collection of projects across a number of UK academic establishments. This fifth call, Supergen V is entitled Asset Management & Performance of Energy Systems (AMPerES) and is a 4 year multiparty collaborative project. The two key aims of the project are to provide platform technologies and tools for integrated network planning and asset management and, to identify methods to develop and implement networks with reduced environmental impact. The impact that Energy storage in its various forms could have on the Transmission network will outline possible industry models for the widespread deployment and adoption of energy storage. This is a Group wide project, of which the UKT contribution will only cover the assessment of the UK network. It will source external expert opinion on the status of the interaction of energy storage with network security of supply and provide guidance in available technologies and their optimisation. Flexible Electricity Networks to integrate the expected Energy Evolution (FENIX) focuses on harnessing distributed generation and demand response to provide balancing services for suppliers, transmission system operators and distribution system operators. National Grid's role is advisory and as a participant in the UK systems trial. The quantified impact assessment on the energy demand profile (peak demands and daily profile) if the current summer / winter clock change regime was altered will be delivered. The report will be a basis for understanding the potential impact of such a change and be able to support a policy position on the issues. It is expected that a different clock change regime could result in lower winter demand peaks and lower energy volumes transmitted. This could result in

<table>
<tr><td></td><td colspan="4">more access to the system, for customers, maintenance and construction as well as the deferral of some asset investments. There is also the potential for lower overall energy consumption giving lower GB carbon emissions.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £47k
External £144k
Total £191k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">Total £109k</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£12m</td><td>Projected 2009/10 costs for National Grid</td><td colspan="2">£56k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">PNRA: The projects for the first cohort of Academy scholars are:
• Overhead Lines Measurement System
• System Impacts and Opportunities of HVDC Upgrades
• Application of Artificial Immune System Algorithm to Distribution Networks
Circuit Breaker Condition Monitoring (No scholar recruited)

AMPerES: WP 1: Programme delivery, outreach and implementation
WP 2: Enhanced network performance and planning
WP 3: Adaptable protection and control techniques
WP 4: Infrastructure for reducing environmental impact
WP 5: Ageing mechanisms
WP 6: Condition monitoring techniques

Energy Storage: In addition to the range of technologies which can be considered, the UK aspect examines the use of PV and wind generation to supply battery storage, which can be utilised to provide substation auxiliary supplies. This will be considered for a pilot project.

FENIX: Distributed energy resources (generation and demand side), through suitable aggregation and control (i.e. by formation of a virtual power plant), could offer balance responsible parties services (i.e. Suppliers, TSOs & DSOs) services that would permit the efficient active management of networks and address challenges that will arise as power from intermittent energy sources increase and regulation from conventional/central generation becomes more expensive or less available (due to retirement). Fenix aims to offer a mechanism so that the owners of such distributed resources could contribute useful services at low transaction costs (using SMART metering, internet communication systems and home automation facilities).

Optimising the use of transmission assets by reducing network loadings in shoulder periods of the year, facilitating easier network access for maintenance and development of the system and also resulting in a net reduction in total energy consumed through better alignment of people's activity hours with daylight hours.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Strategic</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>0 to 8</td><td>1 to -5</td><td>4 to 10</td></tr>
</table>

Expected benefits of project	It is expected that the Academy will: • promote a stronger, more active and robust R & D environment in power networks disciplines at UK universities; • provide capacity and capability to undertake the specialist research needed by industry and wider stakeholders; • strengthen the teaching capability at those institutions; • focus on building the health of discipline across a number of power research universities; • facilitate a resource of trained engineering staff with academic capability, who will be capable of tackling electrical power engineering challenges; and • deliver research output that is industrially relevant. See online for further information at http://www.theiet.org/about/scholarships-awards/pnra/ The expected aims of AMPerES are: • To deliver a suite of intelligent diagnostic tools for plant • To provide platform technologies for integrated network planning and asset management • To progress plans to develop and implement improved and reduced environmental impact networks • To develop models and recommendations for network operation and management Energy storage has the potential of contributing to ensuring supply security of the transmission network, as generation and demand patterns change is becoming an increasing challenge. Due to the variable nature of renewable energy production. Energy storage would enable the full optimisation of cables connecting renewable energies into the network. Minimising energy wastage from renewable sources which would otherwise be subsidised from rational sources. Understanding how Energy storage could be managed to optimise and refine system frequency and offset the variability due to intermittency of renewable wind generation will be very valuable work. In the long term this could lead to more effective and efficient use of renewable generation, through matching the time of demand with energy production and overcome network constraints by the time shifting of energy flows. FENIX contributes to a sustainable business model for distributed generation and demand resources through their contributions to SMART networks. Enhanced value by exploiting diversity (to ensure high dependability of service provision), high resolution locational control of distribution network flows and minimised transaction costs (through automation and integration with new SMART metering). A research project to establish the potential impacts and benefits of a change through assessing the likely load shapes and demand levels under an alternative clock time scenario. The project itself has a number of benefits in moving forward the discussion internally on the merits of the potential policy change and size of benefits to National Grid in terms of the potential to increase access to assets for maintenance in months around clock change plus demonstrating and delivering upon our commitments to actively engage on ways to promote energy efficiency. The size of the benefit could be

	substantial as, just after clock change in October, peak demands currently step change with an increase of about 2GW's from one week to the next, placing increased demands upon our assets. If this step change in demand affect could be reduced or delayed, then access to assets would be consequently easier to facilitate. The potential benefits that are expected are greater access to assets over the shoulder (November & March) winter months for maintenance and construction work and a possible positive contribution to reductions in green house gas emissions.		
Expected timescale of project	5 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£319k
Potential for achieving expected benefits	It is expected that the PNRA will: • promote a stronger, more active and robust R & D environment in power networks disciplines at UK universities; • provide capacity and capability to undertake the specialist research needed by industry and wider stakeholders; • strengthen the teaching capability at those institutions; • focus on building the health of discipline across a number of power research universities; • facilitate a resource of trained engineering staff with academic capability, who will be capable of tackling electrical power engineering challenges; and • deliver research output that is industrially relevant. See online for further information at http://www.theiet.org/about/scholarships-awards/pnra/ AMPerES: Asset management is core to the business. The appropriate use of the emerging opportunities for condition monitoring is key to optimising performance, both financially and in quality of supply. Some of the technologies being developed in this programme are likely to be utilised, however much more important is the broader window this work gives to the global research community. Through demonstration sites the true value of condition monitoring will be identified, enabling appropriate business decisions on adoption of technologies. Justifying energy storage is still proving to be very subjective and this project address long term issues. The present costs and market reluctance for any new technology option is restrictive, in time this will ease. In terms of proving ideas the move towards renewable generation is providing a better opportunity for ES to balance the intermittent gap associated with either the wind or solar intensity. The realisation of a small scale demonstration project is quite high. FENIX: Developments of decentralised electricity markets, SMART metering, home automation and small scale energy facilities means that the technology components for making use of distributed		

	resources are at hand. Experience has already been gained in aggregating certain distributed resources, for example to provide transmission ancillary services. FENIX has already developed and demonstrated suitable decentralised control algorithms. The question of whether a sustainable business model can be developed now depends on system setup costs and ongoing transaction costs versus the benefits that can be realised in electricity markets. Clock change: The benefit has been achieved as fuller and much more definitive quantification of the impact of changing clock time regime to GMT+1 year round has been identified and is now available in a Cambridge University Report. A consistent finding of the three methods researched was that timing sunrise and sunset an hour later in winter would accord better with the activity patterns of the population and would have a net favourable effect on electricity usage over the course of the day. All methods indicate that the direction of effect would be favourable – the net energy saved in GB by the later timing of sunset would be greater than the energy expended as a result of later sunrise. The energy effects are small on paper at a reduction of circa 0.3% of energy volumes in winter months, but these still amount in winter to **6-7GWh's per day** which in broad terms can be taken as a **0.3% reduction in electricity generation sector emissions** each winter day assuming the same generation mix pre and post this potential time regime change. The impact on peak demands from the policy change of moving to year round GMT+1 is a **reduction in peak demand of 0% to 4.3%** (the biggest reduction being in shoulder months and the 0% being at the winter peak itself which is unaffected). The main benefit we were looking at for National Grid is delaying the winter pick up in demands and bringing forward the reduction in Spring to allow us a longer outage season, without the step change in demands at clock change we currently see.
Project progress as of March 2009	In 2008 four projects for the first cohort of PNRA scholars were selected from a number of submissions, using a two tier process. This process comprised; an initial sift to determine the project's industrial relevance and an independent peer review to determine their academic excellence. Scholars were subsequently recruited for three of these projects and a brief summary of the progress achieved to date are detailed below: **Overhead Lines Measurement System (Cardiff University)** A comprehensive survey has been carried out and was used to produce an initial design of the Overhead Lines Measurement System (OHMS) concept. This was summarised in a paper and presented in a poster at the 2nd UHVnet colloquium in January 2009. EDF Energy has provided technical guidance on the use of OHMS for optimising performance on the 11 kV networks. Initial modelling of PLC systems on the 11 kV network has also been carried out using ATP/EMTP software. Laboratory testing of PLC is ongoing and following advice from the magnetics group at Cardiff University group, the simple inductive couplers are being replaced by couplers exhibiting more desirable properties for narrowband PLC. Development of a suitable processing unit to integrate different sub-systems (multiple sensors, ADCs and PLC MODEM chips) into one

stand-alone device working in real time is a challenge requiring both the development of the microelectronics and laboratory testing taking place concurrently with the sensor and PLC testing.

System Impacts and Opportunities of HVDC Upgrades (Imperial College, London)

The initial phase of the HVDC project has concentrated on developing understanding of the fundamental analysis techniques and tools. Using Power Factory DIgSILENT software (used by NG), a two-area AC system of 4-generators with an embedded HVDC link was modelled. The small signal stability was analysed by evaluating a series of non-linear simulations and modal analysis under various contingencies. Due to the limitations of the software, alternative methods using system identification are being explored to obtain the state-space matrices which will allow for designing controllers to improve the damping of inter-area oscillations. A larger power system with 14-generators, consisting of 5 areas has been developed for similar analysis.

Application of Artificial Immune System Algorithm to Distribution Networks (Manchester University)

A comprehensive survey of research on artificial immune systems (AIS) and their application to power systems problems has been completed. An AIS algorithm to cluster arbitrary data sets and detect groupings has been designed and its performance evaluated using a variety of initialisation methods. An AIS based methodology for detection of overloaded lines and voltage weak buses within power system networks has been designed, while a basic negative selection algorithm to detect critical loading in small power systems has been designed and built. The AIS algorithms have been hybridised with other techniques such as support vector machines to produce a classification algorithm and the performance of AIS algorithms compared with neural networks. Power system network data has been obtained from Central Networks to use for a knowledge discovery experiment, where this will be mined using AIS techniques to find patterns. A paper entitled “Application of AIS Based Classification Algorithms to Detect Overloaded Areas in Power System Networks” has been written and submitted to the 8th International Conference on Artificial Immune Systems 2009 (ICARIS) to be held in York, UK in August 2009.

AMPerES Technology & trials:

- The detection, control and protection synchronous islands have been demonstrated on a 50kVA diesel generator. The demonstration employs a real-time phasor measurement system. An AC optimal power flow method for assessing the maximum distributed generation (DG) penetration in distribution networks has been developed. A novel method of detection of loss of grid techniques is being developed. A low-cost system with internet broadcast capability has also been developed: four are currently in operation. An investigation into how regions of a distribution network can operate during emergency islanded mode conditions is also underway.
- Optimized design of existing overhead lines of wood pole line,

	and a lattice tower line. The methodology has been employed to analyse the behaviour of low-sag composite conductors on a 33kV wood-pole structure. The model is now being utilised on a wood-pole line on Scottish Power and a lattice tower line on the National Grid, and may substantially improve the performance of sections of the network without major infrastructure changes. • A unique installation for transformer monitoring at National Grid comprising of two 275/132kV, 180MVA transformers, is implementing results of research on condition monitoring architectures, diagnostics and machine learning. • Development of condition monitoring architecture for power networks has progressed well and is being implemented on a National Grid transmission transformer. Diagnostic and support modules are included, and exploit a range of ageing models including those developed within this project. Work on ageing has shown that the rate of damage may not be affected by harmonic content, but resulting partial discharge signals change significantly. • PP-based alternatives to XLPE cable insulation have been characterised. Additional funding has been secured for the more applied work to develop routes to commercial exploitation. Vegetable oils have been shown to be a basis for replacement of mineral oils in HV equipment. • Strathclyde and Liverpool have been applying knowledge-based partial discharge analysis and chromatic analysis to data from EdF Energy cable monitoring systems. All publications and reports are available to all the partners from a secure web site: http://www.supergen-amperes.org/ Energy Storage: The US report has been completed and issued by Navigant. It summarises that energy storage best opportunity is related to Balancing services (frequency response, black start etc.), in addition using storage to shift the power peak associated with wind generation. A site has been provisionally identified where a pilot project could be developed using renewable energy through a battery storage system to provide site supplies. Currently establishing cost feasibility and a strategy brief is in preparation for discussion internally. FENIX control algorithms have been designed and implemented. Demonstrations for the GB and Spanish markets have been developed. Detailed business models are being refined. See http://www.fenix-project.org/ Clock change project is complete, with benefits being realised through policy and climate change review.
Collaborative partners	PNRA: EPSRC, National Grid, Scottish and Southern, Central Networks & EDF Energy Networks. AMPerES: Scottish Power, Scottish and Southern, United Utilities, Western Power Distribution, Central Networks, CE Electric, NIE, Advantica & EDF Energy Networks. Energy Storage: National Grid US

	FENIX - Areva T&D Energy Management Europe, ECRO SRL, EDF Energy Networks, Electricite de France, Energy Research Centre of the Netherlands, Fundacion Labein, Gamesa, Groupment pour inventer la distribution electrique de l'avenir, Iberdrola SA, Imperial College, Institut fur Solare Energieversorgungstechnik Verein an der Universitat Kassel e.V., Korona Inzeniring DD, Poyry Consulting Ltd, Red Electrica de Espana SA, ScalAgent Distributed Technologies, SIEMENS Aktiengesellschaft Ost, The university of Manchester, Vrije universiteit Amsterdam
R&D providers	PNRA: Universities of Cardiff, Manchester, Queens (Belfast), Southampton, Strathclyde, and Imperial College London. AMPerES: Universities of Manchester, Southampton, Edinburgh, Liverpool, Strathclyde, Queens (Belfast). Energy Storage: Navigant Consulting FENIX: EU project partners Clock Change: Cambridge University

13) EPRI

Project title	EPRI Substations		
Project Engineer	Jenny Cooper		
Description of project	This project encompasses National Grid Electricity Transmission's participation in selected Power Delivery projects from the EPRI (Electric Power Research Institute) R&D Programme. Projects are selected to enable maximum beneficial project interaction and maximum leverage on funds. Additional technical collaborations and access to existing products are included as part of the agreed collaboration at no additional cost together with access to the Technology Innovation Program and participation in the Research Advisory Council.		
Expenditure for financial year	Internal £22k External £534k Total **£556k**	Expenditure in previous (IFI) financial years	Internal £ External £ Total **£308k**
Total project costs (collaborative + external + internal)	**£ (EPRI costs $27.1m)**	Projected 2009/10 costs for National Grid	
Technological area and/or issue addressed by project	Project areas 2008/9: • Greenhouse Gas Reductions Options • Conductor and Wire Corrosion Management • Improve Transmission Line Lightning Performance • Polymer and Composite Overhead Transmission Line Components • Transformer End-of-Life & Condition Assessment • Transformer Life Extension • Advanced Conductors • Life Extension and Best Practices Guidelines for Substation Equipment • Improving Overall Substation Maintenance Management • SF6 Environmental Management and Equipment Performance • Solid-State Fault Current Limiter/Circuit Breaker Development • Management of Substation Ground • Energy Storage (Transmission) • AC/DC Line Conversion • Antenna arrays and wireless mesh sensors for partial discharge location • Zed meter trial • Technology and Innovation Programme including sustainability		

Type(s) of innovation involved	Significant and Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		14	0	14

Expected benefits of project	EPRI is probably the largest research organisation in the world with a large-scale interest in the electricity Transmission business. The organisation is keen to implement research programmes between suppliers and utilities, thus encouraging innovation and bringing novel ideas closer to the market. National Grid has also been invited to be a member of the Research Advisory Group – the executive level group steering the complete research programme. The key benefits to National Grid of being involved with such an environment include: • Gain access to a wide range of R&D objectives both underway and planned • Participate in multi-user discussion and networking including setting the direction of applicable EPRI projects • Commercialisation of R&D into products that can be purchased with minimum risk due to knowledge gained in R&D • Trials comparing diagnostic tools – benefit gained from collaboration as National grid would not support this activity individually • Evaluation of benefit from application of techniques/software currently in development through EPRI projects • Establish further opportunities for tailored collaboration for demonstrations and trials with further shared risk and cost sharing • Access to experts with complimentary skills to in-house specialists • Access to existing products (value up to 10% of contracted 18 costs) – both reports and intellectual property/applicable knowledge • To influence the direction of the EPRI programme to National Grid's best interests through participation in EPRI project working groups and advisory councils. • Significant leverage on funds estimated to be 50:1 in substations. Access to EPRI information is open to all National Grid Transmission employees with a password enabling access to the specifically funded projects and the technology innovation projects. The National Grid selection from the EPRI programme delivers applied research with defined benefit to National Grid's assets including improved transformer analysis, SF6 leakage recommendations and substation monitoring via antenna array technology based at Strathclyde University. The total project portfolio for EPRI in the transmission research area is $104million per annum, National Grid's selection forms part of this total activity giving significant leverage and potential for developing multi utility collaboration on projects leading to networking, cost and risk sharing. Specific benefit areas: *Transformers:* National Grid has a major transformer replacement programme; understanding the end-of -life processes, condition assessment methods and any possibilities for life extension is required to optimise this expenditure. The EPRI projects provide an international perspective to this activity to supplement the other work, both past and ongoing, that is saving something in the region of £5M per year in capex in terms of avoided replacement and failures if the replacement decision making process was less well informed. Additional incremental benefit from ongoing research is difficult to

	quantify precisely, but failure to be informed and up to date in a critical asset management area would have a damaging effect on both revenue and reputation. The EPRI work contributes at least 1% of the £5m per annum and is applied via National Grid's transformer specialist. *SF6:* Strong environmental driver to be involved. Good successes in previous years with benefit achieved through the development of leak sealing technology and partial discharge trials, both leading to implementation on the system. *Earthing:* The benefits of collaboration on the earthing (grounding) project will allow for alternative methods of test to be examined and validated, resulting in a potential cost saving to National Grid Transmission through efficient incorporation of the techniques into National Grid's operation. *Overhead Lines*: Application of TFlash lightning modelling software to analyse performance of current and future assets, also added potential to assess impulse tower footing resistance. Complimentary work to ensure knowledge of asset management of composites in terms of lifetime, handling etc. Facilitating reduced operations and maintenance costs while supporting an aging infrastructure with reduced capital expenditure for new and refurbished equipment. Need to improve reliability and worker safety *Substations:* Safety of people and equipment during operations and outages. Enhancing system reliability, performance, and life of equipment on ever-decreasing maintenance budgets has become essential for an infrastructure that has reached its design life of 40 years. Advanced technologies and tools are needed to maintain and operate substation equipment in the increasingly competitive energy marketplace *Transmission System Development:* Safeguard, protect, and modernize transmission grids. Increasing transmission capacity utilisation is necessary to ensure grid stability. Need to eliminate or relieve transmission bottlenecks to the market reach of competitive generation. Need to increase the robustness of the transmission grid through use of tools that enhance both steady and dynamic state performance *Sustainability:* Understanding implication for National Grid – Model for building sustainability in terms of inputs, operation and delivery of energy. Combined utility view of benefits of sustainability in terms of reduced impact on asset management leading to environmental and cost benefit to the customer.		
Expected timescale of project	5+ Years	Duration of benefit once achieved	5+ Years
Probability of success	50%	Project NPV = (PV benefits – PV costs) x probability of success	£210k

Potential for achieving expected benefits	Total cost of 2008 EPRI programme that National Grid contributed to in part was $27.1m. EPRI feedback from combined utility membership indicates that with a leverage of up to 50:1, there is potential for achieving benefits through • Maintenance guidelines can extend equipment life by 5–10 years • Condition-based maintenance reduces maintenance costs by up to 30% • SF_6 management can reduce losses by up to 50% • Predictive maintenance will reduce maintenance costs by up to 10% • Preventing failure of critical transformers will save £2–5 million per unit • New overhead line design tools that can reduce capital expenditures by up to 5% • Accurate overhead line component condition assessment will be improved to accurately diagnose incipient fault conditions, increasing transmission reliability. • Increased knowledge and understanding of technology-based methods to alleviate transmission capacity constraints and help them optimize use of existing transmission assets • Extending the market reach of competitive generation by eliminating or relieving transmission bottlenecks • Enhanced experience and knowledge about which technologies will increase the robustness and integrity of transmission grids by avoiding or minimizing the impact of cascading failures, voltage collapse, and other major disturbances. Membership of the EPRI L&G Task Force has delivered National Grid guides on the different types of OHL earthing and how to apply them, as well as guidance on the different types of test methods and when to use them. The Task Force is also in the process of delivering a specification for a test meter to allow the earth impedance of individual towers to be measured without removing the earthwire at the peak. This Task Force is also responsible for the development and maintenance of the TFlash software which is used to manage the risks associated with lightning and OHLs, specifically the software allows the probability of an OHL being struck by lightning to be calculated and the potential consequences to be evaluated. Application of the Antenna array trials have reduced radio frequency interference surveys – removing need for weekly surveys and hence saving manpower directly (estimated as 100 hours minimum per survey). Potential failures avoided this year have been a current transformer and a supergrid transformer due to bushing failure on a supply to a major consumer. The avoided costs from these failures are considerable amounting to an estimated £5m but also avoided potential disruption to customers. Work to develop a technique of testing ceramic insulators for defects with the circuit energised has developed to the proof of concept stage. Successful testing at Eakring test facilities has identified the

	possible best technique which now needs further development.
Project progress as of March 2009	Delivered and in progress in Power Delivery Programme to date (08) • Conductor and Shield Wire Corrosion Management: Assessment of environmental factors and new and emerging inspection technologies delivered (08). • Greenhouse Gas Reductions Options: Launched Global Climate Policy Design Forum Series, communicated the importance of technology innovation in addressing climate change through Global Energy Technology Strategy work (08) • Transmission Line Lightning Performance: demonstration of field tool to evaluate Transmission line earthing (including award to Ben Howat for contribution to the project), report on improving lightning performance utilizing TFlash, report on sub-grade corrosion of earth electrodes (08) • Overhead Transmission Insulators: Polymer and composite overhead transmission line components – tool for corona ring selection, report assessing a population of polymer insulators and ageing evaluation. Ceramic insulator integrity assessment – assessment of mechanical and electrical strength of porcelain disc insulators. (08) • Advanced conductors: reports on maintenance and methodology for HTLS conductors (08) • ACDC line conversion, efficient transmission system studies & impact of energy storage on transmission: in progress (08) • Transformer end-of-life & condition assessment: delivered demonstrations of individual monitoring techniques including advanced DGA, additional information in transformer guidebook & real time processing of diagnostics (08) • Transformer Life Extension: Delivered ageing models of cellulose insulation due to moisture, oxygen and heat, PTLOAD enhancements, a transformer moisture assessment tool and guidance on the effectiveness of transformer life extension through enhances oil filtration (08) • Improving Overall Substation Maintenance Management contributes to predictive and condition based approaches to life extension guidelines and risk for transformers and circuit breakers (08) • SF6 management and equipment performance: delivered focus on potential current and future issues including potential alternatives (08) • Solid state FCL development: reviewed potential for SSCL (08) • Circuit Breaker Condition Assessment and Life Extension: research on lubrication, life cycle performance and potential technology transfer (08) • Ground Grid Evaluation, Maintenance and Refurbishment: progress on condition assessment and performance requirements for a field instrument, review of available staged fault test data (08)

