UKERC

UKERC RESEARCH ATLAS: ELECTRICITY TRANSMISSION AND DISTRIBUTION

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1. Overview

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Characterisation of the field

The scope of the transmission and distribution research topic is broad. It covers the following areas:

1. Science and engineering activity focused on the development of new components as well more efficient and environmentally friendly power transmission and distribution plant.
2. System planning and operation activity
3. System control and protection
4. Information and communication technologies

For basic and applied strategic research, the range of disciplinary inputs is wide. It includes materials science, chemistry, mechanical and electrical as well as civil engineering.

Research Challenges

The assets of the UK power system experienced a period of significant and rapid expansion during the late 1950s and 1960s. They are now approaching the end of their useful life and need to be replaced. Developments in distributed generation and other technologies open important questions as to whether the traditional approaches to development and operation of power systems are still adequate and whether the anticipated major re-investment in transmission and distribution networks could be avoided by adopting new technologies. The electricity transmission and distribution infrastructure is strategically important to the UK and its economy. In a bid to improve economic efficiency, the UK electricity supply industry as whole was liberalised in 1990 introducing competition in the generation and supply segments of the industry. The transmission and distribution segments remained as regulated monopolies.

The principal research challenges include the following:

- Aging infrastructure – replacement strategies before failure ➔ models and tools for condition monitoring ➔ risk management of existing T&D infrastructure
- Impact of liberalisation of electricity market
- Energy security & system security
- Environmental sustainability – reducing the impact of electricity production, transportation and use on the environment (strive to reduce green house gases responsible for climate change) ➔ need to incorporate climate change driven constraints into system planning and operation (EU renewables targets; 80% 2050 CO_2 targets; Meeting UK carbon budgets will require large scale decarbonisation of the electricity sector by 2030 (CCC))
- Integration of distributed generation including intermittent energy technologies & micro generation ➔ what type of network architecture ➔ reliability and power quality➔ communication and control aspects of networks ➔ incorporation of demand response and demand side participation➔ role of energy storage
- Transmission and distribution network planning under uncertainty of intermittent renewable resources such as wind and the uncertainty of markets and regulatory policy
- Interaction between electricity and Gas networks ➔ Integrated network (multi energy vector) research and optimisation
- Encouraging network innovation through regulation (price control mechanisms)
- Assessing the potential of heat networks
- Understand the effects of large uptake of electric vehicles (impacts on generation/transmission and distribution)
- Incorporation of smart meters (impact on demand and networks)
- Implementation of smart grids (technical and impact assessment)
- Integration of environmental aims into regulation of system planning and operation.

2. Capabilities Assessment

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The UK capabilities in the transmission and distribution domain are extensive in the area of network operation, network stewardship, consultancy and R&D. There is a significant home-based manufacturing industry.

Internationally, the UK is also perceived to be very strong in the design of incentives to encourage the uptake of clean fuels and technologies for power generation. However, this has limited application globally and is very much supported through publicly funded research programmes.

Table 2.1 UK Capabilities

UK Capability	Area	Market potential
High	• Transmission and Distribution plant design and development (cables and lines, transformers, transmission towers and accessories etc,)	• UK: (High 0-5 years) • Global: (High 0-5 years)
	• Technical consultancy	• UK: (High 0-5 years) • Global: (High 0-5 years)
	• Transmission and Distribution network planning	• UK (High 0-5 years) • Global: (medium 5-20 years)
	• Transmission and Distribution network protection, operation and control	• UK (High 0-5 years) • Global: (medium 5-20 years)
	• Transmission and Distribution network condition monitoring	• UK (High 0-5 years) • Global: (medium 5-20 years)
	• Power electronics and HVDC	• UK: (High 0-5 years) • Global: (High 0-5 years)
	• Materials science	• UK: (High 5-20 years) • Global: (High 5-20 years)
Medium	• Plant installation and commissioning	• UK (medium 5-20 years) • Global: (medium 5-20 years)

	• Test and assessment facilities	• UK (medium 5-20 years)
	• Education and Training	• UK (medium 5-20 years)
Low	• None identified	

3. Basic and applied strategic research

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University-based transmission and distribution research falls into several different clusters ranging from materials science and component design engineering through to protection, communication and control systems, active distribution network management including regulation and commercial aspects.