	• Life Extension Guidelines is a web-enabled database and stand-alone guidebook that provides substation engineers and maintenance crews with up-to-date knowledge, data, procedures, and best practices for substation equipment maintenance, condition assessment, and life extension—transferred through knowledge and use of the database and guidebook; can also be transferred through a training course (07) • Transformer Expert System V 2.0 (Xvisor) is expert system software intended to help non-experts determine the condition of transformers and components—transferred through a training course (07) • Computer-Based Training (CBT) for Overhead Transmission Components or Inspection Techniques is a training tool that utilizes standard CBT protocols to allow members to utilize their in-house training management systems—training is updated on an annual basis with new modules (07) • Transformer diagnostic and risk assessment tools and software (07) • Maintenance best practice guidelines (07) • Development of fault current limiters (07) • New SF6 Camera is an SF6 leak detection camera that is smaller and lighter than a prior version, providing a passive method of detecting leaks which eliminates the safety and training issues associated with lasers—expect to transfer this hardware device through EPRI-developed training courses in the field (07) • Software tools to assist with selection of corona rings for insulators (07) • New Transmission Line Design Workstation (07) • Validation of superconductivity technologies and their values (07) • Increased power throughput in urban corridors by a factor of 3–10 using EPRI research results in superconductivity (07) • Adopting cost-effective, reliable, and secure communication for power systems applications (07) • Reducing the risk of interference issues caused by the application of new technologies to transmission and substation systems (07) • Understanding Transmission Grid Complexity, Information, and Knowledge Sharing delivered through updated information about FACTS technology applications (07) • Common Information Model: The CIM standards, accepted globally, allow replacement of older inefficient energy management systems—transferred through a utility-specific application study or training programme (07)
Collaborative partners	World-wide utilities and universities through EPRI collaboration.
R&D provider	EPRI

14) Substation Compaction

Project title	Substation compaction			
Project Engineer	Paul Coventry			
Description of project	The project has the key objective of reducing the size of substations using air-insulated switchgear (AIS), which will, in turn, reduce National Grid's dependence on sulphur hexafluoride (SF_6) as an insulating medium. This will have benefits in terms of both reduced environmental impact and reduced costs. The specific target of the project is the ability to build a 400 kV substation with the footprint of a conventional 132 kV substation. As a secondary target, the feasibility of constructing a compact conductor system as a 400 kV transmission circuit within a cable tunnel would be studied.			
Expenditure for financial year	Internal £6k External £90k Total **£96k**	Expenditure in previous (IFI) financial years	Total **£74k**	
Total project costs (collaborative + external + internal)	**£219k**	Projected 2009/10 costs for National Grid	£0	
Technological area and/or issue addressed by project	A number of options for reducing the footprint of substations using conventional air-insulated switchgear (AIS) have been identified. A compact AIS design would have advantages in applications where restrictions in the available land are encountered. For example, such a design might allow extension bays to be constructed within an existing substation boundary where space is restricted. Potential applications also arise where a replacement substation is to be constructed off-line on land adjacent to an existing substation, allowing the latter to remain in service during the construction period and avoiding the safety and operational issues associated with bay-by-bay replacement. Applications might also be found in urban areas. In such cases, a compact AIS substation might offer a cost-effective alternative to gas-insulated switchgear (GIS) substation and would reduce dependence on sulphur hexafluoride (SF_6), the use of which is being questioned on environmental grounds. The identified options for reducing the footprint of AIS substations are being investigated in the present work.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		9	5	4
Expected benefits of project	The main driver for the present work is to reduce the use of GIS in switchgear replacement and hence reduce dependence on sulphur hexafluoride gas, the use of which raises obvious concerns on environmental grounds and entails a legislative risk. It is not possible to quantify the financial benefit of reducing dependence on SF_6. However, a compact AIS design would represent a lower cost technology than GIS and the financial benefits associated with the lower cost can be estimated. A bay of GIS costs more than an equivalent bay of AIS, typically costing 40% more at 132 kV and more than twice as much at 275			

	and 400 kV. If the numbers of GIS bays in the switchgear replacement programme were reduced through the use of compact AIS designs, savings in the region of £10 m per year could be envisaged. The potential savings are greater than this, but it would not be reasonable to expect that a compact AIS design could be substituted for GIS in all circumstances. For the remainder of the switchgear replacements that will be AIS, the use of a compact AIS design would allow reduced expenditure on land and land preparation costs in addition to materials, an estimated saving of around £1-2 m per year. A compact conductor system would be a lower cost alternative to conventional cable with reduced fire risk.		
Expected timescale of project	3 years	Duration of benefit once achieved	Ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£166k
Potential for achieving expected benefits	There is a high probability that some size reduction will be achievable allowing materials and land take to be reduced. Benefits will become most significant if sufficient size reduction can be achieved that a compact AIS solution can be used in place of a GIS. The implementation of a compact design will require careful risk management and the collaboration of solution providers.		
Project progress as of March 2009	A report on minimum clearances for conductors in air as a function of basic insulation level and feasibility and difficulties in applying alternative conductor configurations was issued. A historical account of how existing conductor clearances were derived was given and the physical background to clearances and air breakdown reviewed. Three-dimensional electric field studies for existing and proposed new conductor arrangements were performed using the boundary element method. The new conductor arrangements included compact horizontal, delta and vertical arrangements. The associated magnetic fields were calculated and shown to be below the NRPB reference level. A report on proposed compact AIS substation designs summarising the investigated options was issued. Studies were performed on the use of compact conductor systems within tunnels as a low cost alternative to conventional cables. A paper entitled 'Air insulated compact substations' was published at the 2008 Universities Power Engineering Conference and one entitled 'Electric and magnetic fields in 400 kV compact substations' was submitted for publication at the 2009 International Symposium on High Voltage Engineering.		
Collaborative partners	-		
R&D provider	Cardiff University		

15) Substation Design

Programme title	Substation Design This programme of work includes the following projects: • Terrestrial Laser Survey of Substation Assets • Substation Design Reliability			
Project Engineers	Brian Addison, Mark Osborne			
Description of programme	Terrestrial Laser Survey of Substation Assets The key objective is to utilise an existing ground based laser surveying technique, which until now has not been used in substation applications in the UK electricity industry. It is hoped this project will deliver: • A dataset that will allow National Grid to create a 3D model of all substation plant & equipment. • Facilitate the development of survey techniques & specifications to allow a range of value added services to be undertaken that will significantly improve the design & approval phases of substation construction & refurbishment projects. Substation Design Reliability The purpose of this work is to establish a generic assessment model to compare performance and reliability between different substation configurations under various fault and operational contingencies.			
Expenditure for financial year	Internal £11k External £45k Total **£58k**	Expenditure in previous (IFI) financial years	Total **£6k**	
Total project costs (collaborative + external + internal)	**£70k**	Projected 2009/10 costs for National Grid	£0	
Technological area and/or issue addressed by project	The key objective of the laser survey project is to provide a 3D clearance map of the substation, allowing a SAP to judge accurately whether planned works will require proximity outages. The design reliability project will compare the reliability and availability for different substation arrangements based on historical switchgear and protection performance. The impact of various fault scenarios will be examined, to identify the appropriateness of substations for extensions or development. This will form a strategy for new connections, extensions or asset replacement decisions. This will also be used to examine alternative substation configurations (double breaker or one and a half breaker systems) and new technologies such as integrated or hybrid switchgear (such as disconnecting circuit breakers or compact units) can be used to make the network more effective.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		9	0	9

Expected benefits of project	Terrestrial Laser Survey of Substation Assets.
	Creation of a full 3-D model of the substation will bring significant benefits to National Grid.
	• Creation of a dataset compatible with National Grid overhead line records, allowing a full system model to be created
	• Creation of a standard set of feature codes & associated object libraries in the same manner that the NM&E team has developed the Tower libraries for use by all Alliance design teams on overhead line projects. This would enable substation design & layout modification works to be undertaken far more efficiently than currently, saving substantial costs & manpower in the design & draughting processes.
	• Provision of an accurate data set relating to NG substations that could be used in 3D visualisation exercises i.e. for new planning applications where NG wish to demonstrate the impact of new capital works. This would supplement the information already available for use in OHL projects associated with the substation works.
	• Engineering Design & Analysis Improvements:
	  • Proximity outages - creation & documentation of detailed & accurate clearance zones around plant to assist in the planning of outages.
	  • Safe Access Routes -establishing safe access/egress routes for new transformers & other large plant items like Quad Boosters within & around a substation accurately. This scenario could also be applied to the entire routing of a transformer from the manufacturer to the substation.
	Substation Design Reliability
	• This work will be used to support scheme decisions which underpin the long term impact on design reliability when extending substations to meet additional demand.
	• This work will save costs through reducing some of the substation design feasibility work carried out on schemes prior to sanction. On large schemes this can be up to £100k. It is envisaged potential savings could be in excess of £300k over the review period.
	• This tool will also aid with decision support on asset management issues such as maintenance strategies and operational contingencies.
	• This is also an evaluation exercise to determine the capability of this tool to provide further decision support on asset management decisions.		

Expected timescale of project	2 years	Duration of benefit once achieved	Ongoing
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£22k

Potential for achieving expected benefits	There is a very good chance that all expected benefits will be realised
Project progress as of March 2009	Terrestrial Laser Survey of Substation Assets • Following National Grid Person safety training, a specialist contractor has surveyed Skelton Grange, Bolney and West Boldon substations. • The data has been processed & delivered to the NM&E team at Skelton Grange. Substation Design Reliability • Troll have completed the studies comparing the relative performance of two typical substation used in the network. The results conclude that both designs are effective and the design mutually affects circuit performance and vice versa. This reinforces the thinking that keeping configurations simple improves the overall performance. A report has been produced. Further work has been identified and is under consideration.
Collaborative partners	MD(E), ENI
R&D provider	Starnet Ltd, Virtalis, Troll Power Consultants, Norway

16) OMU Top Up tanks

Project title	OMU Top Up tanks			
Project Engineer	Robin Greaves			
Description of project	Innovative process to top-up transformers eliminating technical and safety risks, through the re-design of the top-up tanks and associated pumping/ injection system. 1. Current process involves filling new oil through the conservator which can cause dirt and debris to be flushed into the main transformer. The new system will inject oil through the cooling bank return pipe situated at ground level. 2. At present, top-up's involve working at height, which will be eliminated with this method. 3. Cost savings will accrue with reduction in working at height and less site staff involvement. 4. Potential for automatic/on-load top-up's			
Expenditure for financial year	Internal £5k External £105k Total **£110k**	Expenditure in previous (IFI) financial years	Total **£0**	
Total project costs (collaborative + external + internal)	**£164k**	Projected 2009/10 costs for National Grid	£44,000	
Technological area and/or issue addressed by project	This project addresses a safety Issue "working at height" , once N.G. O.M.U. have the new top up tanks commissioned and approved then all top ups will be carried out from ground level. This will also lead on to cost savings as the requirement for a mobile work elevated platform is eliminated along with the operator.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		11	-2	13
Expected benefits of project	The financial benefits are associated with the reduction in site support and reduction in the hire of access platforms. Based upon the 2008/9 workload, the introduction of this method of work would have reduced operating costs by £45k per year. Future benefit of on-line operation leading to no outage costs to be assessed once delivered.			
Expected timescale of project	2Year	Duration of benefit once achieved	5+ Years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£3k	
Potential for achieving expected benefits	It is expected that the benefits will be fully achieved.			

Project progress as of March 2009	A prototype tank as been manufactured and tested by O.M.U. staff at Koronka Tanks. After testing six modifications have been requested by N.G. After the modifications are complete the tank will be delivered to the O.M.U. at Thorpe Marsh for further trials and testing. After that a production run for all the other tanks will be requested.
Collaborative partners	
R&D provider	Koronka Tanks

17) Earthing

Programme title	Earthing This programme of work includes the following projects: • Development of an Interlock System for portable Primary Earths on the National Grid System • Portable primary Earthing (PPE) • Current and Earth potential at Substations • Measurement of 3rd Party Exposure to Rise of Earth Potential (ROEP)		
Project Engineers	Dave Bedford, Alan Ainsley		
Description of programme	This programme is investigating several areas relating to earthing. Interlock System for Portable Primary Earths • It is intended to use this device for all substations down lead and down dropper portable earthing work completed by the OHL teams. The current prototype has twenty keyway variations of the interlock system, it is intended to increase this to thirty to reduce the possibility of replication. Portable Primary Earthing (PPE) • To gain an understanding of how substation PPEs perform over extended application periods and declare a maximum continuous current rating of substation PPEs under induced current conditions. Current and Earth potential at Substations • This project aims to establish whether a risk exists from the effects of step/touch potentials generated during transient surge conditions. Measurement of 3rd Party Exposure to Rise of Earth Potential (ROEP) • To develop a procedure for the accurate quantification of hot zones and transferred potentials. • To develop a prototype system for the continuous monitoring of substation earthing systems. • To produce recommendations and Guide Notes for equipment and techniques to be used by National Grid for future routine assessment of transferred potential hazards. Further co-funded project enhancements have included: • The provision of new test techniques to quantify substation hot zones. • Guidance to reduce measurement errors during testing of substation earth systems. • A review of probabilistic vs. deterministic risk from currently published safety voltage thresholds.		
Expenditure for financial year	Internal £13k	Expenditure in	

<table>
<tr><td></td><td>External £80k
Total £93k</td><td>previous (IFI) financial years</td><td>Total £158k</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£530k</td><td>Projected 2009/10 costs for National Grid</td><td>£64k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">This programme addresses issues relating to earthing – a subject that has a major importance in ensuring safety of people (National Grid staff and the general public) who are in proximity to high voltage assets. The issues addressed within the programme are the use of portable primary earths, the lack of transient high frequency measurements on substation earthing systems during switching operations, surge arrester operation or during the flow of fault current in practice and finally an assessment of the risk of rise of earth potential to inform the risk assessment process for mitigation of ROEP near high voltage assets.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>Incremental</td><td colspan="3"><table><tr><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr><tr><td>8 to 12</td><td>1 to -4</td><td>9 to 14</td></tr></table></td></tr>
<tr><td>Expected benefits of project</td><td colspan="3">The benefits of the individual projects are as follows:

Interlock System for Portable Primary Earths
• Implementation of this design will reduce the possibility of safety incidents on site. The system is aimed to be deemed ‘foolproof’.

Portable Primary Earthing (PPE)
• The risk associated with manual handling PPEs is dependant on the number per phase required, the larger the number required, the greater the risk. In some cases the number of PPEs applied is driven by the circuit induced current rating rather than the short circuit rating and therefore risks may be reduced if numbers can be reduced. This work will result in a definitive induced current rating for substation PPEs.

Current and Earth potential at Substations
• The work on this scheme will enhance the understanding of fast transient disturbances on substation earthing systems and the associated detrimental effect to the correct operation of modern substation control, measurement and monitoring sub-systems. This research proposal is mainly based around measurements of transients within the earthing system at selected substations. The experimental measurements will help to quantify more accurately the measured current magnitudes and shapes and its potential RoEP at various points within the chosen substations. It is proposed to conduct these transient measurements under two conditions.

Measurement of 3rd Party Exposure to Rise of Earth Potential (ROEP)</td></tr>
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	• This work will feed directly into the Risk Assessment (RA) software tool currently developed as part of the projects previous deliverables. The new amended software tool will afford flexibility to the user entering data by accommodating both a British Standards approach and/or CDEGS (software).		
Expected timescale of project	5 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£73k
Potential for achieving expected benefits	The potential for achieving the expected benefits for this programme is high as the projects are either already delivering benefits or the work is of an incremental nature and as such there is higher likelihood that benefits will be realised.		
Project progress as of March 2009	Interlock System for Portable Primary Earths • The project has reached the final mechanical and electrical testing stage for the new devices. Following this stage the project will await final implementation by a broader review group looking at the implication of interlocks across OHL and substations. Portable Primary Earths • Environmental tests have shown that the contact resistances of various PPE clamps remain stable for extended periods of time. The results from this work have supported an application policy of 6 months within the business. • Short circuit tests have allowed the earthing devices to adopt both a historic 2 second rating and a new 1 second rating. • The provision of the 1 second rating has allowed the number of earths required to meet site fault levels to be reduced thus reducing risks associated with a 'loss of control' event during the application process. Current and Earth potential at Substations • This project is at its end awaiting final report submission. • Successful substation transient measurements conducted under switching operations and impulse testing has revealed much data that has yet to be fully analysed. Most certainly it will provide better/more accurate characterisation of substation earthing systems under surge and switching conditions, resulting in accurate quantification of earth currents and rise of earth potentials at different locations during switching operations. As a result of the measurement programme, it should help to develop a model suitable to represent substation earth performance under surge and fault conditions, and hence, provide verification of the models		

	developed during the course of the previous project. Measurement of 3rd Party Exposure to Rise of Earth Potential (ROEP) • The paperwork is being processed to retain the research assistant and his support team at Cardiff University to extend the project through to November 2009.
Collaborative partners	
R&D provider	P&B Weir, Earthing Risk Management Ltd, Cardiff University

18) Understanding Conduction Mechanisms in Earthing Systems and Optimisation of Earth Electrode Geometries

Project title	Understanding conduction mechanisms in earthing systems and optimisation of earth electrode geometries		
Project Engineer	Alan Ainsley		
Description of project	The proposed programme aims to: - Understand better the conduction mechanisms following current injection at earth electrodes - Develop and test new mitigation techniques suitable for the control of safety voltages - Develop a model for the characterisation of earth electrodes subjected to different magnitudes and shapes of fault current - Check validity and accuracy of existing earthing designs which were based on most popular computational tools through a comparison of experimental results with predictions.		
Expenditure for financial year	Internal £3k External £105k Total **£108k**	Expenditure in previous (IFI) financial years	Total **£130k**
Total project costs (collaborative + external + internal)	**£320k**	Projected 2009/10 costs for National Grid	£32.5k
Technological area and/or issue addressed by project	Previous research efforts have concentrated on the better characterisation of major aspects of practical earthing systems. Both experimental and computer simulation investigations have helped to clarify some performance aspects including determination of safety voltages. However, it is now recognised that little work has been performed to improve the understanding of the conduction mechanisms that control the performance of large/extensive earthing systems. This deficiency in accuracy of knowledge of earthing systems is particularly significant for the control of safety voltages around electrical installations. Presently, several computation tools exist but their comparison with practical systems is not always possible because the computer models assume uniform layer structures of the soil surrounding the earth electrodes. Therefore, it is proposed to conduct an experimental programme using a large scale test electrode system, and investigate the effects of electrode shape, magnitude and shape of applied voltage/current, and assess the accuracy of existing simulation tools.		
Type(s) of innovation involved	Significant	Project Benefits Rating: 8 Project Residual Risk: -1 **Overall Project Score**: 9	
Expected benefits of project	-Reduce risk of fatalities through better assessment of safety voltages at NG installations. -Assess and develop mitigation techniques to reduce risk of electrocution on NG system. -Enhance NG reputation through better understanding of technical aspects of earthing systems and safety.		

	-Increase confidence in results obtained with existing computation tools used by NG. -Enhance existing earthing and safety practice through better understanding of conduction phenomena around earthing systems under fault conditions. -Position the company to better cope if the threshold voltages for touch potentials are reduced following reworking of IEC 61936.		
Expected timescale of project	4 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£30k
Potential for achieving expected benefits	Indications are that the project will deliver all milestones outlined within the Schedule of Deliverables.		
Project progress as of March 2009	The project has met all deliverables set out for this year, with project end forecasted for completion at the end of 2009 Worthy milestones to date have included: • Comprehensive lake resistivity measurements including assessments against seasonable variations. • Preliminary tests (DC, AC and impulse) were carried out on floating earth rods • Analytical calculations and computer simulations have produced values close to measured values of earth resistance. • Production of a floating electrode system taking into account experiences from initial site tests.		
Collaborative partners			
R&D provider	Cardiff University		

19) Transformer Lifetime Modelling

Project title	Transformer lifetime modelling			
Project Engineer	Paul Jarman			
Description of project	Optimising capital investment in replacement transformers. For long term replacement planning purposes transformers have been given asset lifetimes of 40 to 80 years based on experience and engineering judgement. Actual replacements are based on condition, using several assessment methods which have been successfully developed and applied. There is however a gap in the knowledge of transformer end-of -life modelling linking the probabilistic and deterministic approaches of the long and short term plans. This project has the objective of building on existing knowledge of ageing mechanisms to provide a model to bridge the gap and provide credible predictions of medium term (4-10 year ahead) requirements for transformer replacement volumes. The basis for the plan would be the existing policy of maintaining system reliability and unplanned transformer replacements at existing levels. The dependence of system reliability on plant reliability would be part of the study. Transformer replacements will cost between £10M and £30M per year for the foreseeable future, failure to plan effectively could have significant implications for system reliability.			
Expenditure for financial year	Internal £6k External £103k Total **£109k**	Expenditure in previous (IFI) financial years	Total **£17k**	
Total project costs (collaborative + external + internal)	**£277k**	Projected 2009/10 costs for National Grid	£102k	
Technological area and/or issue addressed by project	Optimising modelling techniques to support capital replacement planning for transformers			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		6	-1	7
Expected benefits of project	Being able to accurately predict transformer replacement numbers, and justify those predictions to the regulator will optimise capital expenditure and allowable income. The expenditure is likely to be in the range £10M to &30M over the next 20 years or more. Conservatively assuming that the accuracy of the investment in new transformers could be increased by about 1 % as a result of the knowledge gained, would lead to a saving of about £1 5Ok PA either in the capital programme or in the costs associated with reducing system reliability.			
Expected timescale of project	3 Years	Duration of benefit once achieved	5+ Years	

Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£4k
Potential for achieving expected benefits	As original plan		
Project progress as of March 2009	Initial approaches to data analysis have shown that conventional statistical approaches (Weibull etc.) cannot be applied to the available data, but development of alternative approaches is progressing well and appears to validate existing assumptions. An approach to the treatment of transformers that have been taken out of service before failure that were in very poor condition needs to be refined.		
Collaborative partners	Manchester university		
R&D provider			

20) Transformer Management

Programme title	**Transformer Management.** This programme of work consists of the following projects: • Alternative Fluids for Transformers • Magnetic Models for Transformers Transformer Core Modelling • Transformer Heat Recovery • Aged Transformer Insulation Capability • Control & impact of Ferroresonance on power transformers • Mobile Transformer Assessment Clinic • Transformer Refurb Trial
Project Engineers	Paul Jarman, Gavin Crook, Mark Osborne, Graham Moss, Dave Woodcock
Description of project	The projects in this programme are focussed on improving aspects of transformer and related plant management. Alternative fluids are to be evaluated for use as an insulating fluid for transformers to determine if they can be used at voltages of interest to National Grid. Specifically to look at one synthetic ester and two natural ester materials. Particular emphasis will be placed on investigating dielectric performance at high voltages. Ideally the project will enable sufficient confidence to be gained to enable a trial of the fluid in an in service transformer (a trial would not be part of this project). Tools are being developed to analyse what happens to plant with a magnetic circuit when that circuit starts to become saturated because of extreme operating conditions. Examples of this are transformers under ferroresonant conditions, transformers subject to DC currents such as during geomagnetic (sun storm) events, series reactors under fault conditions and quadrature boosters under high load conditions. Failure to analyse these conditions properly leads either to excessive capital cost in increasing core dimensions, or potential failure in service due to the heating of the magnetic circuit and other steel parts in the transformer or reactor. Waste energy produced by operational transformers is aimed to be utilised for heating and cooling local buildings. This can be achieved by using existing heat transfer technology in a new application. Understanding the dielectric behaviour aged transformer insulation at high voltages may allow the better identification of the factors likely to lead to the failure of old transformers. This will allow optimum targeting of the transformer replacement expenditure and the oil and moisture care regime, to ensure system reliability at minimum cost. Transformer failures pose an environmental risk and tend to attract media attention if they involve a fire. It is aimed to establish the material impact when power transformers

	are exposed to ferroresonance and how an improved understanding can affect the detection and asset management of the entire transformer fleet. The work packages concentrate on: a) Characterisation of the degradation and failure mechanism in different designs of power transformers associated with ferroresonance. Establish what effect this has on the useful lifetime for a transformer. b) Identify the design features of transformers which are susceptible to ferroresonance c) Establish a reliable ferroresonance detection technique, which can be incorporated into new transformer protection relays. The Mobile Transformer Assessment Clinic (MTAC) is designed to offer a finely engineered solution to the fundamental problem of the need to administer expensive and complex on-line dissolved gas analysis systems to oil filled transmission assets that are exhibiting divergence from ideal behaviour. The final project investigates the feasibility and cost effectiveness of transformer refurbishment		
Expenditure for financial year	Internal £23k External £126k Total **£149k**	Expenditure in previous (IFI) financial years	Total **£97k**
Total project costs (collaborative + external + internal)	**£1.3m**	Projected 2009/10 costs for National Grid	£120k
Technological area and/or issue addressed by project	• Use of sustainable materials for plant and reduction of potential environmental impact on failure. • Optimum transformer design and operation within capability to prevent damage. • Energy efficient replacement of building air conditioning and heating systems, targeting 80% reduction in CO_2 emissions by 2050. • Optimisation of replacement plans and reduction of transformer failures. • Understanding transformer ferroresonance and other low frequency phenomena (GIC & switching) and its degrading mechanisms through power system & transformer modelling will enable better identification of the factors likely to lead to the failure of transformers. This will allow asset management to determine the likeliness of circuit configurations to cause transformer ferroresonance, the susceptibility of transformer family towards ferroresonance, to optimise circuit configuration and transformer fleet, and to ensure system reliability at a lower cost. • Currently, on-line DGA systems are a 'fixed' solution, whereby to install an instrument which will take a		

<table>
<tr><td></td><td colspan="4">measurement of the dissolved diagnostic gas profile from a transformer on an hourly basis. The mobile system will be designed to allow full on-line DGA monitoring to be brought to site and connected (if required) within a 2hr timeframe. More over, the system will be completely trailer-based, allowing for complete freedom of transport.
• Investigation into whether sending a transformer with a possible fault which could be repaired to an overseas factory is feasible and beneficial.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6 to 15</td><td>1 to -4</td><td>8 to 17</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Mineral insulating oil as used in existing transformers has potential disadvantages in terms of environmental compatibility, fire safety and sustainability. The use of other fluids particularly vegetable based products could give an alternative which could prove vital if the environmental or supply situation with existing products became unsustainable. The key environmental benefit with vegetable fluid relates to its biodegradability when compared with mineral oil. Some vegetable fluids also have a higher flash point than mineral oil and have a lower energy density when aflame making them beneficial where fire risk would have significant consequences (e.g. built up areas). In addition, ageing tests conducted by other researchers have reported that for paper impregnated with vegetable fluids, the paper lifetime could be extended. Use of vegetable oil could also contribute positively to the image of the company and more widely the electricity supply industry in adopting sustainable solutions. At the moment vegetable fluids are more expensive than mineral oil but through this project National Grid will be in a position to evaluate how to take forward if the background changes.