Table 3.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Preventing wide-area blackouts through adaptive islanding of transmission networks	EPSRC	Recent blackouts and disturbances have shown that the twin drivers of: a) commercial pressures for better utilisation of transmission and distribution networks and b) increased penetration of Distributed Generation (DG) are likely to reduce security margins and lead to a higher probability of blackouts. This interdisciplinary project, involving power engineering, graph theory and operational research, will investigate methodologies to limit the occurrence and cost of blackouts through preventive splitting of large networks into islands when a cascade fault is imminent. The formed islands should preserve a good demand/generation balance, without violating any transmission constraint and avoiding electromechanical instability of any generator. The challenges addressed in this project include identification of conditions when preventive islanding can safely be activated, establishing techniques for forming islands and/or isolating a sick part of the network, and demonstrating innovative methods for control of islands with a high penetration of DG.	£769K	2010-2014	
Agent-based Modelling of Electricity Networks (AMEN)	EPSRC	The project seeks to make a significant and original contribution to efforts being marshalled by the UK Research Councils - following government level advice - to improve the international profile and national strategic impact of energy modelling in the UK. It will provide valuable insights - both quantitative and qualitative - into questions of key importance for policymakers and the power sector as they seek to square the circle of emissions reduction and a viable, secure energy supply by 2050. It will address in the context of the electricity network, perceived	£562K	2013-2016	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		general weaknesses in whole energy systems modelling - from the closely related standpoint of complex systems research - in the areas of end-use behaviour, technology dynamics, and energy in industry.			
Realising Transition Pathways - Whole Systems Analysis for a UK More Electric Low Carbon Energy Future	EPSRC	The project will extend the work of the Transition Pathways project, in which an innovative collaboration between engineers, social scientists and policy analysts developed and analysed a set of 'transition pathways' towards a UK low carbon electricity system. The pathways aimed to meet the UK's target of an 80% cut on 1990 levels of greenhouse gas emissions by 2050. The aim of the new project is to explore what needs to be done to achieve a transition that successfully addresses the energy policy 'trilemma', i.e. the simultaneous delivery of low carbon, secure and affordable energy services. The team will: 1. Analyse actors' choices and decisions in past, current and prospective developments in electricity supply and demand; 2. Analyse the social, behavioural and technical drivers 3. Undertake techno-economic modelling and energy and environmental assessments of the developments in electricity supply (including transmission and distribution networks) needed to meet this responsive demand.	£2,567K	2012-2016	
HubNet	EPSRC	Achieving the decarbonisation of the economy while maintaining the security and reliability of the energy supply will require a profound transformation of energy networks. The creation of a "hub" will catalyse and focus the research on energy networks in the UK. The activities of the members of the hub will focus on five areas: - Design of smart grids (communication technologies / operation of electricity networks / demand-side participation)	£4,746K	2011-2016	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		- Development of a mega-grid that would link the UK's energy network to renewable energy sources off shore, across Europe and beyond. - Research on new materials. - Development of new techniques to study the interaction between multiple energy vectors and optimally coordinate the planning and operation of energy networks under uncertainty. - Management of transition assets: study of how the life of existing equipment can be extended under what is likely to be more extreme conditions.			
Control For Energy and Sustainability	EPSRC	Control engineering is concerned with the design of control systems (controllers) that can improve the performance of all dynamic processes. Relevant examples include the reduction of carbon dioxide emissions from internal combustion engines and power plant, the reduction of pollutants generated by chemical plants, and improvements in a power system's ability to respond to random load and/or supply variations. New technologies for clean electricity generation, fuel efficient transport, and environmentally friendly waste disposal will all depend on a new generation of special-purpose control systems. Current research trends in control engineering, which address complexity and uncertainty, have a great, and as yet unrealised potential to contribute to these technologies. The aim of this research programme is to develop new control engineering techniques which can be applied to a number of energy and sustainability related problems in order to achieve significant advances in the exploitation of renewable energy and vehicle fuel efficiency.	£5,536K	2009-2014	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
UK Infrastructure Transitions Research Consortium (ITRC)	EPSRC	There is an urgent need to reduce carbon emissions from National Infrastructure (NI) systems (energy, transport, water, waste and ICT), to respond to future demographic, social and lifestyle changes and to build resilience to intensifying impacts of climate change. This process of transforming NI will need to be underpinned by a long-term, cross-sectoral approach to understanding NI performance under a range of possible futures. Using an inter-disciplinary approach the aim of UK ITRC is to develop and demonstrate new simulation models to address four major challenges: 1. How can infrastructure capacity and demand be balanced in an uncertain future? 2. What are the risks of infrastructure failure and how can we adapt NI to make it more resilient? 3. How do infrastructure systems evolve and interact with society and the economy? 4. What should the UK's strategy be for integrated provision of NI in the long term?	£4,731K	2011-2016	