Improved modelling of ferroresonance, GIC and QB operation will help to formulate designs, specifications and policy to mitigate these problems at minimum cost. Improved industry knowledge in this area should also improve designs and help to reduce unexpected operational problems as over fluxing phenomena are not usually tested in the factory. Quadrature boosters cost approximately £10M and core saturation needs to be modelled in order to optimise their use and avoid failure. One of the most important operating parameters is the point at which the core saturates when the QB is acting to reduce power flow, this parameter is used to set the QB control system which limits tap-changing and therefore utilisation to avoid failure under these conditions. Better knowledge of the core saturation phenomenon will allow the settings to be optimised. Operational savings in increased utilisation are likely but are difficult to estimate, but a QB failure would be very expensive. Reducing the risk of QB failure by 1% will reduce the potential cost of failure over the QB fleet by about £20k per year, similar savings could be expected for increased utilisation.</td></tr>
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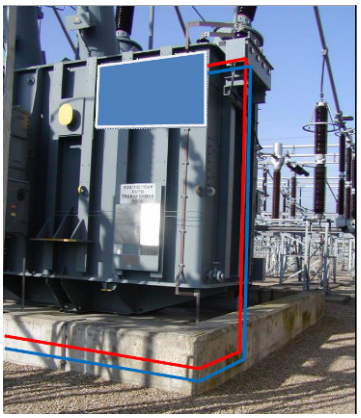
	The need for mitigation measures against ferroresonance partly depends on what damage to transformers may be expected. The project should generate this knowledge and potentially lead to savings of £100k per annum in reduced capital expenditure (where a ferroresonance scheme can be shown not to be required) or avoided failure (if a scheme is shown to be needed). Potential saving £100k PA in reduced capital expenditure on ferroresonance mitigation or transformer damage. Better knowledge of how series reactor impedance varies with current up to the short circuit current will lead to better calculation of fault levels, the benefit from this is hard to quantify but could avoid uprating of switchgear in certain instances. Better knowledge of the effect of GIC on transformers which caused two transformer failures in 1989 depends on understanding core saturation. The next GIC activity maximum is expected around 2012, refining operational guidance based on new knowledge could possibly reduce the risk of failure. Reducing the risk of one transformer failure in 2012 by 10% could save £200k in replacement costs alone, consequential costs of such a failure could be higher. Transformer capital costs are significantly influenced by the size of the core required to avoid saturation under certain system conditions, particularly high voltages on the lower voltage windings which might be experienced when local renewable generation is being back-fed into the HV system. Better understanding the limits can avoid over-specification or potential failure. A 1% reduction in the capital cost of transformers represents a saving of around £400k per year. A modelling capability at the University of Manchester will also be available that has been established during the course of the ferroresonance project and has the potential to be used directly by National Grid in failure investigations and capital project evaluation. This resource is not presently available elsewhere. Installing a transformer heat recovery system is a sustainable environmentally friendly method of heating, reducing our operational carbon emissions assisting towards the 80% reduction of National Grids Carbon footprint by 2050. It is estimated that installation of the proposed system could reduce the carbon emission of a site building up to 80%. The reduction in operational power usage also benefits the business financially, by reducing the annual electricity bill by £6,000 per annum based on £0.095/kWh and remove the need for maintenance of existing air conditioning units and heating units. The non tangible benefit of this development is the potential life extension of the transformers due to the slowing of the insulation degradation by operating at lower temperatures or the capability of over rating the capacity of the units for enhanced system capacity by over loading the unit within the temperature rise limit of 60deg for oil. These need to be evaluated during the monitoring and review of system performance following the trial. Application may be extended to the next generation of lean green substation designs, utilising energy capture from cables and other equipment to heat/cool local auxiliary control buildings and other substation buildings.

	By 2007 the transformer replacement programme cost is likely to be £10M/year, the direct cost of a transformer failure is about £2M, indirect costs of multiple failures at one site could be an order of magnitude greater. Even modest improvements in planning and targeting this expenditure provide a good return on investment in the knowledge underpinning the decisions. The MTAC units are expected to be deployed to at least 4 separate assets each per year, saving the cost of a fixed asset installation each time (£26k). The development will enable National Grid to perform high resolution on-line DGA monitoring to any asset on the system at a typical cost of £2k. Transformer refurbishment could result in a reduction in National Grid's carbon footprint (25kEuros/1tonne carbon) and supply an option that helps to manage the ever increasing asset replacement profile through dynamic asset management.		
Expected timescale of project	5 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£330k
Potential for achieving expected benefits	The majority of projects are on target to deliver expected benefits. In particular the ferroresonance project achieved the desired outcome of providing a secure system model for predicting the occurrence of ferroresonance on a particular network configuration and predicting the resulting ferroresonant waveform. The benefits are already being realised in network design. The MTAC project has built on experience to lead to a solution that is expected to deliver full capability and be in service by the end of July 09. The financial and technical benefit of the transformer heat recovery system are uncertain to date but the environmental benefit would be significant. The transformer refurbishment trial is considered not to be feasible due to the cost/benefit estimates.		
Project progress as of March 2009	A phase 2 consortium of collaborative partners to investigate alternative fluids for transformers has been established and a new work programme agreed. Research staff are in place and results are being produced. On track. Some preliminary experiments related to Magnetic Models for Transformers Transformer Core Modelling have been conducted and the initial modelling approaches have been agreed. Research staff are in post, first progress meeting held.		



The Transformer Heat Recovery project team has undertaken a full design review, refining the design options to optimise the installation and energy used by the system. The preferred option is to use an Oil Natural Water Natural (ONWN) cooler on a single transformer. This has the benefit of not requiring any auxiliary power supplies and simplifies the control systems by separating the interface between the property and the substation. To create the thermal flow in the natural cooler, the inlet and outlet pipes need to be located directly into the tank. To modify the tank, the oil needs to be lowered to enable the access plates to be changed to incorporate valves for the pipes. A second transformer is not required as the building heating system has an emergency back-up.

The connecting pipe proposed is a two way insulated PE-Xa design to minimise the number of joints and the thermal loss over the route. Using this technology makes installation simpler by being lighter to handle and able to bend, the material is also corrosion proof.

Incorporating en efficient heating system with a method of heat recovery decreases the energy usage by five times, meeting the objective of 80% reduction of CO_2 through electricity used.

The Aged Transformer Insulation Capability project has successfully identified threshold limits for moisture in transformer insulation and mechanisms by which transformer failure can occur as a result of poor oil quality. This information is being used in transformer care and replacement decisions. Some further work has transferred to transformer life project.

The Control & impact of Ferroresonance on power transformers project is now complete having achieved the desired outcomes with the exception of modelling the effect of ferroresonance on a particular transformer in terms of heating and damage. This aspect is being continued in the Transformer Core Modelling Project

MTAC01 (the first mobile DGA unit) has been completed and undergone evaluation studies at the Oil Management Unit at Thorpe Marsh. The unit appears to be successful in all major aspects of its intended design and function. Following design testing at the OMU, MTAC01 began a 4 week non-live test on an unused Shunt Reactor. This gave valuable insight into deploying and connecting the unit to a

	realistic scenario without any risk whatsoever to system security. The unit on connection performed perfectly. Data is being sent on the hour to the condition monitoring web server (SAM). Before the last week of June 09, MTAC01 will be deployed to it's first official live deployment target. Phase 1 of the Transformer Refurb Trial identified an ideal transformer repair candidate from Seabank which was taken out of service due to a developing fault detected by condition monitoring equipment (SAM). Phase 2 of this project failed due to high OPEX costs in shipping the transformer repair. No further spend against this project is expected so the project has been closed.
Collaborative partners	EdF, Areva, EPSRC, M@I Materials, TJH2B Electricity North west, Scottish Power. Areva transformers and T&D are funding a parallel linked project to improve their modelling techniques. Retherm, Nibe energy systems and National Grid Property.
R&D provider	University of Manchester, Central Electricity Alliance, Southampton University, Doble PowerTest Ltd

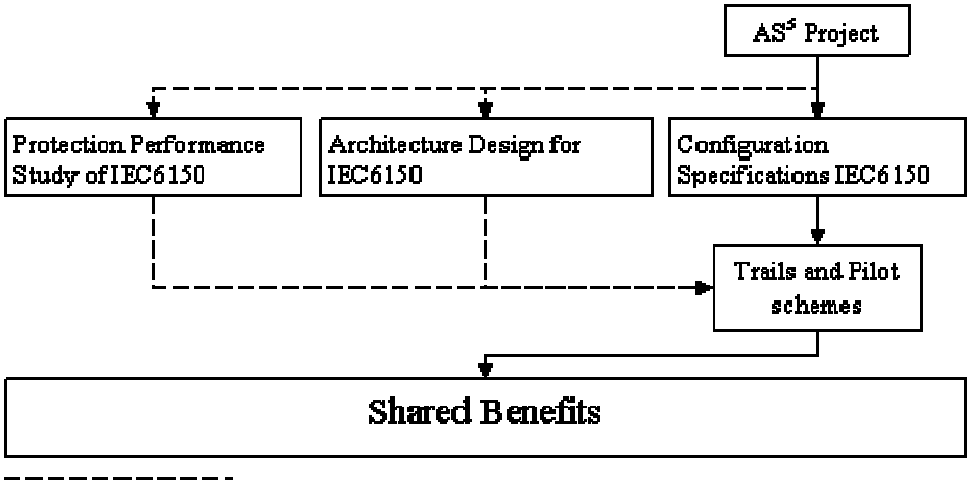
21) Sulphur in Oil Trial

Project title	Sulphur in Oil Trial		
Project Engineer	Dave Woodcock		
Description of project	The objectives of this project are: 1. To trial on a selection of transformers/reactors the possibility of removing corrosive sulphur through oil reclamation and the addition of inhibitor in the oil. 2. To identify a strategy to manage National Grid's oil filled equipment to prevent the unnecessary failure of an asset due to corrosive sulphur. To provide a future strategy that could be implemented worldwide if successful and therefore enhance our reputation in this field.		
Expenditure for financial year	Internal £41k External £770k Total **£811k**	Expenditure in previous (IFI) financial years	Total **£4k**
Total project costs (collaborative + external + internal)	**£1.1m**	Projected 2009/10 costs for National Grid	£310k
Technological area and/or issue addressed by project	This project deals with the issue discussed in Risk Register item AM 138 and OESB 9/08. Following the failure of a supergrid transformer due to corrosive sulphur formation it became clear that National Grid was more exposed to the risk of this globally-experienced phenomenon than previously thought. The issue is debated frequently at numerous conferences and there is much information given with little agreement between contributors. In particular the ability of standard oil regeneration techniques to remove the sulphur problem has been the subject of much disagreement with most of it based on theory rather than practical knowledge. National Grid has some regeneration capability in a 20 year old rig and two newer hybrid units with some regeneration capability. A new dedicated regeneration rig should be developed with a supplier of regeneration technology with unique features to enable high speed capability available for online sulphur removal of energised transformers. On line equipment is used worldwide but would not meet the rigorous UK safety requirements.		
Type(s) of innovation involved	Significant	Project Benefits Rating: 13 Project Residual Risk: -3 **Overall Project Score**: 16	
Expected benefits of project	• A strategy that will prevent the loss of National Grid transformers and reactors • Success will enable National Grid to reach its health, safety and environmental objectives.		

Expected timescale of project	3 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£193k
Potential for achieving expected benefits	The trials carried out so far have shown that sulphur can be removed from contaminated oil using regeneration equipment but it is much slower than regeneration of degradation products. This means online and high speed regeneration would allow sulphur removal to be viable. The trials have also highlighted problems with existing technology that should be eliminated in the new rig but it will only be possible to prove that once it has been constructed. The expected benefits are likely to be achieved but there is a small risk that the rig will still produce a small amount of contamination harmful to the transformers. There is also the risk that the use of online sulphur removal on energised transformers will not be accepted regardless of the safety features provided.		
Project progress as of March 2009	Two trials have been performed proving that sulphur removal through the use of regeneration technology is viable, if somewhat slow – 10 passes of the oil reduces the contamination to the upper limit of the main sulphur contaminant. A contract has been placed with Enervac to provide a new regeneration rig capable of sulphur removal at a rate in excess of 5000l/hr on energised transformers. We will continue to work with them to maximise the efficiency, reduce the risk of sulphur contamination (found to be a problem with existing technology) and maximise safety features. We have also asked for on-line gas monitoring capable of providing data to the infonet through SAM (smart asset management) tools, a feature that would be a first for any regeneration rigs. The rigs could also be operated remotely from the site by OMU operators or even Enervac themselves (in Canada) – a feature unique to this rig in the UK. Some of the work we have carried out has already been included in presentations at Euro TechCon and to CIGRE-UK.		
Collaborative partners	We are informally sharing our work with Doble and ABB who have been able to comment on results and make suggestions for improvements to the way the work develops		
R&D provider	National Grid's Oil Management Unit are delivering the work Testing has been provided by several laboratories worldwide as some of the tests are not standardised and we want to understand the inter-lab variation Enervac are the suppliers with whom we are working to develop the new rig.		

22) Developments in Protection and Control

Programme title	Developments in Protection and Control This programme of work includes the following projects: • Protection Performance Study for IEC61850 Process Bus Architecture of Substation Secondary Systems (AS3) • Multi Agent Based Wide Area Protection • Smart Grid Oscillation Management for a Changing Generation Mix (Psymetrix) • Evaluation of the performance and application of process bus			
Project Engineers	Wen An, John Fitch, Alex Carter, Ray Zhang			
Description of programme	Protection and control systems for the transmission system are of paramount importance for the safe and reliable operation of the GB power system. Modern developments in electronics and the obsolescence of older electromechanical systems have lead to National Grid commencing a large programme of work in the area of protection and control. Modern systems are renowned for having a significantly shorter lifespan than older systems. This can lead to major issues regarding the management of maintenance and planning replacement work that will require outages. The first project addresses this by attempting to create a system where secondary equipment renewals occurring mid-life in the primary plant lifecycle can be undertaken in a safer, quicker and easier way with much reduced outages of primary systems. At any time, secondary system upgrades and modifications can be undertaken without a primary circuit outage. The Wide Area Protection project aims to deliver a proposal for a new network architecture both inside and outside substations that can support new communication technologies and services, to facilitate smart, active, adaptive and learning network control, automation and protection applications. Smart Grid Oscillation Management attempts to improve existing power oscillation detection and give additional oscillation source location information to enable the transmission network to be operated and designed securely at high utilisation. The aim of the final project is to evaluate the functionality and performance of IEC61850 process bus based architecture for substation secondary systems.			
Expenditure for financial year	Internal £32k External £101k Total **£133k**	Expenditure in previous (IFI) financial years	Total **£37k**	
Total project costs (collaborative + external + internal)	**£593k**	Projected 2009/10 costs for National Grid	£163k	
Technological area and/or issue addressed by project	This program addresses issues relating the increased complexity of the transmission system, modern developments in protection and control systems and the impact of these developments on existing and future systems installed on the transmission system.			
Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		7 to 9	2 to -1	6 to 11

Expected benefits of project	The benefits of the individual projects are listed below. Protection Performance Study for IEC61850 Process Bus Architecture of Substation Secondary Systems (AS3) • This project is linked to the AS3 project contributing to increased likelihood of success of the project and therefore has shared benefits with AS3.  The separate business benefits of the project are: • Understanding the impact of emerging technologies on the future protection and control systems to support National Grid's decision-making. • Taking full advantage of the emerging technologies while identifying and minimising potential risks. • Providing a proper basis for the development of future protection systems based on the experience of the protection schemes being studied. • Less site commissioning required for the new protection systems. Most of the tests can be carried out in factory by software simulation using the IEC61850 process bus. • Much reduced outage required for the future replacement of the new protection and control equipments. • Maximising economic and effective utilisation of the transmission asset and network. • Safety, health and the environment is improved by reducing the need for cross-site secondary circuit cabling, mitigating the associated risks Multi Agent Based Wide Area Protection • The potential benefits are the costs and risks associated with the running of excessive generation and the consequences of generator intermittency. In theory the network can be exploited to deliver more capacity and the impact of faults and loss of generation can be controlled locally. The typical cost avoidance of a large fixed Operational Tripping Scheme currently used to manage similar conditions is around £1.5m.

	• The results obtained from this research will demonstrate the efficiency of relay coordination applied to drive power system hard for energy saving with improved system stability and reliability. It will also show the potential of the multi-agent technology for wide area control and automation of power systems, as a generic real-time platform for development of wide area coordinated control systems, which will broaden the vision of power utility and power supplier engineers. The research results will also be useful for improving other existing research on non-platform based wide area protection and control of power systems. Smart Grid Oscillation Management for a Changing Generation Mix (Psymetrix) • Will enable the transmission network to be operated securely at high utilisation and increase the knowledge of windfarm behaviour at a time when the number of windfarms connecting to the transmission network is increasing. Evaluation of the performance and application of process bus • To establish and validate an IEC61850 based architecture and solution that will significantly optimise the life of new and existing secondary system assets and simplify the methodology for its replacement (requiring short or no outages).		
Expected timescale of project	5 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£3.3m
Potential for achieving expected benefits	The first of these projects is at an early stage but there is confidence that the objectives will be delivered. The other projects are making good progress and there is confidence that objectives will be met and benefits achieved.		
Project progress as of March 2009	To date the projects have made the following progress Protection Performance Study for IEC61850 Process Bus Architecture of Substation Secondary Systems (AS3) • The project started in Jan 09, during the first three months a literature survey of the IEC61850 process bus architecture and its impacts on protection performance have been completed. Trial topologies to interconnect the protection relay devices are being studied. Multi Agent Based Wide Area Protection • Project Initiated, however supplier awaiting receipt of contract before proceeding further. Smart Grid Oscillation Management for a Changing Generation Mix (Psymetrix) • The project successfully completed in September 2008. A prototype method was developed for identifying very low frequency oscillations. Also method developed for locating regions of coherent oscillations. Concept for Wide Area Measurement developed. Better understanding of wind farm and system dynamic interaction gained. Some of the		

	techniques will be included in future Psymetrix commercial products while others need further research and development and has highlighted the importance of Wide Area Monitoring systems being able to be integrated with the SCADA/EMS system. Seven papers were published during the project and one patent was raised by Psymetrix. Evaluation of the performance and application of process bus • The required research staff have been fully recruited and all the planned activities are on programme. The survey studies have been successfully completed. The survey covers the topics of the IEC61850 standard, existing applications of the protocol for substation protection and control (P&C) systems, and the methodology of reliability analysis for the P&C systems. The scheduled work for the 2nd year has started and includes the proposal of the optimal architectures of P&C systems for different types of bay and their reliability analyses. A testing platform for this IEC61850 based P&C architecture are going to be set up and fully functioning in the 2nd year of this project.
Collaborative partners	Areva, Scottish Power, Scottish & Southern Energy, Psymetrix, Northern Ireland Electricity plc, University of Edinburgh, Queens University Belfast, Scottish Power, Scottish and Southern Electricity
R&D provider	University of Manchester, University of Bath, The University of Liverpool, Psymetrix

23) WAMPAC

Project title	WAMPAC		
Project Engineer	John Fitch		
Description of project	The key objective of the 1st stage of this project is to evaluate the technology, interoperability and application of Phasor Measurement Units. This will involve laboratory scenario testing and deployment on Transmission systems to baseline and track current and emerging network stability issues. The work is collaborative and shared with Scottish Power, Scottish and Southern Electricity, Northern Ireland Electricity and ESBI (Ireland). Units will be deployed across to collect data for research purposes and validated against systems models. The work will support the development of next generation data and communications infrastructure.		
Expenditure for financial year	Internal £8k External £74k Total **£82k**	Expenditure in previous (IFI) financial years	Internal £ External £ Total **£52k**
Total project costs (collaborative + external + internal)	**£239k**	Projected 2009/10 costs for National Grid	£73k
Technological area and/or issue addressed by project	This project addresses the emerging solution of wide area monitoring, protection and control systems focusing on the technologies, communications architecture and end user applications. This technology could address the growing uncertainties and dynamics posed by the evolution and development of the UK Transmission Network, particularly with respect to system development and performance and secure operation.		
Type(s) of innovation involved	Radical	Project Benefits Rating: 11	Project Residual Risk: 1 / **Overall Project Score**: 10
Expected benefits of project	Understanding of the capability and stability of networks with constraints, intermittent generation and changing generation and demand patterns. Ensuring the network is ready and able to accommodate new generation in line with SmartGrid and Intelligrid initiatives. Understanding of network capacity and constraints. Ensuring plant operates safely within capability and design limits		
Expected timescale of project	3 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£164k

Potential for achieving expected benefits	Technologies are already available to collect phasor measurement data with monitoring applications, however more sophisticated end user applications are still in their infancy. The overall architecture required and the performance and interoperability of the available technologies are,
Project progress as of March 2009	The project officially started March 2008 and three well attended project meetings have been organised throughout the current year. These meetings have provided useful direction and understanding of different partners needs and plans as well as reporting progress to date. The project has delivered an extensive study and report of the implementation of synchronised measurement technology world wide and numerous papers have been prepared on this work to a number of major conferences including CIGRE, CIRED, IEEE and PoweTech. The development of a National Grid strategy for Wide Area Monitoring, Protection and Control and road map is under way with an initial prioritization of potential user applications. The capture of system requirements has been completed and will be validated as part of planned laboratory experiments. Collaboration with AREVA is established in terms of technology and data sharing. Similar but more limited relationship is to be established with Siemens and ABB. Evaluation of the potential to modify existing System Monitoring equipment (Amertek and Qualitrol with a Psymetrix user interface application) will be brought into scope to accelerate the deployment of PMU technology in National Grid. A laboratory demonstration of GPS synchronised phasor measurements has been established with system simulation and test and validation equipment. and a number of Phasor Measurement Units from different suppliers have been sourced. End user visualisation software has also been obtained for display and evaluation. Good engagement with partners has been achieved to date and presentations to National Grid end users has been made to identify needs, project synergies and set future priorities. The work is linked through involvement in Supergen Flexnet showcase project and is co-ordinated with CIGRE WG B5.14 and IEEE PSRC projects and IEEE and IEC standards activities
Collaborative partners	Scottish Power, Scottish & Southern, (and in kind NIE, ESBI)
R&D provider	University of Manchester

24) Collapse Prediction on Transmission Networks

Project title	Collapse Prediction on Transmission Networks			
Project Engineer	John Fitch/Kieran French			
Description of project	This project is to test and evaluate the CPR – D collapse prediction relay manufactured by a-eberle and any other devices and/or techniques as they become available. The CPR-D relay is marketed as innovative in the field of network collapse prediction but as yet is unproven and therefore its operation under system stress conditions has not been confirmed. The techniques used by a-eberle in the design of this relay are; • Detection of gradual network breakdowns using the tap/time method. • Evaluation of power frequency and its rate of change. • Measurement of low frequency oscillations and their comparison with a healthy network fingerprint. • Monitoring of voltage drift. • Examination of Lyapunov exponents • Monitoring of damping profile of the network. The project is undertaken in conjunction with Manchester University, Scottish Power, Scottish and Southern with involvement from Northern Ireland Electricity and Eirgrid. The aim of the project is to test the CPR-D relay in both a laboratory and a field environment in order to understand the capabilities and sensitivities of the device and evaluate if it would be a beneficial tool for a system planning/operation during times of system stress. Units will be deployed across networks in order to collect data for research purposes and validating network models.			
Expenditure for financial year	Internal £11k External £76k Total **£87k**	Expenditure in previous (IFI) financial years	I Total **£82k**	
Total project costs (collaborative + external + internal)	**£270k**	Projected 2009/10 costs for National Grid	£64,000	
Technological area and/or issue addressed by project	Power system collapse prediction, voltage instability.			
Type(s) of innovation involved	Significant	Project Benefits Rating 11	Project Residual Risk 3	**Overall Project Score** 8
Expected benefits of project	Understanding of capability and stability of networks with constraints, intermittent generation and changing generation and demand patterns.			

Expected timescale of project	Year 2010	Duration of benefit once achieved	20 Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£107k
Potential for achieving expected benefits	CPR-D Relay is being installed on a number of Transmission Systems across Europe, following major incidents on their networks. There is great interest in this particular relay and its ability to predict and warn of incipient stability and collapse conditions. The main drive of this project is to evaluate the CPR-D relay and any alternative relays/algorithms (as available) and verify performance in simulation and on line conditions. Benefits will be achieved if it can be clearly demonstrated that a relay of this type can give sufficient early warning for some mitigating actions to be taken in real time or if decision support can be provided to system planning to optimise their planning decisions.		
Project progress as of March 2009	Laboratory based testing of the CPR-D has been undertaken up until February 2009 at which point the relay was installed at a 400kV UK Transmission substation. Since February 2009, monitoring of the performance of the CPR-D in response to system incidents and normal operational practices has been carried out by the R&D provider (University of Manchester.) A two day training seminar on the CPR-D was attended by representatives from National Grid and the University of Manchester at Nuremberg in July 2008 to further understand the operation of the various functions of this relay. A paper on the use of the CPR-D to predict power system collapse was published in 2008 by National Grid, University of Manchester, System & Dynamik and UCAutomation and presented to the IET developments in power system protection conference. Project update meetings have been held with our collaborative partners on an interim basis and regular contact is maintained with the supplier of the relay to gain assistance on issues as they arise.		
Collaborative partners	Scottish Power and SSE		
R&D provider	University of Manchester		

25) Digital Control System Upgrade

Project title	Digital control system upgrade		
Project Engineer	Mark Illsley		
Description of project	Investigate and develop specification for upgrade of a Mark I to Mark III control system in order to manage obsolescence issues associated with Mark I control systems.		
Expenditure for financial year	Internal £7k External £136k Total **£143k**	Expenditure in previous (IFI) financial years	Total **£48k**
Total project costs (collaborative + external + internal)	**£364k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	The age related degradation and obsolescence of electronic components in circuit breaker control systems.		

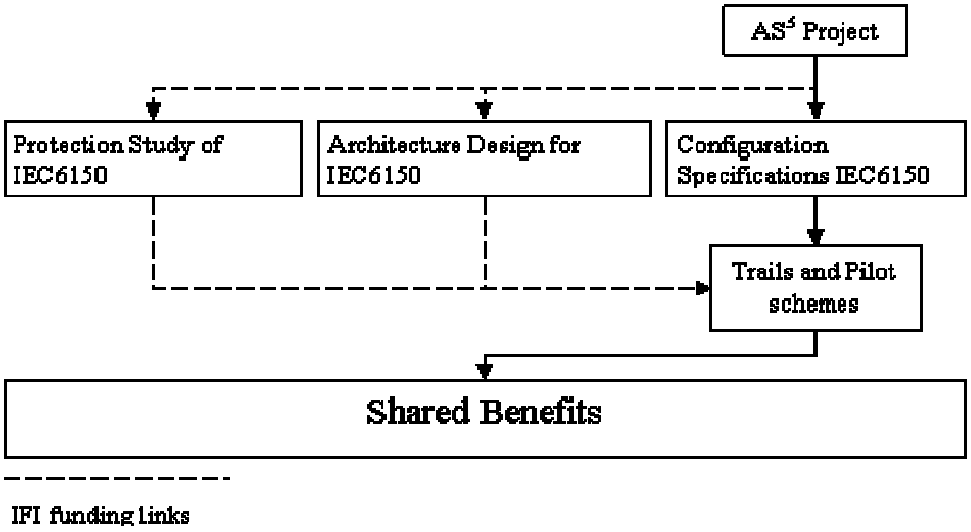
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		7	-3	10

Expected benefits of project	To manage the replacement of Mark I control systems in order to achieve Anticipated Asset lives for Areva FE/MFE type GCBs. If the systems are not upgraded the GCBs, with Mark I control systems will have to be replaced before their earliest onset of significant unreliability.		
Expected timescale of project	5 Years	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£220k
Potential for achieving expected benefits	The project delivery has been affected by cancellation of outages and resource constraints from both Areva and National Grid. I anticipate the control system development work will be completed but aspects of the site development will not be fully realised.		
Project progress as of March 2009	At April 2009 there have been 2 systems developed and installed on circuit breaker variants. One site trial has taken place at Exeter on GCB X710. The initial findings are positive.		
Collaborative partners	Areva T&D Stafford		
R&D provider	Areva T&D Stafford		

26) Architecture for Substation Secondary System (AS3) Project

Project title	Architecture for Substation Secondary System (AS3) Project		
Project Engineer	Ray Zhang		
Description of project	To form a new policy for substation light current systems aimed at maintaining high availability and reliability of the transmission network by balancing the whole life-cycle risk, performance and cost of assets; To develop a new architecture for substation secondary system by introducing new technologies, targeting on a quicker and easier approach for the installation and replacement of protection and control equipment beyond 2011 Review of current policy and practice • To identity and understand the whole life cycle issues for the existing protection and control systems. Strategy document for substation secondary systems • To develop a road map to show the strategy for the application of protection and control new technology in the short, medium and long term. Feasibility Study • To investigate new technologies • To collaborate with major suppliers/Alliances to share information. • To standardise Substation primary and secondary system interface • To benchmark with leading utilities Trials and Pilot schemes • To try the new approach in parallel with existing systems with outputs disabled -"Piggy-back" trials • To apply the new approach to some real projects as pilot schemes (Min 2) New Policy • To develop a new policy for the substation secondary system, • To develop associated technical specifications.		
Expenditure for financial year	Internal £36k External £120k Total **£156k**	Expenditure in previous (IFI) financial years	Total **£0**
Total project costs (collaborative + external + internal)	**£768k**	Projected 2009/10 costs for National Grid	£364k
Technological area and/or issue addressed by project			

Type(s) of innovation involved	Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	3	7

Expected benefits of project	This project is to identify and understand the potential benefits and risks associated with designing and implementing new substation secondary system architecture. It will do this by deploying new technology/developments such as standard interface modules, bay process bus and IEC61850 communication protocol. It is important the National Grid take a leading role in this area so we can provide manufacturers with specification as to what is needed rather than being led into this system by the manufacturers. AS^3 has linked IFI projects that contribute to the overall shared benefits of the project increasing the likelihood of success as the project progresses as shown below.  The benefits expected from this project will not be appreciated until the AS^3 system has been implemented. The full benefit of the project will only be seen when all AS^3 systems have gone through a complete life cycle estimated to be roughly 20 years. This project will investigate the possibility of this new architecture which will have a long lasting interface to the primary plant, which should not have to be altered or replaced should the secondary systems need to be replaced. This project is investigating the feasibility of achieving whole life cycle benefits, so that the asset life of light current system in a substation can be optimised. The project will investigate benefits in the following areas: • The design and development potentially can be standardised at all levels (station, bay and interfaces) within a substation. This will allow proven solutions be used repeatedly for different projects/sites, thus the project risks and resources will be minimised saving time and money. • The installation and commissioning will be much safer and quicker than traditional approaches. The “plug and play” will be possible for the installation and replacement due to use of IEC61850 based fibre optical bus and standardised interfaces. Therefore the required outages of primary system will be significantly reduced ensuring availability is maintained. Safety, health and environment are improved by reducing the need for cross-site secondary circuit cabling migrating associated risks.

	• The operation and maintenance could greatly benefit from the new approach. Full deployment of digital technology and removal of copper wirings should make the operation of the secondary system more reliable as faults can be more easily recognised and replaced. This would also challenge the traditional concept/requirements for maintenance. The new technology will enhance functions such as condition monitoring and remote access, which should further improve the operation and maintenance by providing real time information to enable the operator to take the best-informed action. Also this process will be safer as the new secondary systems transmit data of CT and VT analogue signals via bay process bus. This poses no safety risks of opening CT circuits, and hence improving the safety when the protection replacement is carried out with primary circuit in service. • The replacement and de-commissioning can be achieved in a quick "plug and play" manner. Components used will no longer be limited to a specific manufacturer due to Inter-operability/Inter-changeability facilitated by the IEC61850 protocol. This will significantly reduce the requirements and costs for the Post Delivery Support Agreement (PDSA). By enabling any unit to be replaced by any other IEC61850 machine therefore not tying National Grid into uncompetitive PDSA's The new technology using IEC 61850 communication protocol will enable vendor interoperability and easier modification and extension of the secondary schemes, particularly allowing reconfiguration and feature enhancement by software means, rather than the modification of hardwiring as would have been the case in the past. The fully digitised fibre optical architecture will also form an additional "isolation layer" for the electromagnetic noises from primary system. This will significantly improve the reliability of secondary systems and consequently reduce the requirements for the costly Electro-Magnetic Compatibility (EMC) for the protection and control devices. A similar pilot scheme by GE has reported potential savings of 25% in the installation of secondary systems using a plug in and play system of installation. Estimating a saving of approximately £50K (5%) per substation with AS3 implemented. With an expected roll out rate of approximately 50% of substations refurbished or newly built to have AS3 each year. Making a total saving of approximately £500K per year.		
Expected timescale of project	3 Years	Duration of benefit once achieved	10 +Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£18k

Potential for achieving expected benefits	It has a good potential to achieve expected benefits as • International committees such as IEC and CIGRE have set up working groups to carry out studies on relevant technical subjects; some standards and application guides have been published. National Grid is participating most of the working groups directly or indirectly. • All the major suppliers have been working in this area for more than 10 years, product prototypes are being produced and tried. Some trials and pilot schemes with leading suppliers are planned within this project. • Some leading utilities such RWE, Tennet have started some pilot schemes. Benchmark with those utilities is one of the key feasibility studies within this project. • This project is governed and managed with a hierarchical structure including a sponsor, project board, project manager and working groups, to ensure that all the planned activities will be properly delivered.
Project progress as of March 2009	The project has been progressing well since it started. However, due to R&D project sanction process, some of the R&D work was not able to be charged to the project in time before the end of financial year and resulted in some "under-spent" in the 1st year budget. All the planned activities under 5 key deliverables are running on programme : **1. Review of current policy and practice** Working Group 1 was set up for this key deliverable. Seminars and workshops have been held with NG internal departments and external suppliers to identify the whole life-cycle issues regarding protection and control systems. Some high level policy and specifications are being reviewed, and a final report will be produced at the end of this activity August 2009. **2. Strategy for the development of substation secondary systems** A draft document has been produced by the Working Group 2. This deliverable was aimed to develop a strategy (road map) for the application of new technology in the development of the substation secondary system in the short, medium and long term. **3. Feasibility Studies** 3.1. Working Groups for Testing & commissioning (WG8), Safety & Operation (WG9), I/O standardisation (WG6), Scheme Implementation Strategy (WG3) are all kicked off and up-running on the programme. 3.2. A contract has been placed with Siemens to develop a strategy for IEC61850 protocol Implementation/configuration. The work is also participated by all NG alliances/suppliers within WG7. 3.3 National Grid has made commitment to participate the following CIGRE working groups which are directly beneficial to this project • B3-10 Primary / Secondary system interface modelling (Standardisation I/O signals) • B5-27 Implications and Benefits of Standardised Protection Schemes • B5-24 Protection Requirements on Transient Response of Voltage and Current Digital Acquisition Chain

	3.4. Benchmark took place with Tenet (Dutch) and RWE (German) for their pilot projects using Locamation and Siemens systems respectively. **4. Trials and Pilot Schemes** Dedicated working groups (WG10-13) were set up with Areva/SE alliance, ABB/central alliance, Mitsubishi/SW alliance, Siemens/North alliance, to pursue the collaborations/*"Piggy-back" trials*. • Area is upgrading their existing trial at NG Osbaldwick substation to further develop it into a feeder bay with the AS3 Architecture • ABB, Siemens, and Mitsubishi are finalising their trial proposals. **5. New Policy Statement and Associated Engineering Documents** WG2 has been conducting some high level strategy analyses on the management of technologies, risk assessment, long term costs/benefits as well as the philosophy for testing, installation and commissioning within AS3 architecture. A business case and AS3 proposal are going to be produced based on those studies by the end of August 2009.
Collaborative partners	A potential collaboration with NGUS and PG&E from the west coast of US are under discussion/preparation.
R&D provider	ABB, Areva, Mitsubishi, Siemens, Univ. of Manchester, Univ. of Strathclyde, Univ. of Bath

27) Remote Access to Substation

<table>
<tr><td>Project title</td><td colspan="4">Remote Access to Substation</td></tr>
<tr><td>Project Engineer</td><td colspan="4">Stuart Mann</td></tr>
<tr><td>Description of project</td><td colspan="4">• A scalable technical solution that provides a system, method and proof of concept for remote access to substation information with access management security and resilience against malicious intent.
• Business process review and development
• Identification of whole life costs in terms of capital, installation, operational and maintenance costs
• Site access requirements for installation and installation options
• Integration into and facilitation of improvements in post fault investigation process.
• Integration into and facilitation of improvements to asset condition and capability</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £5k
External £113k
Total £118k</td><td>Expenditure in previous (IFI) financial years</td><td>Total £0</td><td></td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£118k</td><td>Projected 2009/10 costs for National Grid</td><td>£0</td><td></td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">The solution employs various components to achieve an overall solution. These consist of industrial networking devices, a system user access manager software and client token software. The combination has been specifically developed and customised to meet the requirements for the NERC-CIP regulations. However the system has required specific configuration for National Grid and this part of the work is the scope of the R&D. This is the first deployment of this system in the UK and is reasonably new as a worldwide product. The current state of deployment of this solution has addressed the difficulty in providing a remote access solution but requires completion. Part of the work to complete the deployment is to roll out a new version of the software with further facilities requested by National Grid and to enhance the security features already offered.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>16</td><td>-1</td><td>17</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Risk avoidance through fast post fault response and enhancements to condition and capability monitoring.
Enhancements to condition and capability monitoring to provide improved asset condition assessment and health, reduce costs in data collection, improved asset life management. Call outs to attend SF6 gas alarms typically cost around £70k p.a. Having the ability to predict and schedule gas top ups during normal hours would reduce this cost.</td></tr>
</table>

	Resolving post fault uncertainty. A loss of supply incident can cost around £33k per MWh of demand. A loss of supply incident of 100MW for I hour can cost £3.3M so the ability to determine if supplies can be restored quickly will reduce the compensation payment. The old standby arrangements where a standby engineer interprets information derived at site doesn't work anymore due to complexity of systems and information. Modern systems require specialist support to extract information and interpret results. • Reduction in unnecessary call outs to substations to resolve system alarms that do not provide sufficient information. The call outs are to obtain information that is incomplete or unavailable to remote users. • Delivery of recommendations from Hurst incident investigation. • Considerable improvement in security of substation system remote access and provision of management of user remote access. • Help to prevent against loss of reputation		
Expected timescale of project	1 Year	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£104k
Potential for achieving expected benefits	Extremely positive. The elements of the solution that have been deployed are delivering positive responses and results. Other collaborators within National Grid have requested involvement and the technical scope has increased to include solutions for numerous additional requirements.		
Project progress as of March 2009	Certain items of the system have been installed. Currently, 6 out of 14 substations have been fitted with the remote equipment, 1 of the 2 central management units have been located in a temporary location at Warwick and 5 users are able to access some of the devices that are connected to the system. Faster progress has been prevented by site issues e.g. systems that are expected to be connected have had some facilities removed or are not functional. Unexpected site installation issues can only be resolved by purchasing additional items of equipment. In addition we are expecting to take delivery of a new version of central management unit software which will overcome issues with installing software on locked down PC's. Additional site installations are to be undertaken in July with connection of devices at these and existing sites when additional hardware is delivered. We are now also resolving the following issues in addition to the original project scope :-		

	• Resolving unexpected site connectivity issues with a range of technology solutions • Developing configurations to overcome ongoing problems and further enhance the potential of the system • Connecting devices not originally included within the scope of works in order to develop knowledge of these systems and a full range of solutions.
Collaborative partners	Other sections of National Grid, Ruggedcom, Westermo and CSC
R&D provider	

28) Cable Asset Life project

Project title	Cable asset life project		
Project Engineer	Michelle Le Blanc		
Description of project	To review and develop our understanding of the factors affecting oil-filled cable asset lives		
Expenditure for financial year	Internal £7.5k External £113k Total **£20.5k**	Expenditure in previous (IFI) financial years	Total **£19k**
Total project costs (collaborative + external + internal)	**£124k**	Projected 2009/10 costs for National Grid	£26k
Technological area and/or issue addressed by project	With an ageing population of oil filled cables on the transmission system National Grid needs to develop its understanding of cable assets particularly with respect to the factors that contribute to cable deterioration		

Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		9	-1	10

Expected benefits of project	This project will provide National Grid with a further understanding of the degradation mechanisms and deterioration modes of oil filled cables and develop the ability to understand better the assessment of risks and costs and performance. This will provide National Grid with the means to establish whether cables' anticipated asset lives can be revised. The project will describe practical methods to assess the level of degradation of oil-filled cable systems. This will feed into the Asset Lives project which is designed to optimise Capex and Opex and will then form the basis of the Capital Plan for replacement of cables.		
Expected timescale of project	Currently aiming for Mar 2010 (it does depend on being able to obtain cable samples)	Duration of benefit once achieved	Several years and will be subject to constant review
Probability of success	60 %	Project NPV = (PV benefits – PV costs) x probability of success	£207k
Potential for achieving expected benefits	This work will produce an asset health index and deterioration model for cable systems. Once available, the outputs of this project will feed into the capital plan and will form part of our Asset Health process. This will be implemented in the capital plan by the Asset Investment team.		

Project progress as of March 2009	The Cable Asset Life project has completed the following deliverables: • Review and development of our understanding of the life limiting factors for each element of an oil filled cable system. • Develop a cable health scoring system • Develop a deterioration model to represent the degradation mechanisms of oil-filled cable systems. The next stage is that of gaining further confidence in the deterioration model and a number of cable samples are now with ERA technology and undergoing forensic analysis to determine remaining life for the papers, reinforcing tapes, lead/Al sheath and PVC/PE oversheath. Collated results from the initial samples are expected in June. Further cable samples are being obtained on an ad-hoc basis to provide additional information which will enhance the model.
Collaborative partners	
R&D provider	Energyline – Denis Procter ERA Technology – Ray Houlgate

29) Cable Development/Protection and Recovery

Programme Title	**Cable Development/ Protection and Recovery** This programme of work includes the following projects: • Plastic V concrete - Cable Protection • Further Development of PFT in Service Cable Oil Leak Location Technique • ROADS • Recovery of cable core • Sustainable Power Cable Materials Technologies with Improved Whole Life Performance			
Project Engineers	Francis Waite, Mike Fairhurst, David Payne			
Description of programme	This programme seeks to address many issues that arise from National Grid's sizeable high voltage cable installations. The projects within the programme address a wide range of issues from cable materials to methods of cable removal. One of the projects is a trial of plastic rather than concrete tiles for cable protection. This project investigates the performance of plastic tiles in a series of field trials. Another project looks to provide National Grid with a leak free oil filled cable system by further developing the use of Peroflurocarbon Tracer (PFT) for 400kV cables. There is a project to trial a distributed strain sensor currently being developed by SENSA in collaboration with National Grid and BP and jointly funded by the DTI. National Grid is also researching methods whereby the cable core can be removed during the decommissioning of the cable while leaving the rest of the cable in situ (possibly to be reused by other utilities). Finally National Grid is involved in a collaborative project with other industrial partners and part funded by the Technology Strategy Board to develop a new generation of power cable materials that have a better thermal performance than current XLPE materials.			
Expenditure for financial year	Internal £29k External £120k Total **£149k**	Expenditure in previous (IFI) financial years	Total **£0**	
Total project costs (collaborative + external + internal)	**£1m**	Projected 2009/10 costs for National Grid	£233k	
Technological area and/or issue addressed by project	This programme addresses cable related issues including cable protection, oil leak detection, insulation materials and cable decommissioning. This will help to ensure that existing and future cable systems are managed and utilised as efficiently as possible.			
Type(s) of innovation involved	**Significant**	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		9 to 18	2 to -5	11 to 19

Expected benefits of project	There is a wide spectrum of benefits to this programme. The benefits are listed per project below. Cable tiles project • During construction there is improved manual handling (compared to concrete tiles) due to their light weight • The plastic tiles are made from recycled materials and therefore have an environmental benefit. • Reduced unit costs and reduced delivery and installation costs combined with easier storage will ensure that costs are kept to a minimum. Oil leak detection • This project will lead to a reduction in costs and resources associated with cable oil leak location with potential to give an accuracy of within 2 metres on all cable voltage ranges. To put this into context: In 2003/04, 9 cable oil leaks required freezes for leak location, the cost of this work varied between £360k and £720k per leak location. Historically, on average, National Grid spends £500k per year on cable oil freezes. Assuming PFT location reduces the requirement to freeze by 50%, this would realise a saving of £250k per year or £1.25m over a 5 year period. • Improved response to cable oil leaks is also an integral part of driving forward improvements in environmental performance and cable circuit availability and is consistent with National Grid's philosophy in promoting the use and development of best available practises. Distributed Strain Sensor • The new system will have a greater range than existing DTS systems resulting in fewer systems being required to monitor long cable tunnels. For example in the 22km Elstree tunnel six separate DTS were installed and the output from each combined on a dedicated server. The new system will require only one system to be installed. A conventional individual DTS cost is in the order of £100k. It follows that considerable savings can be made by using the new system in longer tunnels rather than several conventional systems. Cable Core Removal • The benefits of the successful development of this method would lead to removal of a major environmental risk oil leaks from decommissioned cables. • Reducing the health and safety risks associated with the labour intensive cable removal. • Turning the decommissioned route into an asset (unfilled conduit for reuse by communications

	cables) Power Cable Materials • This initial project is strategic for National Grid with benefits likely to accrue in the long term. It is predicted that the demand for materials to service the high voltage (HV) and extra high voltage (EHV) cables industry will grow as old oil filled cables are replaced by environmentally cleaner polymeric cables and where like-for - like replacement will not be a viable option. The vast majority of new cable projects at all voltage levels will be based on cross linked polyethylene unless an alternative can be developed. This sector of the market accounts for approximately 95% of the total installed circuit kilometres globally over the last 5 years. Although the HV and EHV sector is small compared to the MV market, the technologies to be developed under this proposal will likely be readily adopted in this sector. This is in part due to many of the technical issues with existing HV / EHV cables being eliminated in the solution proposed here and providing highly recyclable cables.		
Expected timescale of project	5 Years	Duration of benefit once achieved	Ongoing
Probability of success	The individual projects within the programme have a 30 – 60% chance of success. The overall probability of success for the programme is therefore 4%.	Project NPV = (PV benefits – PV costs) x probability of success	£1.3m
Potential for achieving expected benefits	Two of the projects (Plastic Tiles and the sensor project) have finished and the benefits will be successfully realised via policy amendments and implementation within Asset Management. The remaining projects are progressing well and there is a medium-high chance of success for achieving the benefits of each project.		