Power Networks Research Academy	EPSRC	Since the early 1990s, there has been a steady reduction in the number of engineers working in this power sector. Parallel to this university-based research has also shrunk to a minimum in this area. This reduction in the pool of power engineers has inevitably had an impact on the availability of academic and research staff to: * teach electrical power engineering courses at undergraduate and taught post-graduate level. * provide power networks engineering research solutions in the UK to respond to the challenges arising from power grid renewal,	£1,084K	2008-2015	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		the impact of government low carbon policies, and to ensure future network resilience. This application for the creation of the Power Networks Research Academy (PNRA) will provide a future supply of academic/research staff for the UK university sector. From the industrial side, UK transmission and distribution network operators as well as manufacturers are supporting this proposal.			
Energy Futures DTC	EPSRC	The Energy Futures Doctoral Training Centre provides depth and breadth in PhD training in energy and its role in climate change mitigation. It will integrate with other energy DTCs recently awarded by EPSRC, but will not offer the full 12 month training programme associated with other fully funded DTCs. Our DTC will focus on future energy generation and distribution, aimed in particular on the role of the energy sector in achieving the UK's ambitious mitigation goals required to meet the challenge of climate change. It will accept 10 of the very best science and engineering graduates annually, funded by a strategic investment from Imperial College, and supported by industry.	£444K	2010-2015	
Transformation of the Top and Tail of Energy Networks	EPSRC	There are two very particular places in energy networks where existing network technology and infrastructure needs radical change to move us to a low carbon economy. At the Top of network, i.e. the very highest transmission voltages, the expected emergence of transcontinental energy exchange in Europe that is driven by exploitation of diversity in renewable sources and diversity in load requires radical innovation in technologies. The Tail of the network is the so-called last mile and behind the meter wiring into customer premises. More than half the capital cost of an electricity system is sunk in the last mile and cost and disruption barriers have made it resistant to change. The challenge is to reengineer the way in which the last mile assets are used without changing the most expensive part: the cables and pipes in the ground.	£4,132K	2011-2015	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Advanced Communication and Control for the Prevention of Blackouts (ACCEPT)	EPSRC	ACCEPT seeks to bring together a joint UK-India consortium with the skills necessary to address the potential for using Smart Grid technologies to support novel integrated protection and control tools for the prevention of blackouts. These tools would help prevent society from incurring the huge costs and discomfort associated with blackouts and increase confidence in the power system's ability to satisfy the long term needs of society and industry, as the level of uncertainty and risk in the power system increases.	£980K	2014-2016	
The Autonomic Power System	EPSRC	In the move to a decarbonised energy network the heat and transport sectors will be fully integrated into the electricity system. Therefore, the grand challenge in energy networks is to deliver the fundamental changes in the electrical power system that will support this transition, without being constrained by the current infrastructure, operational rules, market structure, regulations, and design guidelines. The drivers that will shape the 2050 electricity network are numerous: increasing energy prices; increased variability in the availability of generation; reduced system inertia; increased utilisation due to growth of loads such as electric vehicles and heat pumps; electric vehicles as randomly roving loads and energy storage; increased levels of distributed generation; more diverse range of energy sources contributing to electricity generation; and increased customer participation. These changes mean that the energy networks of the future will be far more difficult to manage and design than those of today.	£3,429K	2011-2016	
DESIMAX: Multiscale Modelling to maximise Demand Side Management (Part 2)	EPSRC	Modern energy systems are complex technical, social and economic endeavours formed through the assembly of a broad set of elements and shaped by the actions of many multiple actors including consumers, suppliers and regulators. While some gains can be achieved by optimising parts of these systems, significant reduction in energy demand is a major challenge requiring changes in behaviour from all the actors involved. In this proposal we wish to exploit the ability of digital technologies to monitor, model and represent the operation and effects of energy demand to promote changes in these systems. This is often realised	£613K	2010-2014	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		through a set of actions and measures, commonly known as demand side management (DSM). This proposal adopts an end-to-end approach to exploit digital technology to understand the overall energy supply system (from generation to transmission, distribution and utilisation).			