Project progress as of March 2009	The progress of the individual projects is as follows: Cable tiles Project • The project has been completed. National Grid's Technical Specifications will be altered to allow plastic cable tiles. It is anticipated that the use of plastic cable tiles will become widespread. Oil leak detection • Some Materials ordered, other materials are being investigated and sourced. Contract negotiation with PFT Technology is as yet ongoing and informal discussions are taking place, Project to start in earnest soon. Distributed Strain Sensor • The design and analysis elements of ROADS project have now successfully concluded with SENSA now in a position to market the end product. National Grid offered to provide a trial site at the new Woodhead cable tunnel. This was originally expected to take place in Summer 2009, but cable works have been delayed and it is not expected that any trial could take place before Summer 2010. Cable Core Removal • The project is about to start. Materials have been paid for upfront. Power Cable Materials • Within the first 9 months of this 2 year project strong candidate polymeric materials have been defined and variants produced and measured with very promising findings. Higher operating temperature semiconducting screen materials have also been identified to operate with these new materials and trial model cables are being produced for laboratory testing. In parallel thermal rating studies have been progressed for cable tunnel, cable trough and underground deployments including the assessment of new modelling methods required to undertake these assessments. Transmission network system constraints and deployment opportunities relevant the new cable technology have also been defined and a series of deployment and operating profiles are being defined to enable life cycle modelling of the cable from production through to operation and end of life management, including recycling. A life cycle framework has been defined for the assessment of the life cycle economic and environmental performance of the new cables and the benefits that will be conferred in the most advantageous applications and operational scenarios. Published life cycle assessment

	studies of power cables and transmission systems have also been reviewed to provide potential data sources for the current study. Significant interest from within the UK and internationally has been shown in this project and a process for informing interested parties of progress has been put in place.
Collaborative partners	PFT Technology, GnoSys, Dow Chemicals, University of Southampton
R&D provider	Electricity Alliance West, Pirelli, PFT Technology Inc, AES and AGT Sciences

30) Cable Oil/Ratings and Thermal Data Analysis

<table>
<tr><td>Programme title</td><td colspan="4">Cable Oil, Ratings and Thermal Data Analysis
This programme of work includes the following projects
• Finite Element Analysis of Ratings (FEAR)
• Ratings of cables in tunnels (ROCIT)
• Cable oil leaks & thermal data analysis
• Portable oil-in-soil measuring instrument (DTI)
• Ostwald Coefficients for Cable Oil</td></tr>
<tr><td>Project Engineers</td><td colspan="4">David Payne, Jeremy Lee, Gordon Wilson</td></tr>
<tr><td>Description of programme</td><td colspan="4">Two of the projects in this programme are concerned with producing more accurate ratings for cables by using finite element analysis and reviewing the ratings methods used to design cable tunnels to develop a specification for a rating method for cable tunnel installations with independent cable circuits.
Cable oil leak data currently logged by National Grid will be examined and analysis methods developed to provide an estimate of the position and magnitude of oil leaks, guidance on enhanced rating methods and techniques for the early detection of thermal anomalies and overheating.
The prototype oil measuring instrument produced by Cranfield University will be developed to extend its functions and make a smaller, more robust package that could be marketed commercially.
The final project addresses the determination of solubility (Ostwald) coefficients of diagnostic gases in linear alkyl benzene (LAB) fluid used in high voltage cables. The coefficients are required to perform dissolved gas analysis (DGA) accurately when using a headspace sampling technique</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £29k
External £155k
Total £184k</td><td>Expenditure in previous (IFI) financial years</td><td colspan="2">£108k</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£755k</td><td>Projected 2009/10 costs for National Grid</td><td colspan="2">£37k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">This programme is concerned with issues arising from an increasingly large high voltage cable population. This includes cable ratings, mitigation of oil contamination and the identification of fault gasses.</td></tr>
<tr><td>Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td></td><td>4 to 12</td><td>-2 to -5</td><td>7 to 17</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">Finite Element Analysis of Ratings (FEAR)
• A better understanding of cable ratings and in particular cable joints by analysis using FEA could lead to cable thermal rating enhancements providing more flexible operation of the transmission network, facilitating outage planning and avoiding generation constraints.

Ratings of cables in tunnels (ROCIT)
• A better understanding of rating of cables in tunnels would lead to:</td></tr>
</table>

	○ Increased use of existing tunnels for new cable installations ○ Potential use of smaller cables for a given rating through understanding the true rating capability of cables. ○ Optimisation of tunnel cooling systems or in some cases removing the need for any cooling system from better understanding of natural ventilation effects. Cable oil leaks & thermal data analysis • The early detection of oil leaks reduces their environmental impact. A method for locating leaks without digging sequential holes will improve cable system availability by reducing outage times, reduce repair costs and minimise the disruption to traffic. • Improved understanding of DTS data can enhance cable ratings, reducing costs associated with thermal constraints. Additionally it should prevent an Auckland-style blackout on the system through the early detection of thermal anomalies and prevent cables overheating avoiding expensive damage to the cables and accessories. Portable oil-in-soil measuring instrument (TSB part funded) • The project will allow decisions on excavation and remediation around cable oil leaks to be made immediately. This will avoid the costs of lab tests and reduce the waiting time for contractors on site. It will also allow the amount of oil recovered in excavated material to be measured. Ostwald Coefficients for Cable Oil • The identification of solubility coefficients for DDB enables DGA to performed accurately on cables and allows direct comparison with results obtained using gas extraction		
Expected timescale of project	5 Years	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£703k
Potential for achieving expected benefits	The potential for achieving the expected benefits of the majority of projects is high based on positive project progress to date.		

Project progress as of March 2009	Finite Element Analysis of Ratings (FEAR) • The project is nearing completion. The project has clearly demonstrated the use of FEA for providing analysis of complicated cable rating problems. Ratings of cables in tunnels (ROCIT) • A review of existing rating methods has been carried out. Several tunnels have been visited and data gathered for further analysis. Algorithms are being developed to consider tunnels with more than one type of cable construction. Cable oil leaks & thermal data analysis • Initial data has been collected and analysed. From this data a predictive model of cable pressure variation with load has been built. Also tests have been carried out to simulate and aid understanding of how Aluminium sheathed cables corrode. • An interim report has been received on progress to date. Further refinement of the model is required in the next year. • Initial results are promising but difficulties are being experienced in obtaining data and the quality of the data is poor. • Project is a year behind schedule due to the difficulty in recruiting a PhD Student. Portable oil-in-soil measuring instrument (TSB) • The project is complete. The only actions are to complete the administration to the terms of TSB funding agreement. • Ostwald Coefficients for Cable Oil • Ostwald coefficients have been determined and found to be very similar to those for transformer oils, with the exception of acetylene. Using generic Ostwald coefficient values result in significant underestimation of acetylene concentrations in DDB.
Collaborative partners	H&R ChemPharm, WSP Remediation
R&D provider	Southampton University, Cranfield University, Morgan Shaffer

31) SODA

Project title	SODA		
Project Engineer	Graham Moss		
Description of project	To simulate, in the laboratory, the degradation processes seen in silicone oil insulated cable sealing ends and to develop a sufficient understanding of these processes to facilitate the analysis of samples taken from the field in order to provide a measure of asset health.		
Expenditure for financial year	Internal £2k External £79k Total **£81k**	Expenditure in previous (IFI) financial years	**£28k**
Total project costs (collaborative + external + internal)	**£184k**	Projected 2009/10 costs for National Grid	£56.5k
Technological area and/or issue addressed by project	The breakdown pathways and kinetics of poly-dimethylsiloxane (PDMS) insulating fluids are not fully understood, and the study and deeper understanding of how these fluids behave under electrical stress may lead to the identification of significant components which may be used to determine the early determination of fault activity within silicone fluid filled terminations. It is envisaged that with the chemistry fully understood, a much greater appreciation of fault level and time to failure will be derived. Furthermore, the identification of selective analytical markers of fault activity will allow simple routine testing methods to be migrated to the contract oil laboratory, enabling National Grid to look for fault symptoms in a similar way to that already practiced for instrument transformers and bushings		
Type(s) of innovation involved	Significant	Project Benefits Rating 13	Project Residual Risk 3	**Overall Project Score** 10
Expected benefits of project	Oil-based insulation systems have been used for many decades and, consequently, a number of techniques have been devised to monitor the condition of a range of critical assets. Dissolved gas analysis, for example, has a long and successful history in identifying issues with transformers. In contrast, no comparable testing methodologies exist for silicone oil and, even if testing methodologies were to be borrowed from other oil-based systems, at present it would not be possible to interpret the results. Since silicone oil is already being used on the transmission system and is giving problems of the type described above, our current inability to monitor the condition of silicone oil-based cable sealing ends renders National Grid susceptible to further unplanned outages and the loss of critical circuits. This project sets out to address this issue. In Stage 1 this project will: • Examine field aged samples of silicone-oil and examine the feasibility of simulating, in the laboratory, equivalent time dependent degradation processes by thermal and electrical means. • Explore a range of potential analytical tools capable of being		

	used to quantify degradation. If it can be shown that appropriate accelerated ageing methodologies can be developed and the degradation detected in the oil, then Stage 2 will: • Examine the effect on silicone oil of a broad the range of ageing parameters, including both electrical and thermal factors. • Identify physical and chemical indicators of ageing and relate these to changes in key electrical properties. • Compare these with changes seen in field-aged samples. • Seek to determine end-of-life indicators. The above will bring the following business benefits: • For the first time, National Grid will be able to monitor the condition of silicone oil-filled cable sealing ends. • This will enable National Grid to identify assets in distress. From this information, it will be possible to determine appropriate maintenance strategies and to minimise unplanned outages through the avoidance of failures.		
Expected timescale of project	4 Years	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£24k
Potential for achieving expected benefits	From the work performed previously by Southampton University on Cable fluid degradation, this work should have an excellent chance of producing the answers National Grid need to manage the silicone fluid filled assets in the same way we manage bushings and instrument transformers.		
Project progress as of March 2009	Initially, progress was slow as silicone oil from used source is hard to come by, and a series of problems with the test equipment used to electrically age the oil. Work has progressed very well on unused oil supplied by Dow Corning since January 2009, with great strides being made in the study of the pathways and products of the silicone fluid degradation under electrical and thermal stress, both with and without the presence of 'system materials' such as copper and paper. Some excellent additional work is being performed in which varying viscosity grades are being assessed together in the stress rigs to discover if National Grid can rationalise many different grades of fluid in favour of no more than three viscosity grades. The work here is looking into the potential effects of space charging and molecular breakdown in interfaces which do not include a phase change (e.g. solid to liquid) but rather an interface of differing viscosity.		

Collaborative partners	-
R&D provider	-

32) Tower and Conductor Design, Capability and Maintenance

Project title	**Tower and Conductor Design, Capability and Maintenance** This programme of consists of the following projects: • Potential Impact of Wind Turbines on Overhead Lines – Phase 1 • Development of Multi response Stockbridge Damper at 400kV • Uprating of overhead lines • Remote control of bird scarers • Greasy conductor; Interstices cleaner • Effective Protective Coatings for OHL Towers • Ageing Mechanisms In Composite Insulators • Phase III Centrifuge Modelling and Field Monitoring of Wind Induced Loads on Transmission Towers • Composite Technology Conductor Trial • OHL Conductor Asset Lives • ACSR Corrosion Research
Project Engineer	Michelle Clark, Dave Bedford, Boud Boumecid, Mark Winters, David Clutterbuck, John Hyde
Description of programme	A literature review on the potential impact of wind turbines on overhead lines will identify mechanisms for potential damage to high voltage overhead lines from wind turbines (both direct physical damage and indirect wind-induced damage), concluding in a report containing an initial assessment of the likelihood of any of these mechanisms actually causing damage to overhead lines, and a proposal for testing (if required). The Development of Multi response Stockbridge Damper at 400kV will • Design attributes to ensure approval for future high temperature conductors • Be more conductor friendly than current designs, expected to reduce damage and mechanical stresses at attachment points • Improve damping efficiency - multi response as opposed to current twin response for increased conductor life. Uprating OHLs. Compact lines is a new technology area addressing the possibility of reducing the size of an OHL and consequently its impact on the environment. The technology this project will be using as a tool to control the overvoltages is Surge Arresters. To achieve the expected results, much work will be required including simulations and modelling, data collection and field testing trials. At present, our bird scarers [20 off] do not have a remote control or

	indication capability. This project will deliver remote control and indication economically, simply and efficiently by means of SMS from any mobile phone. This functionality is urgently required for several key reasons. Providing the platform to mute the equipment opens up other exiting functionality options, and will dramatically minimise the number of times a tower has to be climbed. Running costs will be negligible, as "pay as you talk" SIM cards will be used, costs around 10p per call. To develop simple hardware to be used in advance of other conductor cleaning techniques, to displace and remove the interstices grease. Coatings. A number of tests have been carried out by EA Technology on behalf of a group of ESI companies. This includes the evaluation of a number of new products and special purpose paint systems. Inspections of trial towers painted with a newly developed environmentally friendly water based system have also been carried out. National Grid has requested the opportunity to participate in the final stages of the testing. Participation will ensure access to all test results to date and the final report when complete. Developing an ageing model for composite insulators and continuing to use new techniques to see if these models can be developed further to identify and manage any risks associated with their use on the National Grid transmission system. Wind induced loading of transmission towers. To carry out enhanced environmental modelling of a full OHL support system fully instrumenting a short section of line. To carry out centrifuge modelling to expand the range of foundation and soil types currently considered, using the data collected by the environmental modelling. To gain experience in and develop methods and procedures for the handling, installation and maintenance of both Composite Technology Corporation conductor (fibre glass core) and polymeric insulator strings. To review the technical asset life for ACSR Conductors. Phase 1 of Cormon ACSR Equipment replacement.		
Expenditure for financial year	Internal £47k External £150k Total **£197k**	Expenditure in previous (IFI) financial years	**£50k**
Total programme costs (collaborative + external + internal)	**£985k**	Projected 2009/10 costs for National Grid	£137k
Technological area and/or issue addressed by programme	As the number of windfarms and the size of individual turbine blades increase, there is increasing potential for interactions between the turbines and our overhead lines. At present, National Grid does not have a policy regarding proximity. There are four areas of concern:		

	1. Catastrophic failure of a turbine support, resulting in direct contact with a transmission circuit. This is analogous to falling trees, and can probably be handled in a similar manner. 2. Catastrophic failure of a turbine resulting in debris impacting on an overhead line. Limited examples of analysis of turbine failures to date suggest that whole blades can be thrown 1.5 diameters, while smaller fragments can travel 6 diameters. We will review the work done by GNI to cover this area. 3. Ice shedding from turbines, which could also impact on an overhead line. This is similar to item 2. 4. The impact of turbulence on conductors downwind of turbines. A number of utilities and universities around the world have looked at turbulence patterns, however the interaction of these with bundled or single overhead line conductors is not yet resolved. National Grid currently uses a range of twin response dampers with bolted clamp attachment based upon optimum performance based on corona performance and mid range damping qualities. These generic designs are between 20 & 30 years old. With the improvements in analytical design tools National Grid are seeking to develop a damper that has acceptable corona performance at 400kV, increased reliability of attachment points, minimised conductor damage & improved damping efficiency. Functionality improvements to existing bird distress call bird scarers minimising habituation of birds, noise nuisance to neighbours and almost eliminating expensive visits to site to adjust settings or investigate faults. Cleaning contaminated conductor to alleviate environmental acoustic noise problems has been effectively demonstrated in the laboratory environment using either water jet washing or pulsed laser cleaning technology. Both methods however struggle to remove thicker clumps of grease which form in the root of the interstices. The same applies for the traditional hand cleaning method! The key objective of this proposal is to develop simple hardware to be used in advance of other cleaning techniques, to displace and remove the interstices grease. Impending European legislation will electively ban the use of high VOC paints for any industrial use. The only approved National Grid tower paint product falls into this category. Maintenance policy requires the painting of approximately 1200 towers per year. Requirements have been identified for continued research to test and evaluate the performance of alterative paint products to ensure the company is prepared for any changes to legislation. Overhead line insulation systems/ asset management implications of using new composites technology (principally life expectancy and associated ageing mechanisms) and maintenance of these technologies

<table>
<tr><td></td><td colspan="4">once installed on the system.

To assess the appropriateness of current British Standard method for determining tower foundation uplift capacity and influence the change of industry design codes.

Overhead line conductor systems/Installation and handling of new conductor technology and maintenance access across composite insulators.

Historically, conductors used on the system are aluminium conductors, steel-reinforced (ACSR) of Zebra (400mm2, 54/7, 28.62mm diameter) design, but with different levels of grease protection, and past exposure to environmental conditions that vary widely throughout the UK. Other stresses (e.g. conductor vibration due to subconductor oscillation) may also have a significant influence on remnant life. This project is to determine the condition of conductors, both in service and taken from service, assess the extent and form of any damage and corrosion, and determine the likely remnant life of conductors.

Internal corrosion is a major factor limiting the life of steel reinforced aluminium conductors (ACSR) and a crucial stage in the corrosion process is the loss of zinc from the central galvanised steel strands. Once this galvanising is lost the aluminium strands are subject to galvanic corrosion and the conductor deteriorates rapidly. The effects of this form of internal corrosion are not visible or detectable by infra-red methods until the conductor is near to failure.</td></tr>
<tr><td>Type(s) of innovation involved</td><td>e.g. Incremental Tech Transfer
Significant
Radical</td><td>Project Benefits Rating
6 to 16</td><td>Project Residual Risk
0 to -8</td><td>Overall Project Score
5 to 19</td></tr>
<tr><td>Expected benefits of programme</td><td colspan="4">Without a policy, the current default position re the potential impact of wind turbines on overhead lines is that turbines may be sited as close as the turbine’s total height plus 20 metres (i.e. a “falling tree” criteria). One academic study suggested that, given a high voltage overhead line two to three blade diameters downstream of a modern turbine and an unperturbed wind speed of 20ms^{-1} normal to the line, 10% of the conductor strands might fatigue in 18 days. If this were true, the proliferation of windfarms would have a serious impact on the safety and reliability of our overhead line network. The benefit is therefore avoided safety risks (for both staff and public) and avoided costs (for enhanced maintenance or early replacement) for affected spans. Conversely, producing a policy that would require an unfeasibly large “exclusion zone” around our overhead line routes would result in unnecessary constraints on the sitting of renewable generation.

The development of multi response Stockbridge Dampers at 400kV could lead to:</td></tr>
</table>

	• Reduced numbers of instances of inner layer damage caused by aeolian vibration, therefore offering an extended life for conductors. • Reduction of damage to outer layers of alloy conductors, minimising the risk of conductor failures. The recent ZPA conductor failure cost in the region of £24K to recover not including constraint costs. • Removal of installation errors, impossible to over torque and can be reapplied more times than current guidance suggests for bolted attachments. • Compatible with AGS / HSU applications. Uprating OHLs could lead to possible application/implementation of new technology without major modifications to existing structures. Some of the studies to be carried out in this project will evaluate the use of surge arresters and polymeric insulators. Both technologies are of interest to National Grid. Additional benefit could be gained by avoiding the long process of consent applications for a new route, reusing the existing assets by the implementation of technology advances such as the use of modern high load carrying conductors. The cost of a newly built L8 line with twin Rubus conductor (500mm^{2}AAAC)/km is approx £500K. Voltage uprating of an existing L3 line using novel conductors such as Cork ACCC (by CTC) in association with surge arresters is circa £350K giving a cost benefit of £150K/cct km. Moreover, the consent process for a new line would be more elaborate than re-using an existing line. The duration of the design and construction phases will also be remarkably longer for the new line option. There is an additional possibility of developing a compact line which reduces the extent of OHL corridors. A compact line may encompass low height and narrow towers. This will not only reduce the amount of conductor sail and land take but also improves the visual impact of the OHL on the landscape and the environment. When deployed, the remote controlled bird scarer would be seen as a reassuring demonstration of our professionalism and capability to what may be very irate grantors or neighbours with the option for complainants [in appropriate circumstances only] to “self manage” their scarer and hence their problem. Rapid reaction times to turn units on or off as dictated by birds or noise complaints or to switch the operating mode from normal to reinforce or to intense if birds are stubborn. Fast diagnosis of the most likely faults without having to climb a tower. Without remote control, a tower would need climbing at least four times per annum to manage the scarer “On” and “Off” cycles. The cost of one “quick” visit is no less than £800 and probably in excess of £1K as well as resourcing an appropriately skilled linesman. Being able to manage the units means that the scenario of the unit being removed for deployment elsewhere can be easily tested. At present, we have no spare units available. It takes a group of six linesmen at least one week to manually clean all conductors on an L2 span. This is in excess of 200 man hours. Previous attempts at conductor cleaning by hand have failed to remove all grease. Using a cleaning device that helps remove all grease

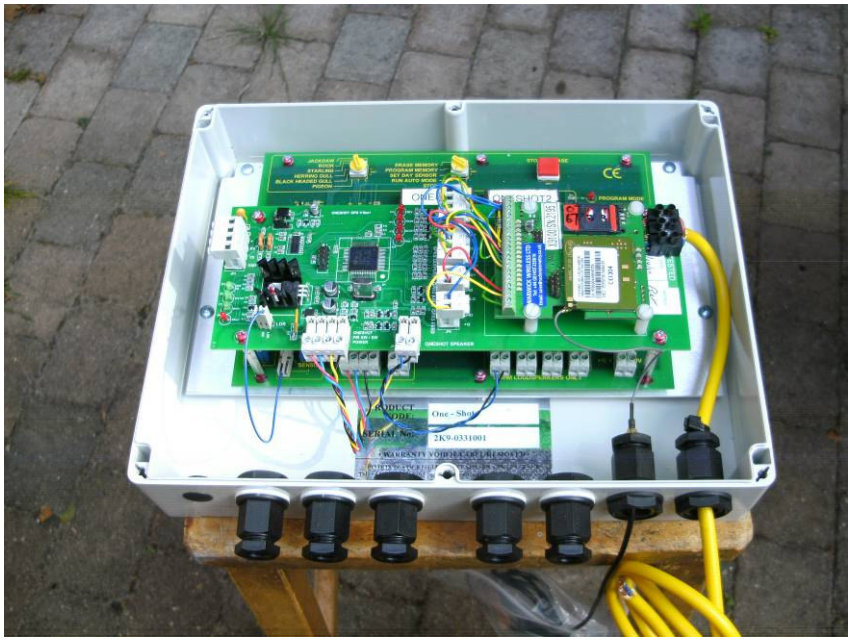
	deposits may result in less man hours cleaning but more importantly would be far more effective. This would reduce or avoid the need for repeat cleaning operations at a later date. Manual cleaning of conductor may not be a viable option due to existing H&S concerns. This R&D proposal is the first step in developing an effective cleaning method which is the main obstacle in realising a consistent automated solution. If a cleaning solution is not developed then it is highly likely that conductor replacement will be the only option. A current estimate of reconductoring double circuit twin Rubus for 1km is £250k. If there are any other issues with replacement then this cost could increase. Replacing the conductor is therefore undesirable if other methods of noise control are available. The expected benefits of undertaking coatings research are as follows. • Compliance with European Law regarding VOC emissions • Reduction to single coat paint systems (two coats currently used). • Reduction of steelwork replacement during OHL refurbishments. The ageing model provided by this project will enabled National Grid to develop and co-ordinated asset replacement regime for exchanging ceramic insulators with composite ones. Composite insulators are expected to provide the following benefits to the business: • Improved health and safety performance (composite strings at 400 kV are around 15% of the weight of cap and pin ceramic strings) • Reduced installation costs (composites are expected to be around 85% of the price of ceramics) • Faster installation and therefore shorter duration outages • Better pollution performance and therefore increased network reliability. National Grid will benefit from the tower foundation research by being able to assess OHL foundation capacity reliably, optimise tower strengthening upgrades and avoiding unnecessary foundation reinforcements. The research will contribute to updating to National Grid's Technical Specification for line refurbishment and provide a high level of confidence that structures are fit for purpose. This research will help significantly reduce the number foundation upgrades required during the planned capital refurbishment program. As an alternative to Gap conductor ACCC (Aluminium Conductor Composite Core) is likely to reduce outage time for installation and repairs. The use of high temperature low sag conductor has already been proved as a means of avoiding upgrading the network without the need to build additional lines. The reduced weight and installation complexity combined with exceptionally low sag characteristic may make ACCC particularly suitable for high level crossings.

	There is a requirement to maintain and operate reliably ACSR conductor to end of asset life and produce an optimised plan for replacement. To optimise replacement decisions, an accurate view of remaining life for installed conduction on a range of environmental conditions is required. There is significant OHL asset replacement planned for this and future 5 year periods. The work will provide information to feed into a review of ACSR conductor asset lives by enhancing the understanding of corrosion and fatigue as deterioration mechanisms. Confirmation of existing lives with the recent sample data will give confidence that the current asset lives are valid and if possible there may be scope for life extension and replacement deferral. If one 200km scheme is deferred beyond the current price review period as a result of this project, this will lead to deferral of £60m of Capex. Investment decisions on scope, timing and prioritisation of full refurbishment or fittings only schemes are informed through condition information. The capability to deliver an optimised OHL asset replacement plan relies on the ability to select suitable routes for fittings only schemes. Without ACSR corrosion test equipment, extensive in span destructive sampling would be required leading to additional longer system outages, additional site resources and thus higher costs for collecting the condition information. It is essential National Grid can continue to use a non destructive test to measure steel core loss to ensure condition information can be accurately and efficiently collected. Without this equipment it is expected the costs for collecting the condition information will increase from £1500 to £4500 for each section of a route where condition information is collected. This could equate to an additional cost of £600k for the tests which are required to support the plan for this five year period.		
Expected timescale of project	5+ years	Duration of benefit once achieved	10+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£3.8m
Potential for achieving expected benefits	The potential for success of this programme is deemed to be good. More specifically, the potential for developing a wind turbine related policy is 100%; whether it adequately protects our assets has 80% confidence. The functionality of the bird scarer units is working entirely as expected, and is extremely simple to use via mobile phone SMS messaging. There seems no reason to expect problems when in service. A full scale change to the originally proposed epoxy paint is unlikely in the near future but in the medium term a change to one of the alternative coatings being tested is almost certain as impending		

	European legislation on VOC's will mean the current vinyl paints can no longer be used. The Ageing mechanisms in composite insulators project has delivered its anticipated benefits. National Grid has been able to incorporate in its overhead line insulator policy document asset management guidance on the use of Composite/Polymeric insulator assigning initial product life expectancy figures and incorporating this into an overall overhead line conductor system asset management programme. The tower foundation work completed to date has delivered significant benefits already. The theory behind the work has been developed from and documented although the site based trials have yet to be completed. The Composite Technology Conductor work has supported type registration of this conductor system by feeding into the production of installation and maintenance procedures. The project made use of the overhead line training facility at National Grid's Eakring site. The installation of the new conductor and insulators on equipment that is not part of the energised network gives the following benefits: • The new conductor has specialised jointing equipment; the installation was supervised by the conductor manufacturer and therefore enabled the development of an installation methodology. • The use of polymeric insulators on overhead line tension towers creates a unique issue for maintenance access to the conductor. This is because the insulator cannot be walked on. End of life for ACSR conductors has historically been taken as a 15% loss of conductor strength. However recent forensic work has found slower rates of loss of strength than previously expected. This work is to better understand the degradation mechanisms. Potential for achieving this goal and the ACSR corrosion research are high.
Project progress as of March 2009	The literature review on the potential impact of wind turbines on overhead lines is complete and a comprehensive report has been produced. This concluded that, of the many damage mechanisms postulated, only turbulent buffeting is of genuine concern. The interim policy on separation distance between wind turbines and overhead lines was set at five blade diameters as a precautionary measure. We are now, based on the literature review, consulting with the British Wind Energy Association with a view to reducing this to three diameters. The report concluded that computer-modelling of this interaction would be prohibitively difficult/expensive, and that an opportunity should be sought to monitor an actual installation. National Grid does not yet have a suitable case for monitoring, but the BWEA are searching for options both in the UK and possibly Europe. The Stockbridge Damper developments are still in discussion.

Uprating OHLs: Arrester design refined, carried out simulation work on switching overvoltages on a 275kV line uprated to 400kV followed by optimising Surge Arrester design and progressing the investigation of electromagnetic fields.

The bird scarer units have been successfully developed, tested and delivered. Further desktop testing and evaluation is ongoing whilst waiting for the field staff to facilitate installation on tower sites, hopefully prior to September 2009. The supplier has provided a very professional product. The box and base circuit board are standard; the daughter board is the NG modification.



Conductor cleaning developments have been disappointing. A rotating polypropylene brush concept and a scraper concept were investigated. The rotating brush idea was not considered desirable because the brush may clog up with grease, and there was excessive abrasive contact with the conductor surface. The simple scraper concept was investigated with a plastic and a metallic scraper. Whilst the plastic one wore out too quickly, the metallic one dug into the conductor jamming or producing burrs. We still believe that there is a better way of removing grease than by hand, latterly with access provided by an access platform for H&S reasons.

Coatings: A field inspection of the National Grid 4ZC line had been

	carried out. A report on the previous inspection on the 4ZE line was included in the final report. Results of the tests on insulator samples contaminated with paint have been published. The Prohesion test report on a range of alternative paint products has been completed and report published. The tower paint specification and list of approved suppliers has been published together with the contact details of all the sponsors' representatives. The National Grid specification for the top coat of the modified vinyl system had been changed to the lower viscosity version, this is still in the trial stage. A list of the toxic constituents of paints currently used for tower painting had been drawn up. The approved suppliers of tower paints have been contacted to ensure that they complied with REACH legislation. The Ageing mechanisms in composite insulators project has completed. The project also identified a potentially significant environmental driver that may affect insulator aging due to the asymmetrical growth of organic compounds on the north facing side of the test specimens. Tower Foundations. Preliminary site testing is complete. Scope of uplift tests, site access, test layout and scheduling of works/details has been agreed. Detailed design of foundations, Reaction Pile, test methods and associated equipment is complete. Composite Technology Conductor Trial completed. ACSR Samples 1 – 188 condition assessed, The generic grease type (i.e. grease or bitumen) established and extent of the grease applied within the conductor (i.e. core-only / all inner-layers /all-layers greased) captured. Tensile measurements completed on 139 samples. Preliminary presentation issued. Spreadsheet of all test data compiled and issued. The first 3 stages of the ACSR corrosion work have been completed.
Collaborative partners	We are sharing a full copy of our wind turbine literature review with Scottish Power. Babcock Networks Ltd, Balfour Beatty Utility Solutions Ltd, eon Engineering Ltd, SP Power Systems Ltd, United Utilities, CE Electric UK (NEDL), Scottish and Southern Energy, Central Networks.
R&D provider	University of Manchester, Preformed Line Products GB, Cardiff University, Adaptive Wireless Solutions Ltd, Clean Laser, EA Technology, University of Southampton, Babcock Networks Ltd – Eve Transmission, ERA Technology.

33) Understanding and mitigation of hazards related to TT bases

Project title	Understanding and mitigation of hazards related to TT bases			
Project Engineer	Alan Ainsley			
Description of project	The project is to enhance risk assessment methods from the effects of step/touch potentials generated during transient surge conditions. This will allow National Grid to more effectively target resource for mitigation, avoiding unnecessary expenditure and, more significantly, approaches from third parties.			
Expenditure for financial year	Internal £5k External £92k Total **£97k**	Expenditure in previous (IFI) financial years	Total **£108k**	
Total project costs (collaborative + external + internal)	**£350k**	Projected 2009/10 costs for National Grid	£20k	
Technological area and/or issue addressed by project	Increasingly, Rise of Earth Potential issues are being considered both by National Grid and residents alike from legacy and new build sites. Current and previous research programmes on the characterisation of tower base earthing has revealed that the step and touch voltages and the rise of earth potential can be significant under fault and surge conditions. These potentials are shown to be affected by the geometry of the tower structure and the soil properties. Investigations have also demonstrated that the magnitude of these hazardous potentials can be reduced by introducing control measures such as modifying the earthing system of the tower base or on the earthing wire arrangement. On the other hand, it was found that there is a shortfall in the understanding of the dynamic behaviour of tower base earthing which is essential for the accurate prediction of potential distribution and hazard assessment around the tower base.			
Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		8	-1	9
Expected benefits of project	• The provision of guide notes for monitoring and maintaining integrity of earthing systems including terminal towers. • A quantification of effect of earthwire isolation on hazard limitation and system performance • A study on the effects of transmission lines on buried metallic objects under flashover conditions • Methods for limiting hazards at tower bases using insulation techniques • Recommendations on working practices near transmission lines • A better understanding of current distribution on tower lines under fault and surge conditions • Characterisation of tower lines and associated step and touch voltages under impulse conditions • Guidelines for mitigation of earthing hazards along transmission lines			

	• Model database of towers with risks to third parties on a selected transmission line		
Expected timescale of project	5 Years	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£99k plus safety benefit
Potential for achieving expected benefits	The potential for achieving benefit within NG is guaranteed. The work deliverables from this project will feed directly into company specification/policy documents.		
Project progress as of March 2009	This project is running up to completion at the end of this year. Progress has been good with no delivery problems to mention of. Many of the deliverables to date will aid in providing a better understanding of problems associated with transmission towers under system fault and lightning conditions, particularly in understanding the associated risk to person and property in the immediate environment. There has been interesting findings and effects seen during steady state and fault conditions on buried pipelines in the immediate environ of an OHL tower using simulation techniques. ROEP mitigation techniques on transmission towers were analysed on a pro/con basis.		
Collaborative partners			
R&D provider	Cardiff University		

34) Terrestrial Laser survey

Project title	Terrestrial Laser survey		
Project Engineer	Brian Addison		
Description of project	The key objective is to utilise an existing ground based laser surveying technique, which until now has not been used in the UK electricity industry. The ground based laser surveying tool is to be trialled in areas where aerial surveys are not possible, it is hoped this project will deliver: 1. A dataset that will allow National Grid to undertake detailed condition assessment of power line assets. 2. A dataset to allow development of detailed structural & electrical power line engineering models in PLS- CADD format for the VW line		
Expenditure for financial year	Internal £7k External £94k Total **£101k**	Expenditure in previous (IFI) financial years	**£N/A**
Total project costs (collaborative + external + internal)	**£156k**	Projected 2009/10 costs for National Grid	£55
Technological area and/or issue addressed by project	1. System Operation – Network capacity. The completion of the PLS-CADD model will allow National Grid to undertake detailed thermal analysis of the VW route (not currently available).		

Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		6	0	6

Expected benefits of project

The business benefits from successful delivery of this project will be as follows:

1. PLS-CADD model of the power line

Creation of a full PLS-CADD model for the W route will bring significant business benefits to National Grid. The model will allow the following works to be completed:

- National Grid will have data for a power line that currently has no engineering records other than those created 'as designed' in 1957
- Enhancing Network Capacity I Capability -through thermal uprating assessment of route. This work will allow National Grid to identify just what the full capacity of the power line route is. In many previous cases, the engineering assessment was able to identify up to 15% additional thermal capacity with only minimal engineering works
- Reducing vulnerability -analysis of the data will be fed back into the National Grid vegetation management process to ensure that any potential vegetation encroachment is addressed as well as identification of any potential 'falling tree' hazards on the route
- Reducing Environmental Risks -the Lidar datasets are

	formatted and provided to National Grid Asset Management staff so that EMF assessments can take place. This process has been undertaken on all other surveyed routes. In addition to this the Lidar survey will identify any potential Hard Infringements to the power line and will result in further analysis to create an engineering solution to remove the hazard from the system. • Assessing Lifecycle Costs -the PLS-CADD model is used to develop a range of possible engineering solutions to meet with potential system changes brought about by new connections or asset replacement activities. The ability to thermally & structurally model the route performance under a range of different conductor types provides the Asset Manager with a powerful tool upon which to base investment decisions at a cost range that can be delivered by the construction alliances • Health & Safety/Zero by Design -The lidar datasets, imported into the PLS-CADD model are also used to create digital fly-through of the power line route. This data has been classed as very valuable by the power line design engineers in development of safe engineering solutions for power line refurbishment. They can visualise access routes & equipment positions very quickly, without having to resort to a full ground-based review of the site works. • Enhancing system flexibility -the data will allow MORE (Met Office ratings Enhancement) assessments to be undertaken on the route. This assessment allows the Network Operations engineer a degree of flexibility during winter ratings to temporarily exceed the normal rating of the line during periods of system faults. Asset Condition Assessment Data 2.) Asset Condition Assessment Data The high resolution TLS of towers will provide the opportunity to use the data for the assessment of lifecycle costs including: • Steelwork condition -The millimetre accuracy of the survey will allow both the condition & alignment of individual steel tower members to be analysed. This data can be used in asset investment decision making to sanction schemes with a cost range based on detailed tower datasets • Tower Verticality -the survey will be able to quantify any deformation of the structure and become a baseline for other surveys to assess degradation of the tower foundations or steelwork. • A number of other asset condition assessments will be developed, once the full extent of the dataset has been analysed. 3.) Summary of Benefits • The most significant benefits to National Grid through completion of this R&D project will be realised through use of the data in a range of different engineering analyses. The financial quantification of benefits is more difficult until the engineering analyses have been undertaken. In previous

	situations, a thermal rating study & associated engineering works (cost £50k) resulted in a significant reduction in constraint costs. This is the real value of the project.		
Expected timescale of project	1 Year	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£98k plus safety benefit
Potential for achieving expected benefits	100% following successful change control of remaining funding into 202009/10.		
Project progress as of March 2009	All field survey works are complete and data has been delivered to NM&E. NM&E staff have completed the PLS-CADD model of the line (excluding conductor temperature calculations)		
Collaborative partners	None		
R&D provider	Merrett Survey Partnership, Blom Aerofilms		

35) River Crossing dampers

Project title	River Crossing Dampers		
Project Engineer	Dave Bedford		
Description of project			
Expenditure for financial year	Internal £2k External £9k Total **£11k**	Expenditure in previous (IFI) financial years	**£82k**
Total project costs (collaborative + external + internal)	**£99k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	Monitoring levels of vibration across three large river spans on the National Grid Network, Implementing a solution to manage the vibration.		

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		11	0	11

Expected benefits of project	Development of a new vibration damper for National Grid and reduction of vibration levels across three large river spans. Extension of the life of the three crossing beyond the current expected life.		
Expected timescale of project	2 Years	Duration of benefit once achieved	25 Years
Probability of success	100%	Project NPV = (PV benefits – PV costs) x probability of success	£132k
Potential for achieving expected benefits	Good		
Project progress as of March 2009	River Usk – Initial vibration monitoring complete and dampers installed on one circuit. Further vibration monitoring required to ensure the installation has been successful. River Severn – First Installation of vibration monitors completed and data analysed, Further studies are required and will be completed by the end of March 2008. Recommendations implemented by the end of May 2008. Final monitoring of installation expected to be completed by the end of July 2008. River Thames - – First Installation of vibration monitors completed and data analysed, Further studies are required and will be		

	completed by the end of June 2008.
Collaborative partners	Preformed Line Products (GB)
R&D provider	National Grid

36) Development of a Live Wrap Replacement techniques for OHLs Using a Modified SCC System

Project title	Development of a Live Wrap Replacement techniques for OHLs Using a Modified SCC System		
Project Engineer	Oliver Aries		
Description of project	Develop a new technique and associated equipment which will allow National Grid's OHL suppliers to replace fibre optic cable wrapped on the earthwire with an OPGW using a live technique (i.e. both circuits live). This technique will eliminate the need for installing temporary fibre diversions (needed to keep telecoms services going during the work) and without the need for transmission outages. The process will reduce scheme costs, reduce the requirement for optical and transmission outages, enable the work to be carried out in all environments and be less damaging to the environment.		
Expenditure for financial year	Internal £30k External £128k Total **£158k**	Expenditure in previous (IFI) financial years	**£82k**
Total project costs (collaborative + external + internal)	**£186k**	Projected 2009/10 costs for National Grid	£30k
Technological area and/or issue addressed by project	Replacement of wrapped earthwire without use of temporary bypasses. System can be deployed without requiring transmission outages (i.e. live) Significant reduction in the number of optical outages (reducing risk to customers). Can be deployed over difficult terrains where there is no method at present. 		

Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	0	10

Expected benefits of project	• Removal of the need to install temporary diversions should save National Grid ~£3m between 2008/9 and 2011/12. • The method can be used without the need for transmission outages. • The method will significantly reduce the number of optical outages which will benefit C&W and their customers and reduce National Grid's project risks. The procedure can be used to replace the wrapped fibre across all terrains and environments which is not possible at present.		
Expected timescale of project	2 years	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£1,576k
Potential for achieving expected benefits	Project was delayed due to technical problems and access problems to trial new OHL process. It is expected the technique will be available for commercial use from 2010/11. However, volumes have increased. It is expected that from this time the net benefit will realise ~£2m but key benefit will be that this system will enable the work to be carried out over difficult crossings and in built up areas which cannot be achieved by other methods.		
Project progress as of March 2009	In Sept 2008 a full live trial was carried out on a section of line near Tilbury. This was very successful but exposed some minor technical issues which are now being resolved. The next step is to roll the system out to other OHL suppliers, which is programmed for August 2009. Following its acceptance it is expected that the R&D will be completed around Sept/Oct 2009.		
Collaborative partners	BBPNL (East OHL Alliance)		
R&D provider	BBPNL (East OHL Alliance)		

37) Composite Cross Arms study

Project title	Composite Cross Arms study
Project Engineer	John Hyde
Description of project	**Task 1. Case Study Specification** Upon commencement of the project, National Grid (NG), The University of Manchester (UoM) and EPL Composite Solutions Ltd (EPL) will meet and agree specifications for the L2 and L3 lattice tower cross arms. The specification will include the following. i. Current construction details in steel; ii. Design rules and standards for both structural and electrical performance (these being based on existing cross-arm / insulator standards); iii. Current weight and installed cost for steel cross arms / insulators, which will be used for benchmark purposes. The specification will also include the required life time, handling techniques, maintenance practices, installation characteristics etc that may be essential or useful to take into account during the design process. This specification will be used as a reference document through the course of this and any future phases of the project to ensure that the final product is fit for purpose and satisfies the requirements of NG. **Task 2. Techno-Economic Benefits Of The Case Studies** Given that the uptake of this technology would rely on the development of an economic case, it is essential that this is considered within this phase of work. UoM and EPL will provide to NG the benefits that can result from the composite cross-arm. This information will be largely based on work already presented to NG with some refinements based on recent work. It is anticipated that while UoM and EPL will contribute to this task with engineering support, the bulk of this work must be undertaken by NG who can cost the potential benefits of the technology. **Task 3. Resolution Of Technical Barriers To Composite Cross-Arm Development** This task aims to carry out an initial analysis of the following aspects of the composite cross-arm technology. These specific areas were all identified in the phase 1 report to NG as potential barriers to the development of the composite cross-arm technology. • Solution to allow maintenance access to conductor fittings • Selection and test of an appropriate coating technology • Selection of an appropriate pultrusion profile • Identification of a suitable shedding profile for the pultrusions • Design and fabrication of a wet test facility for the prototype • Consideration of failure mechanisms of existing composite

	insulators in relation to composite cross-arms • Software development for modeling of lateral loading • Development of method to provide co-ordination gaps It is not expected that these phases of work will be fully resolved in terms of defining the final solution by the end of this project phase. However, as a minimum, the challenges will have been more clearly defined and initial developments will have allowed potential final solutions to have been identified. For example, it is highly unlikely that a choice for the optimum silicone rubber coat will be selected in this work but the main challenges will be understood in terms of both manufacturing and electrical performance. The emphasis is therefore in the continued reduction of risk associated with the issues presented in the phase 1 report. At the end of this task, the expectation is that the additional knowledge gained will lead to a review of the three composite cross-arm design options. **Task 4. Manufacture And Test Of Full-Scale Prototypes** Within this task, a full-scale mechanical prototype (defined in task 1) will be manufactured and tested. EPL will design a structure that can be used to support the cross-arm for the purposes of mechanical testing. A second electrical rig will be developed that will be used in the UoM HV Laboratory for electrical testing only (this rig being relatively light-weight as it will not support significant load). The cross-arm will be designed using software developed in phase 1 of the project which will be updated to include lateral load applications and relevant commercial codes. The testing will be performed according to the specification defined in task 1. However, in terms of mechanical testing, it will check the ability of the prototype to withstand static loads only and not consider long term durability at this stage. Through the mounting of the cross-arm on the test rig (replicating a tower) and by the inclusion of a conductor fitting allowing the installation of a length of conductor, electrical tests will assess the ability of the cross-arm to withstand AC, lightning and switching voltages. An assessment of the levels of visual corona will also be carried out. **Task 5. Development Of Future Project Road Map** At the end of this project phase, the feasibility of a composite cross-arm should be fully established. It is therefore essential to have a future project road-map that builds on the proposal previously presented to National Grid. This task of work will be carried out by EPL and UMIP (the University of Manchester Intellectual Property Company).		
Expenditure for financial year	Internal £9k External £370k Total **£379k**	Expenditure in previous (IFI) financial years	**£0**
Total project costs (collaborative + external + internal)	**£372k**	Projected 2009/10 costs for National Grid	£4k

<table>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">Overhead line cross-arms. The use of an insulating cross-arm potentially allows the upgrading of an L3 275 kV tower to operate at 400 kV and the elimination of the insulator strings on other tower types.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">e.g. Incremental
Tech Transfer
Significant
Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8</td><td>1</td><td>7</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">If it proves feasible to upgrade L3 towers to 400 kV operation there are several areas of the transmission network where future generation connections, that would ordinarily require new overhead line routes to be constructed, could be accommodated by upgrading a 275 kV route to 400 kV operation, increasing its power carrying capability, thereby avoiding the need to construct a new line.</td></tr>
<tr><td>Expected timescale of project</td><td>2 Years</td><td>Duration of benefit once achieved</td><td colspan="2">10+ Years</td></tr>
<tr><td>Probability of success</td><td>10%</td><td>Project NPV = (PV benefits – PV costs) x probability of success</td><td colspan="2">£30k</td></tr>
<tr><td>Potential for achieving expected benefits</td><td colspan="4">There is very high potential for realising the above benefits provided that this project indicated that the use of composite materials for tower cross-arms is feasible.</td></tr>
<tr><td>Project progress as of March 2009</td><td colspan="4">The feasibility project is complete and has shown that composite tower cross-arms are feasible. In particular the project concentrated on the use of composite technology to allow the operating voltage of L3 towers to be increased to 400 kV. While it is equally feasible to use composite cross-arms on other tower types the business case for asset replacement of existing cross-arms (not normally a planned activity) is very weak.