Resilient Electricity Networks for Great Britain (RESNET)	EPSRC	The resilience of GB's electricity energy network is being challenged on three fronts: (i) policies aimed at reducing greenhouse gas emissions through decarbonising energy supply will alter substantially the existing supply mix; (ii) decarbonising of the 'energy' system will likely involve considerable shift of previously non-electric energy demand onto the electricity network with accompanying changes in how much electricity is needed and when it is needed; and (iii) the expected mean changes in climate will alter the electricity demand and performance of electricity infrastructure, and increased severity and frequency of extreme weather events will impact on the electrical network and distribution systems.	£978K	2011-2015	
Adaptation and Resilience In Energy Systems (ARIES)	EPSRC	The energy supply sector is undergoing massive technological changes to reduce its greenhouse gas emissions. At the same time, the climate is progressively changing creating new challenges for energy generation, networks and demand. The Adaptation and Resilience in Energy Systems (ARIES) project aims to understand how climate change will affect the UK gas and electricity systems and in particular its 'resilience'. A resilient energy system is one that can ensure secure balance between energy supply and demand despite internal and external developments such as climate change. The physical changes in climate up to 2050 coincide with the energy sector moving towards a low-carbon future, with massive renewables targets, new smart grid infrastructure and more active demand management. ARIES will develop new methods to model the impacts of climate changes on current and new energy generation technologies and understand its effect on gas and electricity demand.	£772K	2011-2015	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Integrated Operation and Planning for Smart Electric Distribution Networks (OPEN)	EPSRC	This consortium brings together leading researchers from the UK and China to jointly investigate the integrated operation and planning for smart distribution networks to address two key research challenges: -Conventional network operational and planning approaches do not address the emerging opportunities offered by increased measurement and control. -A general understanding of how national or regional electricity distribution infrastructure should be developed and operated using Smart Grid interventions is required. New techniques and approaches will be investigated to address these important questions: -Distribution state estimation and probabilistic predictive control approaches will be used to determine the location and control policies of smart grid interventions. -Novel dynamic pricing techniques will be proposed to resolve conflicts between energy markets and network operation. -A very fast network assessment tool and a rolling planning tool that will bridge the gap between planning and operation will be developed. -New visualisation and reporting techniques will be developed.	£1002K	2013-2016	
Enhanced Renewable Integration through Flexible Transmission Options (ERIFT)	EPSRC	China is installing wind farms faster than any other nation and the UK is leading deployment of offshore wind-farms. Both nations will face challenges in connecting renewable sources in remote areas over (electrically) long cable or overhead DC routes. This proposal identifies areas of common technical challenge and lays out a joint programme to analyse the issues and assess possible solutions. Fully exploiting the potential transfer capacity is vital; in China	£880K	2013-2016	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		this is from hydro resources to cities and in the UK from Scottish/North-Sea wind resource to southern load centres. We will investigate coordinated control of AC, DC and FACTS elements to optimise transfer capacity and will develop tools to support operator decision-making including risk analysis. Two specific aspects will be investigated: the ability to provide frequency response services across a DC link without explicit communication of frequency data and the headroom required in power converters to accommodate this service.			
Energy Storage for Low Carbon Grids	EPSRC	It is expected that 35 to 40% of the UK electricity demand will be met by renewable generation by 2020, an order of magnitude increase from the present levels. In the context of the targets proposed by the UK Climate Change Committee it is expected that the electricity sector would be almost entirely decarbonised by 2030 with significantly increased levels of electricity production and demand driven by the incorporation of heat and transport sectors into the electricity system. The key concerns are associated with system integration costs driven by radical changes on both the supply and the demand side of the UK low-carbon system. Our analysis to date suggests that a low-carbon electricity future would lead to a massive reduction in the utilisation of conventional electricity generation, transmission and distribution assets. The large-scale deployment of energy storage could mitigate this reduction in utilisation, producing significant savings.	£5,621K	2012-2017	
Grid Economics, Planning and Business Models for Smart Electric Mobility	EPSRC	The project will provide strategic insights regarding the integration of the transport sector into future low carbon electricity grids, and is inspired by limitations in current grid investment, operation and control practices as well as regulation and market operation, which may prevent an economically and environmentally effective transition to electric mobility. Although various individual aspects of the operation of electricity systems within an integrated transport sector have received some research attention, integrated planning of the grid, EV charging infrastructure and ICT (information and communication technologies) infrastructure design have not been addressed yet. In this project we propose to tackle these challenges in an integrated manner.	£1,006K	2013-2016	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		At the heart of this project is a whole systems approach. It recognises the need to consider: EV demand and flexibility, electricity network operation and design, charging infrastructure operation and investment, ICT requirements and business models for electric mobility.			