The initial prototype built for basic mechanical and electrical testing proved that the concept is feasible. The next phase is to product a production level prototype.</td></tr>
<tr><td>Collaborative partners</td><td colspan="4">None at present</td></tr>
<tr><td>R&D provider</td><td colspan="4">University of Manchester and EPL Composite Solutions</td></tr>
</table>

38) Long Term Performance of Silicone Based Composite.

Project title	Long term performance of silicone based composite Insulators			
Project Engineer	John Hyde			
Description of project	The key objective of this project is to advance the ageing model for composite insulators in order to maximise the return on previous research work in identifying and managing any risks associated with their use on the National Grid transmission system			
Expenditure for financial year	Internal £3k External £140k Total **£143k**	Expenditure in previous (IFI) financial years	**£80k**	
Total project costs (collaborative + external + internal)	**£ 421k**	Projected 2009/10 costs for National Grid	£140k	
Technological area and/or issue addressed by project	Overhead line insulation systems/asset management implications of using new technology (principally life expectancy and associated ageing mechanisms.			
Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		12	3	9
Expected benefits of project	The further development of the ageing model will provide National Grid with and asset management tool that enables cost-effective management of composite insulators used on the transmission network. This could lead to significant mid-life refurbishment savings, improved health and safety performance and improved grantor relations. Furthermore, composite insulators are proving to provide better pollution performance than ceramic insulators with a resultant increase in network reliability.			
Expected timescale of project	202009/10	Duration of benefit once achieved	Ongoing	
Probability of success	60 %	Project NPV = (PV benefits – PV costs) x probability of success	-£370k	
Potential for achieving expected benefits	This research will allow National Grid to hone its asset management of composite insulators. Should the research support the increase in assigned asset life the potential for realising the benefits identified above is very high.			
Project progress as of March 2009	Significant progress has been made regarding the aging process associated with surface discharges on the insulator. Research has shown that arc duration and energy levels have a major impact on aging and in particular on the rate of aging. The arc duration and energy is also highly dependent on the pollution level and type experienced. Evaluation of the impact of water drainage and flashover performance of the insulator is now in progress although this is in the			

	early stages of analysis. A key deliverable of this research programme is asset management intelligence and tools that enable an increase level of objectivity in the asset replacement process. A hand held tool currently under review that makes use of data analysis techniques is providing good prediction result on insulators of known condition and may therefore be an extremely useful input in the asset condition element of the asset replacement programme.
Collaborative partners	National Grid is currently exploring possible collaborative funding of this project with Scottish Power and Scottish and Southern Energy. Should they agree to support this project it is anticipated that the funding split would be 80 %/10 %/10 % National Grid, Scottish Power and Scottish and Southern respectively.
R&D provider	The University of Manchester

39) Lubricant Rationalisation

Project title	Lubrication rationalisation			
Project Engineer	Pete Denyer			
Description of project	Reduce the cost and diversity of lubricants purchased within National Grid leading to the replacement of obsolete and harmful lubricants.			
Expenditure for financial year	Internal £12k External £0 Total **£12k**	Expenditure in previous (IFI) financial years	**£0**	
Total project costs (collaborative + external + internal)	**£145k**	Projected 2009/10 costs for National Grid	£112k	
Technological area and/or issue addressed by project	Lubrication and maintenance			
Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		11	-1	12
Expected benefits of project	Extension of maintenance frequencies for a large proportion of National Grid HV equipment. Increased availability and reliability. Rationalisation of existing lubricants.			
Expected timescale of project	3 Years	Duration of benefit once achieved	10+ years	
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£412	
Potential for achieving expected benefits	The expectations are that this project will achieve the benefits expected as good lubrication is the key to reducing maintenance costs whilst ensuring good availability and reliability. Technology in the tribology field has developed considerably and this project will ensure National Grid will use the most suitable lubricants available.			
Project progress as of March 2009	Delays have been experienced due to contractual issues between National Grid and Imperial College. Contracts were signed earlier this year and interviews have taken place for Imperial College to recruit a suitable Research Associate with the necessary skills and experience to carry the project forward.			
Collaborative partners	None			
R&D provider	Imperial College			

40) Design and Development of Maintenance Delivery Tools

Project title	Design and Development of Maintenance Delivery Tools			
Project Engineer	Martin Wilson			
Description of project	All projects aim to deliver improvements in both the current maintenance techniques used to complete routine maintenance activities and the Health and Safety of the personnel completing the activities.			
Expenditure for financial year	Internal £46k External £128k Total **£174k**	Expenditure in previous (IFI) financial years	**£25k**	
Total project costs (collaborative + external + internal)	**£218k**	Projected 2009/10 costs for National Grid	£31k	
Technological area and/or issue addressed by project	Health & Safety (Occupational health)			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		5 to 11	-1 to -6	6 to 15
Expected benefits of project	All the projects have a focus on the health and safety of the personnel ensuring they have the best possible working environment to eliminate the risk to their health. The long term occupational health benefits to the company will mean less man hours lost due to lower back and muscular injuries sustained during the routine maintenance activities. The reduction in long term occupational health issues is unquantifiable but the reduction of injuries we cause to our staff undertaking their routine duties cannot be underestimated. The projects also focus on the techniques used with a view to improving them to ensure maximum efficiency and safety for personnel. As well as this equipment being developed for the benefit of National Grid it is anticipated the Overhead Lines contractors could utilise some of the equipment.			
Expected timescale of project	Final project end date expected to be in 2010.	Duration of benefit once achieved	20 Years	
Probability of success	70%	Project NPV = (PV benefits – PV costs) x probability of success	£4k plus large health and safety benefit	
Potential for achieving expected benefits	All of the projects are at different stages but all are expected to provide the benefits as detailed on their individual proposal forms.			

Project progress March 2009	
Powered Ladder Access Basket **TAO/OL120**	 Further Extensive field trials completed and an issue with the winch arrangement has been identified. A new winch has been sourced and attached to the equipment, testing has proven very successful. Further work required on the battery arrangement. Basket drop test successfully completed, equipment progressing to completion. Final production model is in production, approval will then be sought prior to roll out to site.
Portable Earthing Trailer **TAO/OL121**	The concept evaluation is completed with the main criteria fully investigated. Design of machine is nearing completion. The manufacture of the first prototype is expected to begin during June 2009. Once prototype is complete extensive field trials will be completed to ascertain if the initial design meets the functional specification. These trials will also allow valuable feedback to be sourced from site which will guide the project to a final specification.
Earthwire Platform **TAO/20574**	 First prototype trialled, this identified a change to the spec and design parameters. Second prototype manufactured and tested, field trials to be completed to ascertain the suitability of current design and any required design changes. Field trials to be completed during 2009.
Severn Cable Tunnel Access / Egress Trolley **TAO/20573**	 The tunnel trolley has been designed and manufactured. Final trials have been successfully completed. Investigations to be undertaken to ascertain if the trolley can be utilised in any other cable tunnels and if any further work is required.
Trolley Jump Kits **TAO/20575**	 First prototype of new jump kit equipment manufactured and trialled. A number of improvements were identified. A second prototype has now been manufactured and tested. Field trials are now required to ensure the new equipment works efficiently and to identify any further modifications.

Development of Yoke Plates TAO/20786		Development of lightweight maintenance yoke plates is progressing well. Yoke plates A and V are complete, Yoke Plates O and L are currently in the design phase. Yoke plates to be approved and made available to OHL teams.
Earthwire Lifting Beam TAO/20622		Initial design manufactured and tested. Extensive trials successfully completed. A possible improvement to the design and a reduction in weight is currently being investigated.
Collaborative partners	None	
R&D provider	Spondon Engineering Gold Consult Rossendales	

41) Reduction of Asset Based Safety Incidents

Project title	Reduced Asset Related Safety Incidents		
Project Engineer	Nigel Lilley		
Description of project	As part of research into the Electricity Supply Industry, National Grid are part funding through the ENA the research to look at safety culture and improving the performance of the industry. To look at asset related incidents that have caused fatalities and/or injuries across the supply industry and recommend improvements to reduce the risk of asset failure		
Expenditure for financial year	Internal £8k External £11k Total **£19k**	Expenditure in previous (IFI) financial years	**N/A**
Total project costs (collaborative + external + internal)	**£89k**	Projected 2009/10 costs for National Grid	£0
Technological area and/or issue addressed by project	Enhanced understanding of human factors in reducing incidents and increased reliability of assets		

Type(s) of innovation involved	Significant	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		8	-8	16

Expected benefits of project	Both National Grid and the industry will benefit by having greater clarity of issues to focus on in ensuring appropriate action is taken proactively to improve performance. Will deliver a tools and techniques for enhanced safety management leading to increasing asset reliability and reduce operating costs through fewer incident investigations (conservative estimate 20 man days per incident @ £10K)		
Expected timescale of project	1 year	Duration of benefit once achieved	5+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£24k + health and safety benefit
Potential for achieving expected benefits	High potential due to driving changes in human behaviour to eliminate incidents.		
Project progress as of March 2009	Project completed in February 2009		

Collaborative partners	Health and Safety Laboratories United Utilities ENA
R&D provider	ENA

42) EMF

Project title	Electric and Magnetic Fields and Health		
Project Engineer	David Renew		
Description of project	The possibility that there may be effects of EMFs on health is an important issue for National Grid and stakeholders. This project will enable National Grid to strengthen its position in the face of the external threat posed by the EMF issue, through helping it to avoid unjustified constraints in its operations while at the same time ensuring that the EMFs associated with the operations are not the cause of any adverse health effects. This is an umbrella project providing resource for a variety of aspects of research on EMFs and Health, including resource directed towards management of projects funded elsewhere. National Grid lead this project on behalf of the UK electricity industry.		
Expenditure for financial year	Internal £38k External £1,000k Total **£1,038k**	Expenditure in previous (IFI) financial years	**£283k**
Total project costs (collaborative + external + internal)	**£7.5m**	Projected 2009/10 costs for National Grid	£746k
Technological area and/or issue addressed by project	Interaction of electric fields and magnetic fields with people, and the assessment of fields associated with the use of electricity		

Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		12	0	12

Expected benefits of project	While there is not likely to be a direct financial gain from this long-term research, without it there may be considerable additional costs and constraints imposed on the electricity industry operations arising from lengthy and costly debates about EMF and from unwarranted exposure limits or other constraints on operations. For example an assessment provided to the then DTI about the possible cost to National Grid of implementing the EU Recommendation (1999) on public exposure to EMFs included estimates of up to £850M. Another assessment, to the HSE, about the cost to National Grid of implementing an early version of the EU Directive on occupational exposure to EMF identified costs of the order £10-100M per year. In 2005, the Assessment published by the Stakeholder Advisory Group on EMFs estimated compensation costs payable by National Grid to landowners if an EMF risk because established as potentially several hundred £M.		
Expected timescale of project	Year: Ongoing	Duration of benefit once achieved	Indefinite

Probability of success	20%	Project NPV = (PV benefits – PV costs) x probability of success	£2.5m
Potential for achieving expected benefits	The EMF issue has existed for many years, and so has funding of research in this area by National Grid and its predecessors. It is clear that this funding up to now has made real difference in both the lay and scientific arenas – for example the recent conclusions of the WHO Environmental Health Criteria now focus on childhood leukaemia as opposed to other widespread health outcomes such as breast cancer. Nevertheless the issue is so broad and continuously developing that continued efforts will be needed for the foreseeable future.		
Project progress to March 2009	The multiple strands of this long-term project progress at different rates. The work of the EMF Biological Research Trust has, in the last year, produced two important negative results from experiments designed to test a high-profile positive result reported from Austria. The Trust have also made progress with work refining understanding of one specific proposed mechanism, the "free radical" mechanism, and are supporting a group in Glasgow who are reporting some intriguing results about DNA damage. The Trust have also started supporting a group at the University of Birmingham to focus on interactions of induced currents with nerves, which will allow greater precision about compliance with exposure limits, an issue of great commercial significance to National Grid. The Electric Power Research Institute in the USA have supported an existing study of childhood leukaemia in California to add EMFs to their study, enabling the evidence in this area to be further tested. They are also progressing with other work designed to fill gaps in knowledge of EMFs, for example a breed of mice which can be used to test development of childhood leukaemia more directly than at present, and a new design of epidemiological study of childhood leukaemia which should overcome some of the limitations of the existing studies. National Grid staff are working directly with the University of Oxford to explore in more detail the implications of the finding from 2005 that childhood leukaemia rates are higher close to power lines. A different strand of the project has been investigating electric field issues as they apply to linesmen climbing transmission towers, building an understanding of the underlying science that allows the phenomena experienced by linesmen to be assessed and, if necessary, addressed. National Grid also contributes to the wider industry research on EMFs and, although this strand is not within IFI, it is run as a single integrated programme. Research in this strand includes ongoing work on the health of electricity industry employees, using the database of staff created in the 1970s, which continues to provide reassuring results and is now being expanded to look at incidence of some cancers not just fatalities. There are also specific individual projects designed to address potential vulnerabilities: for example one which seeks to address the evidence on electric fields and thereby to influence the scope of the EMF issue, and another performing analyses to prevent inflated claims of the possible consequences of any health effect.		

Collaborative partners	Energy Networks Association, Department of Health, EPRI, Children with Leukaemia, Childhood Cancer Research Group, EMF Biological Research Trust (some of these partners are involved in the components of the research programme which do not come under IFI) National Grid lead this project on behalf of the UK electricity industry.
R&D providers	Resource Strategies Inc, Manchester University – HVRDC, EMF Biological Research Trust and others via collaborative partners including HPA-RPD, UCLA, Microwave Consultants Ltd, SAHSU, Institute of Occupational and Environmental Medicine (University of Birmingham). (some of these providers are involved in the components of the research programme which do not come under IFI)

43) Environmental Improvement/Remediation

Programme title	Environmental Improvement/Remediation This programme of work includes the following projects: • Unmanned aerial vehicles (UAVs) • Feasibility of using Trifluoromethyl Iodide as a replacement for SF6 in high voltage switchgear • Replacement of SF6 in transmission switchgear • Reducing NG carbon footprint • Reducing Climate Change Impacts • Development of Toolkit for the Remediation of Oil-Contaminated Soils • UK Investment Recovery
Project Engineer	Duncan Hoyle, Paul Coventry, Ian Welch, Shanti Majithia, Jeremy Lee, Gregory Tzemis
Description of project	Unmanned aerial vehicles (UAVs) • To investigate whether a UAV is capable of carrying out the same tasks as a manned helicopter for observing and inspecting overhead lines. • The drivers behind this project are to: Reduce costs for asset inspection by reducing the £/flight hour. Increase safety of inspection activities through reducing the amount of time pilots need to be in the air. Increase the number of assets accessible to aerial surveillance and increasing the number of available flight days through the ability to fly lower light conditions and poor weather. Increase mobility through the ability to transport the UAV close to the lines. • If phase one gives positive results further work will investigate the testing/trialling and implementation of the UAV's and analyse of data showing how they could be useful to National Grid. • The final objective of this project would be to have a UAV completely autonomous using GPS to track lines/pipes recording data which is downloaded and analysed. With the ability of a manual override so the operator can investigate faults and potential faults further. Feasibility of using Trifluoromethyl Iodide as a replacement for SF6 in high voltage switchgear • The project will establish the feasibility of trifluoromethyl iodide (CF_3I) as an environmentally compatible alternative to sulphur hexafluoride (SF_6) in high voltage switchgear applications and identify those areas which would require further work in order to achieve application. Replacement of SF6 in transmission switchgear • The project will develop an understanding of the fundamental physical mechanisms of arc quenching by chemical components produced from solid particulate material and subsequently deliver a demonstration interrupter unit for transmission applications that does not require SF_6 for its operation. This is considered to be a very important area of

	research. Reducing NG carbon footprint • Knowledge and innovation search external to the existing energy providers, with a specific target being reducing energy losses, seeking alternatives to SF6 gas and reducing environmental impacts Reducing Climate Change Impacts • In order to meet some of our **Strategic Goals** set out in our **R&D strategy in Jan 2007,** this project on Climate Change tries to address various adaptation and mitigation issues within NG. Development of Toolkit for the Remediation of Oil-Contaminated Soils • The development of a predictive 'tool-kit' for the assessment of appropriate remediation strategies for transformer and cable oil contaminated soils. • The analytical toolkit will give accurate measure of toxicity and bioavailability of oil in soils and any required nutrient or microbiological augmentation for effective remediation and reuse of soils. It should provide confidence in the appropriate selection of remediation techniques or justify the use of landfill facilities where remediation is not a viable option. • Project will be delivered through support for a 3 year EPSRC Ph.D. Case Studentship to be hosted at Lancaster University. UK Investment Recovery • To explore the opportunities available to optimise operational waste management across UK electricity transmission and thereby reduce the cost to the environment and improve value recovery. • To include a review of the value received from operational scrap from both Capex and Opex schemes across electrical equipment types, the potential recovery of grey spares and explore opportunities for knowledge transfer and innovation.		
Expenditure for financial year	Internal £51k External £152k Total **£203k**	Expenditure in previous (IFI) financial years	**£96k**
Total project costs (collaborative + external + internal)	**£2.7m**	Projected 2009/10 costs for National Grid	£474k
Technological area and/or issue addressed by project	UAVs • Pilot-less surveillance drones would certainly reduce the risk of pilot fatality and environmental impact of aerial surveillance and should also reduce the cost. The questions are whether they would be permitted to fly by air traffic control; and whether they can provide effective surveillance Feasibility of using Trifluoromethyl Iodide as a replacement for SF_6 in high voltage switchgear • The high global warming potential of SF_6 gas has encouraged research for alternative gases and mixtures in order to address		

	the environmental issues. In recent years, several mixtures of SF_6 gas have been the subject of investigations by academics and manufacturers, including a large European project. However, these have led to an incremental progress, and therefore, it is desirable to find an alternative gas to SF_6 and remove it completely from future electrical power applications. • Research work initiated at Tokyo University in Japan has investigated the electrical insulation characteristics of CF_3I gas, a gas which is widely used for fire extinguishing applications. It possesses the important physical and chemical properties of SF_6, but has a much lower global warming potential. The project aims to establish the feasibility of using CF_3I in high voltage switchgear applications and identify those areas which would require further work in order to achieve application. Replacement of SF6 in transmission switchgear • Sulphur Hexafluoride (SF_6) gas has excellent arc interrupting properties which have lead to it being the only commercially available technology for circuit-breakers in electricity transmission applications. It does, however, have an extremely high global warming potential. Much work has been done in the search for alternative gases, but candidates having the appropriate chemical and physical properties also tend to exhibit high global warming potentials. Recent work performed at the University of Liverpool has adopted an alternative approach. An arc interruption technique has been demonstrated that uses chemical components produced in the presence of the arc from solid particulate materials. Its basic performance has been assessed with fault currents of up to 60 kA with moderated rates of rise of recovery voltage of up to 1.2 kV/µs. The work is continuing at present as part of AMRDE 1043 'Use and management of SF_6'. In the proposed work, the fundamental physical mechanisms of the technique will be studied and the four stages of arc interruption, thermal recovery, dielectric recovery and dielectric withstand will be optimised such that an interrupter unit for transmission applications can be developed. An approach using modelling and experimentation will be adopted and a demonstration unit for transmission usage developed. Reducing NG carbon footprint • To search for and import technology propositions and solutions from non energy related R&D sectors (i.e. in this case the major UK provider for defence) which have potential for electricity (and gas) transmission Reducing Climate Change Impacts • Developing information to implement via an adaptation strategy. Development of Toolkit for the Remediation of Oil-Contaminated Soils • Optimisation of the methods available to remediate residual oil left in the ground following repair of a cable oil leak, and make recommendations on how to achieve the best results in

<table>
<tr><td></td><td colspan="4">different situations.

UK Investment Recovery
• UK Waste and Resource Recovery, Environmental Management leading to a potential reduction in waste disposal costs and an increase in investment recovery.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">e.g. Incremental
Tech Transfer
Significant
Radical</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>6 to 14</td><td>4 to -4</td><td>6 to 10</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">UAVs
• Increased safety no longer risking pilot and co pilot.
• Reduced costs (through reduced fuel and staffing costs)
• Ability to fly previously un-flyable areas due to size constraints (e.g. roads)
• Low level noise pollution (increase operation capability) (allowing for more flights)
• Increased boundaries on safe flying conditions. (low light, poor weather)
• Portability the ability to easily transport the UAV to location
• Reduction in CO2 emitted
• Reduced Way leave problems (lower staffing costs).

Feasibility of using Trifluoromethyl Iodide as a replacement for SF6 in high voltage switchgear
• The proposed work is intended to contribute to a reduction in SF_6 emissions by establishing whether switchgear using an environmentally compatible alternative gas is feasible. DEFRA has adopted a shadow price for carbon (SPC) in 2007 of £25/tCO_2e and, according to its guidance on use of the SPC, a price of 23,900 x £25/t or £597 k /t would be applicable to National Grid's SF_6 losses. The savings would be dependent on the volume of SF_6-based equipment replaced with the environmentally compatible alternative. In the event of a successful outcome, it is conceivable that all SF_6-based equipment on the transmission system would be replaced by 2050, representing a significant saving per year, depending on the residual level of SF_6 losses that would otherwise have been achieved.