Whole Systems Energy Modelling Consortium (WholeSEM)	EPSRC	Energy models provide essential quantitative insights into the 21st Century challenges of decarbonisation, energy security and cost-effectiveness. Models provide the integrating language that assists energy policy makers to make improved decisions under conditions of pervasive uncertainty. Whole systems energy modelling also has a central role in helping industrial and wider stakeholders assess future energy technologies and infrastructures, and the potential role of societal and behavioural change.	£4,608K	2013-2017	
Reconfigurable Distribution Networks	EPSRC	The "SmartGrid" is a concept that has emerged from its initial discussion in engineering circles into the wider public arena because its importance has been recognised for securing future electricity supply and facilitating the de-carbonisation of electricity. Much of the SmartGrid debate has so far focused customers with "smart homes" or "smart appliances". Behind the scenes, there is a parallel debate about how new control methods for existing electricity plant and equipment may enable electricity networks to offer the flexibility needed to incorporate low-carbon energy sources. The "reconfigurable distribution network" presents a great opportunity in both the Indian and UK context. It also presents research challenges on a number of fronts: innovation in power electronic equipment to reduce power losses and increase lifetime; the need to design new control algorithms to exploit the new flexible equipment to the benefit of consumers and network operators.	£1,224K	2014-2017	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Interface and Network Infrastructure to Support EV Participation in Smart Grids	EPSRC	This project will investigate new technologies that can support high levels of electric vehicle (EV) charging and deliver the benefits that flexible charging can bring for electricity supply and the integration of renewable generation. Electric Vehicles (EVs) are a central part of transport and energy policy for many nations. They represent a key pathway for reducing petroleum dependence and promoting transportation sustainability (provided the electricity generation mix has been successfully decarbonised). If EVs displace most petroleum vehicles then they will represent a very significant new and additional demand to be serviced via electricity networks. EVs also present opportunities for power network operation; their charging also represents a very large discretionary load that can be managed to provide Smart Grid services and assist the integration of clean energy.	£941K	2013-2016	
High Energy And Power Density (HEAPD) Solutions to Large Energy Deficits	EPSRC	Many countries around the world face an uncertain future over the next few decades as they move to greater electricity use and at the same time look to more intermittent low-carbon generation. India, which suffered numerous serious blackouts recently is already operating near the limits of its generation and network capacity and so provides an ideal case study for testing innovative solutions that can make power networks more resilient. The research outputs from this project will provide foresights into the development of low-carbon smart grids in India and the UK. This consortium of Indian and UK experts in Energy Networks will take the timely step of investigating how DC networks, can increase the efficiency of renewable energy-storage systems deployed at a community level to benefit the resilience of the National Grid..	£1,006K	2014-2016	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Development and Evaluation of Sustainable Technologies for Flexible Operation of Conventional Power Plants.	EPSRC	The increasing amounts of renewable energy present on the national grid reduce C02 emissions caused by electrical power but they fit into an electrical grid designed for fossil fuels. Fossil fuels can be turned on and off at will and so are very good at matching variations in load. Renewable energy in the form of wind turbines is more variable and there is a need for existing power plants to operate much more flexibly to accommodate the changing power output from wind, tidal and solar power. The research covers a wide range of activities from detailed analysis of power station parts to determine how they will respond to large changes in load all the way up to modelling of the UK electrical network on a national level which informs us as to the load changes which conventional power plants will need to supply.	£1,944K	2013-2018	
Integrated, Market-fit and Affordable Grid-scale Energy Storage (IMAGES)	EPSRC	It is accepted that UK energy networks face a number of unprecedented challenges in the upcoming decades. These challenges include the threat to the security of energy supply due to declining indigenous fossil fuel reserves, increased reliance on imported fossil fuel (it is predicted that gas import will be over 80% in 2020), and planned retirement of ageing generation capacity over the next decade (approximately 20GW or 25% of the existing generation capacity); decarbonising electricity generation to achieve the goal of 80% reduction in CO2 emissions by 2050; and coping with the future increases in electricity demand from electrification of transportation and space heating. To address these great challenges, it is recognized that the UK energy networks, must change, strategically and the existing regulatory arrangements should be examined to check if they are fit for the purpose of future energy network operations.	£3,019K	2012-2017	
DC Networks with DC/DC Converters for Integration of Large Renewable Sources	EPSRC	This project studies various aspects of integration of large renewable power parks with DC networks which include DC/DC converters. UK and China alike have enormous wind power potential which theoretically can exceed total national energy demand. Much of this energy is located offshore or in remote sites like North	£735K	2013-2016	