Replacement of SF6 in transmission switchgear (in addition to above)
• National Grid has committed to reducing its greenhouse gas emissions by 80% in advance of the target date of 2050 set by the UK Government. SF_6 losses from switchgear constitute the third largest source of National Grid's baseline emissions in the UK, which highlights the importance of reducing SF_6 losses in order to meet the above greenhouse gas emission target.
• An interrupter unit for transmission applications that does not require SF_6 for its operation would eliminate a proportion of the losses by displacing SF_6-based interrupters from the inventory,</td></tr>
</table>

	the level of savings depending on the number of units displaced. In the event of a successful outcome, it is credible that all SF_6-based interrupters in air-insulated switchgear (AIS) applications would have been replaced by 2050, eliminating a contribution to National Grid's SF_6 losses of a few tonnes per year representing considerable annual cost savings. • EC Regulation No 842/2006 on Certain Fluorinated Gases which came into force in June 2006 prohibits the use of SF_6 in some applications. If legislation banning the use of SF_6 in switchgear were to be introduced significant other costs would be incurred including replanting of substations, which could be avoided by the timely adoption of a non-SF_6 based interrupter. • By supporting the proposed work, National Grid will be demonstrating a proactive and innovative approach to reducing global warming. Reducing NG carbon footprint • To search for and import technology propositions and solutions from non energy related R&D sectors (i.e. in this case the major UK provider for defence). Reducing Climate Change Impacts • To mitigate our climate related risk management on our transmission System and provide information on possible extreme events. Recent extreme events have lead to loss of supply to customers; potential avoidance of extreme event costs (up to £1m in 2007/8) will give financial benefit in addition to the strategic objective of addressing climate change issues. Development of Toolkit for the Remediation of Oil-Contaminated Soils • Predictive 'tool-kit' – This study builds on the research previously carried out at Lancaster University. It is proposed to integrate the techniques already developed to create a set of analytical steps (decision 'tool-kit') that can be used to assess a particular site, and enable appropriate remediation decisions to be made. The recently developed oil-in-soil monitor can also be used to give an indication of preliminary contamination to support the 'tool-kit'. • The project will be supported through an EPSRC CASE studentship to be hosted at Lancaster University with work carried out at both Lancaster and Aberdeen Universities. The involvement of Lancaster will allow the project to build on the wealth of experience already built. The involvement of Aberdeen gives access to a group who have already developed and demonstrated the toolkit approach to the remediation of waste, particularly for the off- and on-shore oil industry (and patented industry specific applications). • The EPSRC Case studentship route provides a highly cost effective route to realise this work. UK Investment Recovery • The Business will gain an understanding of the scale and value of operational waste in the UK. There is potentially an

	opportunity to increase the value recovery from scrap from capital schemes. There may be some intangible benefits which could improve the environmental and social responsibility credentials of the company.		
Expected timescale of project	5 Years	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£160k + large environmental benefit
Potential for achieving expected benefits	The majority of projects are expected to achieve a range of the potential benefits. In particular: Feasibility of using Trifluoromethyl Iodide as a replacement for SF6 in high voltage switchgear • With regard to the likelihood of CF_3I being found suitable for use in switchgear applications, initial reports are encouraging. It has already been reported that the gas has a dielectric strength around 20% higher than that of SF_6 and an arc interrupting capability between that of SF_6 and CO_2. On the other hand, it has a boiling point at atmospheric pressure of -22.5°C and measures would need to be taken to prevent condensation at low temperatures. It has been widely investigated as a fire extinguishing medium and can be produced at a reasonable cost. • In the event that CF_3I is found to be suitable for use as an environmentally compatible alternative to SF_6, new designs would need to be developed and type tested by switchgear manufacturers. Replacement of SF6 in transmission switchgear • Although the technique for interruption without SF_6 has been demonstrated in the laboratory, there is a significant level of risk associated with the project. Out of arc quenching, thermal recovery, dielectric recovery and dielectric withstand, it is the latter that is expected to present the greatest challenge. • Given the current imperative to reduce greenhouse gas emissions, a successful outcome to the research is likely to result in significant pressure for implementation. Production prototype devices will need to be built and type tested at a short circuit test laboratory. The involvement of a switchgear manufacturer will be essential for production of a commercial device. Reducing NG carbon footprint • Knowledge that solutions available to the defence sector are equivalent to / no better than those available to the energy sector would be treated as a successful outcome. Development of Toolkit for the Remediation of Oil-Contaminated Soils		

	• Foreign micro-organisms and nutrients are currently used in soil clean-up. The results of this project will inform the 'trial-and-error' approach used to date resulting in more effective clean-up and better evidence to present to the Environment Agency
Project progress as of March 2009	UAVs The project is planned to establish the likely availability of UAV technology for overhead line surveillance within the next few years. This project is being undertaken by Qinetiq, who are familiar with the military application of UAV systems. Key issues for UAVs on pipeline monitoring applications include the fact that they can currently only fly within the visible range of their operators. Feasibility of using Trifluoromethyl Iodide as a replacement for SF6 in high voltage switchgear • A candidate for the short term research project is being sought. • Initial contact has been made with Professor Hidaka at the University of Tokyo and discussions on collaboration are on-going. Replacement of SF6 in transmission switchgear • The details of the project are still under discussion. Reducing NG carbon footprint • This two year project is now complete. Work commenced with Qinetiq to import knowledge into the energy sector of emerging research from the military sector. The project methodology was to undertake a sweep of emerging technologies and see how these might map across to electricity and gas transmission. • The initiating idea, a search for alternatives to SF6, proved not to be successful. However a number of other promising areas were assessed. The areas are: o Unmanned aerial vehicles for surveillance of gas transmission assets and condition monitoring of overhead lines – with reduced carbon footprint and increased safety to personnel o Import of "stealth" technology to reduce the audible impact of transmission assets (e.g. reduced noise emissions) o specialised coatings e.g. lower thermal vulnerability to solar o possible energy scavenging from waste heat sources • Where appropriate follow-on projects have been, or will be commenced. Reducing Climate Change Impacts • This project delivered in Oct 2008 with results communicated via four lunch time presentations, feeding in to the climate change strategy delivery. Development of Toolkit for the Remediation of Oil-Contaminated Soils • Laboratory Work is complete, and we are waiting for the final

report and any proposals for follow up extension.

UK Investment Recovery

- The Project has explored several case studies across the electricity business. These have addressed the 5 elements of the Sustainability Matrix - Retain (Extend life), Re-use, Refurbish, Re-Sale, Recycle.
- In the light current area, a new policy for the re-use of "Grey" Protection Relay spares has been written and a stores facility is being set up in the Leicester Area.

- A Recycling Case study/ exercise was held at the Circuit breaker Refurbishment Centre at Thorpe Marsh and some £4.7 k of scrap was sold at market rates to local scrap merchants, instead of having to pay to have this recovered as part of a National waste collection contract. This has the potential to provide enduring savings to the business. The opportunity will be explored further in 202009/10 and specific proposals made. Note that a spin- off to this exercise has led to the recovery of £72.6k from the sale of used transformer oil.
- A Refurbishment case study has explored the viability of refurbishing rather than replacing a family of transformers experiencing early life failure modes.
- A re-use/ recycle/ re–sell case study has explored a large Overhead Line replacement scheme. The technical and economic case for the resale (for reuse) of short life OHL has been found not to be viable. An opportunity might exist for OHL with longer residual life, but this would have to be based on one-off opportunities rather than a 'business as usual' scenario.
- Based on the findings of this research, it has been agreed with the Risk and Responsibility Committee that a specific review be undertaken to explore the viability of establishing a dedicated Waste Management centre in the UK, along similar lines to a similar facility in Syracuse, USA. This will focus on

	bay/substation refurbishment.
Collaborative partners	Discussions are being held with potential collaborative funding partners including EPSRC.
R&D provider	Cardiff University, University of Liverpool, Qinetiq, Met Office, Ms Rosemary Devos, MBA, Master of Environmental Management.

44) Environmentally Acceptable alternatives to SF6

Project title	Environmentally acceptable alternatives to SF_6		
Project Engineer	Paul Coventry		
Description of project	The key objective of the proposed work is to enable National Grid to achieve the targets set out in its Climate change Strategy by means of the following: To identify environmentally acceptable alternatives to SF_6 gas To participate in collaborative efforts to develop alternatives to SF_6 gas		
Expenditure for financial year	Internal £7k External £151k Total **£158k**	Expenditure in previous (IFI) financial years	**£27k**
Total project costs (collaborative + external + internal)	**£300k**	Projected 2009/10 costs for National Grid	£56k
Technological area and/or issue addressed by project	Sulphur hexafluoride (SF_6) is widely used in electric power transmission equipment on account of its excellent properties both as an insulating material and as an arc-interrupting medium. It has become the only commercially available technology for circuit-breakers at transmission voltages. However, it has a high global warming potential, approximately 23,000 times that of CO_2, and its use raises concerns on environmental grounds. Against this background, it is essential that the electricity supply industry should actively consider environmentally more compatible alternatives to SF_6. The proposed work is intended to allow National Grid to identify and evaluate candidate alternative technologies to SF_6 for further development, to drive improvements in containment of SF_6 in equipment, to maintain an awareness of research and development into potential alternatives to SF_6 and to collaborate where appropriate.		

Type(s) of innovation involved	Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		5	3	2

Expected benefits of project	National Grid is committed to a Climate Change Strategy that aims to achieve a target of a 80% reduction in emissions of greenhouse gases by 2050 from a baseline of 6.6 million tons CO_2 (equivalent). The proposed work is aimed at identifying ways of reducing or eliminating the use of SF_6 in transmission switchgear and reducing leakage rates and is in direct support of the above target. The cost of SF_6 gas lost to the atmosphere, although significant, is small compared to the cost of the environmental impact of gas leakage. According to DEFRA's guidance on the Shadow Price of Carbon (SPC), the shadow price for SF_6 is given by the SPC of carbon multiplied by 23,900 or £ 575k per ton at 2007 prices (www.defra.gov.uk). It is foreseeable that, as pressure increases to improve environmental performance, taxes on greenhouse gas emission will be introduced.

	The project will accrue benefits few years into the future as the first generation of SF_6 filled equipment on the transmission network reaches its end of life and significant portions of the SF_6 inventory is replaced by equipment having lower leakage rates or not using SF_6 at all. At this stage, if the project reduces the leakage rate of new equipment by 0.25 percentage points, then additional savings on the environmental cost of SF_6 emissions will be accrued at a rate of the order of £200k per year, depending on the volumes replaced. It is envisaged that further R&D investment will be required beyond the end of the project to develop, test and implement any promising alternatives technology to SF_6 identified in the course of the present work. A provisional figure of £150k per year for the following two years is forecast as National Grid's contribution to the further development. It is recommended that this figure be reviewed depending on the outcome of the present work and the level of interest shown by potential collaborating partners.		
Expected timescale of project	4 Years	Duration of benefit once achieved	20+ Years
Probability of success	10%	Project NPV = (PV benefits – PV costs) x probability of success	-£143k +large environmental benefit
Potential for achieving expected benefits	The development of environmentally acceptable alternatives to SF_6 constitutes a high risk. Any alternative technology would have to be comparable in effectiveness to SF_6 based technology and would have to be economically viable. On successful completion of the present work, a demonstration project or projects will be required to prove any prototype technique or techniques. Manufacturer collaboration will be essential to the development of any commercial product. Application issues will need to be identified and managed.		
Project progress to March 2009	An evaluation of a number of alternative technologies to SF_6 for insulation and for power interruption is in progress. The alternatives addressed include vacuum, air (for interruption), hydrogen, alternative oils, alternative gases and compact technologies. Further progress was made on developing a quantitative understanding of the SF_6-less interruption technique demonstrated by Liverpool University. A self-blast type interrupter unit has been set up to investigate the influence of polymer materials on the current interrupting performance. Tests have been conducted in the current range 2000 to 9000 A and current and voltage characteristics as well as the arc-induced pressure rise have been obtained.		
Collaborative partners	Discussions are ongoing with potential collaborative partners for future work.		
R&D provider	University of Manchester		

45) Flooding Risk Analysis Pluvial Flooding Risk

Project title	Flooding Risk Analysis Pluvial Flooding Risks			
Project Engineer	Doug Dodds			
Description of project	This is a joint project with National Grid Gas (Transmission) to improve the understanding of pluvial flooding (also known as "flash flooding"), by relating potential fluvial, pluvial flooding and inundation maps to the National Grid Transmission assets on the National Grid GIS system, so that it can be used for planning and risk assessment purposes.			
Expenditure for financial year	Internal £12k External £83k Total **£95k**	Expenditure in previous (IFI) financial years	**£0**	
Total project costs (collaborative + external + internal)	**£255k**	Projected 2009/10 costs for National Grid	£73k	
Technological area and/or issue addressed by project	The traditional assessment of flood risk is based on river levels (fluvial flooding) and coastal flooding. However, recent experience has shown the impact and potential impact of pluvial flooding, whereby local ground conditions and/or topography cannot handle severe rainfall over a sustained period of time. This project therefore aims to develop an improved understanding of how pluvial flooding (or "flash flooding") could affect National Grid Transmission assets. For Electricity Transmission, these include towers and substations; while, for Gas Transmission, these include metering offtakes, block valve sites, multi-junctions and compressor stations.			
Type(s) of innovation involved	e.g. Incremental Tech Transfer Significant Radical	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		10	-3	13
Expected benefits of project	National Grid's Transmission licences require operation of networks with the minimum of disruption to service. Any preventable losses of service due to flooding should be mitigated through appraisal management and reduction of the flood risk. Climate change appears to be resulting in a greater frequency of flash flood events, similar to that experienced in June/July 2007. Currently, National Grid undertake post flood surveys of all National Grid assets each time they potentially have been affected by a flooding event. It is envisaged that the solution being developed by this project will enable most assessments to be carried out remotely by cross-referencing details of at-risk components of the asset against the new data on pluvial flooding resulting from sustained heavy rainfall. This will result in significant OPEX savings in the aftermath of flash flooding events. In order to gain a clear picture of exactly what items are at risk on site surveys will be carried out to identify the site levels and the lowest points also the plant and building site levels and their 'critical heights' this will be done as part of the temporary barrier site surveys on the 1 in 100 and 1 in 200 risk sites at an approximate cost of £1500 per site (£30,000 for the twenty 1 in 100 risk sites) in order to capture this data for the 60 lesser at risk substation sites and			

	possibly other potentially at risk sites Cable Sealing Ends and tunnel entrances etc.		
Expected timescale of project	2 Years	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	-£110k
Potential for achieving expected benefits	There is a high likelihood of delivering the expected benefits.		
Project progress [to March 2009	Based on progress to the end of the year, delivery of the first round of LIDAR (Light Detection and Ranging) maps for the 1 in 100 risk sites is expected during summer 2009. Internal work is ongoing to assess National Grid Transmission assets against the Environment Agency's surface water flooding data. Engagement on flood resilience has been initiated with CIRIA (Construction Industry Research & Information Association).		
Collaborative partners	National Grid Gas (Transmission)		
R&D provider	Environment Agency, Network Mapping		

46) Flooding Risk and Severe Weather Mitigation

Programme title	Flood Risk and Severe Weather Mitigation This programme of work includes the following projects • Demountable Flood Barrier Facilitating work Phase 1 and 2 • Flood risk strategy development • Flood risk study • Weather observation network review and trial
Project Engineers	Doug Dodds, Shanti Majithia
Description of projects	Demountable Flood Barrier Facilitating work Phase 1 and 2 • To ascertain feasibility of demountable flood defence on flood risk sites including the safety issues with respect to the Geo-Design demountable barrier. • Carry out trial deployment of temporary flood barrier system • Carry out 2nd trial deployment of temporary flood barrier system on completed site • Produce flood barrier deployment plans for all of the at risk sites to facilitate and maximise the effectiveness of the temporary flood barrier and carry out works on trial sites • Develop model deployment plan to maximise the effectiveness of the temporary flood barrier • Obtain LIDAR data for 1 in 100 year flood risk sites to give a greater understanding of the flooding profile of a site also to indicate low points on site and show potential flooding routes onto site. Flood risk strategy development • Generic solutions and indicative costs to mitigate the risk of flooding should be identified. These may be permanent or temporary and appropriate for new substations or retrofitting to existing substations. It is envisaged that solutions may be site specific, or involve wider flood protection provided by the Environment Agency. • The form of the output from this work should be considered. In particular how improved mitigation measures would be delivered through industry guidance, regulation or statutory obligation. Flood risk study • Climate change is resulting in greater frequency of flood events similar to the flooding experienced in June/July 2007. In order to reduce the requirements to initiate an assessment of all sites after each of these high profile flooding events, it is envisaged that a robust strategic solution is needed that will be flexible enough that in depth site assessment will not be necessary. Weather observation network review and trial • There is a widespread and overlapping requirement for weather information. The project will examine the use of observations in transmission operations and asset management, and resilience to severe weather as it is collected. It will complement the current system and will

<table>
<tr><td></td><td colspan="4">establish whether enhanced provision of data delivers benefits in practice and will highlight relevant issues with equipment. The project will deliver high quality observation using up-to-date technology, to be accessible live data as it becomes available.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £72k
External £37k
Total £109k</td><td colspan="2">Expenditure in previous (IFI) financial years</td><td>£55k</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£488k</td><td colspan="2">Projected 2009/10 costs for National Grid</td><td>£123k</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="4">This programme of work is concerned with mitigation of the impacts of severe weather events. This is being achieved by assessing technology that will enhance National Grid's preparedness for flooding events and developing better weather observation techniques.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>8 to 15</td><td>1 to -4</td><td>12 to 18</td></tr>
<tr><td>Expected benefits of project</td><td colspan="4">The benefits of each project are as follows:

Demountable Flood Barrier Facilitating work Phase 1 and 2
• Understanding the complexities, potential limitations and risks associated with deploying the demountable flood defence through study and trials will give visibility to safety and installation problems reducing the need for learning lessons during actual incidents and the potential risks associated with this.
• Cost effective assessments can be made as to the amount of barrier required to protect a site. Through the innovative combination of flood defence systems together with permanent works, greater flexibility and cost savings will be delivered associated with removing the need to purchase extra barrier or the construction of a total flooding protection in the form of permanent works on site.

Flood risk strategy development
• Projected savings of not establishing reactionary virtual teams/secondments every 2/3 years after each event can be projected to 480 direct hours @ £120k per annum and a minimum of 600 indirect hours @ £150k.

Flood risk study
• By obtaining and retaining data electronically it will contribute to a mechanism which can be utilised regularly to reassess any changes in flooding risk mitigating the need to establish a flood assessment project after each incident.
• The application of this data will drive the implementation of preventative measures allowing savings to be made similar to the reactionary expenditure seen at Walham substation (an estimated £500k) given that costs will inevitably be incurred on high risk sites.</td></tr>
</table>

	Weather observation network review and trial • This project will clarify current use of weather data, highlight core requirements and examine options for the future. With a number of partners it will promote a common solution, which is likely to enhance the security and effectiveness of the observing network, lower costs and improve service delivery. Financial benefits derive from the reduction in costs due to more accurate data. With estimated costs incurred of greater than £1m due to flooding in the summer of 2007, better data will reduce likelihood of similar emergency preventative action, reducing costs by at least 10%. The current cost of observation data is in the range of £40k-£50k and it is expected this direct cost can be reduced by 10% per annum.		
Expected timescale of project	5 Years	Duration of benefit once achieved	10+ Years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£58k
Potential for achieving expected benefits	There is a high potential of achieving the expected benefits as two of the projects have been completed and the rest are progressing well.		
Project progress as of March 2009	Demountable Flood Barrier Facilitating work Phase 1 and 2 • A number of test sites are being assessed for suitability; we expect the detailed site surveys for all 1 in 100 year risk sites to be available by September 09 which will give us a base for costing the permanent fixing works and the deployment routes for the barrier at a test site. • There have been further controlled test deployments exercises carried out to better understand the seepage rates we can expect on different ground surfaces. • There has been engagement with Gas Transmission on developing deployment plans for their at risk sites with the possibility of a deployment exercise being carried out. Flood risk strategy development • This project has been completed and is now closed. • A strategy has been developed and implemented via inclusion in policy. Flood risk study • This project has been completed and is now closed. • A report has been submitted and the results incorporated into National Grid's flooding policy Weather observation network review and trial • Metra and Doble have worked together to install the weather observation equipment at St. Johns Wood substation. • Over the next six to nine months progress and reporting on		

	the quality of the data will be carried out. • This reporting will help decide the next stage of the development.
Collaborative partners	EoN, EdF Energy, SSE and Centrica
R&D provider	Mott MacDonald, Metra (Weather Intelligence), Doble Powertest

47) Vegetation Growth Model

Project title	Vegetation management research			
Project Engineer	Matthew Murphy			
Description of project	Research into vegetation growth rates.			
Expenditure for financial year	Internal £ 2k External £ 144k Total £ 146k	Expenditure in previous (IFI) financial years	£ 42k	
Total project costs (collaborative + external + internal)	£ 1.8m	Projected 2009/10 costs for National Grid	£ 37k	
Technological area and/or issue addressed by project	Vegetation growth rates vary across the country, dependent on a variety of climatic factors. Currently we have little research to base these growth rates on. This project aims to provide a growth model, taking these conditions into account.			
Type(s) of innovation involved	Incremental	Project Benefits Rating	Project Residual Risk	**Overall Project Score**
		8	-1	9
Expected benefits of project	The country can be split into discrete climatic zones; this means that geographical location can have a big effect on growth rate. After the first years research we expect to have a model of vegetation growth rates based on a variety of environmental factors, for many different types and age of tree. This will be refined, based upon additional data obtained over the next 4 years. The result will be a detailed growth model leading to a better understanding of the risks to our system from vegetation. A better understanding of these risks will help us to mitigate them appropriately, and will lead to reduced risk to the system in the future.			
Expected timescale of project	4 Years	Duration of benefit once achieved	10 years plus. (results will inform future decisions for many years)	
Probability of success	50%	Project NPV = (PV benefits – PV costs) x probability of success	£131k	
Potential for achieving expected benefits	This project is a collaboration between National Grid and several Distribution Network Operators. It is funded jointly by these companies. It is in everybody's interest to see a successful conclusion and the potential for achieving the expected benefits is high.			

Project progress as of March 2009	The measurements for the first year of the project have been completed and analysed. The results indicate a very strong correlation between bioclimatic zones and tree growth rates. This indicates that the project has a high potential to deliver the expected benefits. The first year of the project has been completed successfully, and has exceeded our expectations in terms of results obtained. The first measurements for 2009 have now been completed with a second measure programmed for Nov 2010.
Collaborative partners	DNOs
R&D provider	ADAS forest research.

48) Automatic Risk Based Handling of Plant Enquiries

<table>
<tr><td>Project title</td><td colspan="3">Automatic Risk-based Handling of Plant Enquiries</td></tr>
<tr><td>Project Engineer</td><td colspan="3">Phil Brewer</td></tr>
<tr><td>Description of project</td><td colspan="3">Development and trial of an automated web-based response service to advise developers of construction restrictions in the vicinity of National Grid energy transmission assets.</td></tr>
<tr><td>Expenditure for financial year</td><td>Internal £2k
External £36k
Total £38k</td><td>Expenditure in previous (IFI) financial years</td><td>£0</td></tr>
<tr><td>Total project costs (collaborative + external + internal)</td><td>£43k</td><td>Projected 2009/10 costs for National Grid</td><td>£0</td></tr>
<tr><td>Technological area and/or issue addressed by project</td><td colspan="3">This project is evaluating whether the risk of third party interference can be reduced by automatic handling of developers' enquiries relating to critical National Grid assets. Such interference can have consequences for security of energy supply, public safety and the environment, together with the associated operational costs and costs from potential prosecution and/or damages claims.

Interference damage from third party developers, causing a London black-out, is a credible and potentially costly incident. Having a system that gives instant, repeatable, reliable responses to those third parties (including utilities, contractors and local government) involved in development work in the vicinity of National Grid assets should reduce the risk of interference damage.

Third party interference causing environmental damage is also a credible possibility. Methane released from gas pipelines is 20 times more damaging than carbon dioxide. Oil releases from electrical cables can lead to the risk of prosecution, especially if not discovered by National Grid at the time of the damage.</td></tr>
<tr><td rowspan="2">Type(s) of innovation involved</td><td rowspan="2">Significant</td><td>Project Benefits Rating</td><td>Project Residual Risk</td><td>Overall Project Score</td></tr>
<tr><td>18</td><td>-1</td><td>19</td></tr>
<tr><td>Expected benefits of project</td><td colspan="3">The proposed system is designed to mitigate the risk of third party damage.

The system will provide comprehensive, accurate and timely asset information and advice based on agreed plant protection rules. Known areas of critical supply and priority/vulnerable customers can be defined in the system and monitored for high risk works. Notification emails can be triggered to plant protection engineers when enquiries are received matching criteria setup in the system, such as the examples listed above or when monitoring named users/organisations that may be causing frequent damage or near misses.</td></tr>
</table>

	National Grid Transmission Land and Development currently handle plant location enquiries from external organisations on a manual basis, utilising a team of about 7 fulltime employees. With an automated response service in place, this team could focus more time on any exceptions, for example the more difficult enquiries, as well as conducting quality assurance and identifying potential improvements to the automated response service.		
Expected timescale of project	1 year	Duration of benefit once achieved	5+ years
Probability of success	60%	Project NPV = (PV benefits – PV costs) x probability of success	£175k
Potential for achieving expected benefits			
Project progress as of March 2009	A pilot system is available for a trial evaluation following the completion of the following: • Codification of National Grid Transmission Asset Protection rules for use in the automatic response system • Development of module to generate asset locations plans for National Grid Transmission apparatus against OS background mapping, with appropriate disclaimers, legends and warnings. • Development of web-based system to allow submission of plant location enquiries, and return by email of appropriate responses (as defined in the codified Asset Protection rules), with a plan attached as appropriate.		
Collaborative partners	National Grid Gas Transmission, National Grid Gas Distribution		
R&D provider	GL Industrial Services (UK) Ltd		