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
		Scotland and North West China which have no electrical grid or have very weak grid infrastructure. These factors together with wind energy intermittency cause integration challenges, demand new approaches in developing transmission/collection grids. The main aims of this project are: 1. To study integration technologies and control strategies of large scale renewable power parks with DC networks incorporating DC/DC converters, 2. To study key technologies required for DC grids 3. To investigate meshed and hybrid DC grid topologies 4. To develop new wind generator topologies, converters and controls suitable for connecting to DC grids			

Table 3.2: Key Research Providers

Name	Description	Sub-topics covered	Number of Staff	Field
Centre for Sustainable Power Distribution, University of Bath	The Centre for Sustainable Power Distribution is researching into all aspects of power generation, transmission and distribution. It has internationally recognised expertise in power system planning, operation and management, security and stability analysis of large system, control and protection of power system, distributed generation, power system economic and market operation, FACTS, condition monitoring and protection of power plant. The centre has major contracts with a wide range of utility and	• Power System planning operation & Management • Control and Protection of Power Systems • Modelling and Simulation of Extended Electrical Power Networks • Sustainable and Renewable Energy Generation and Integration	10 Academics 25 Researchers and PhD students 2 visiting Fellows	Engineering & Technology

	manufacturing partners and welcomes many visiting Fellows from overseas institutions and companies.			
Institute for Energy research and policy, University of Birmingham	The Institute for Energy Research and Policy is a multi-disciplinary centre researching many different aspects of energy, including engines, hydrogen, nuclear power and energy efficiency. This entry reports only IERP work on power systems.	Power system research; • Application of power electronics such as FACTS (Flexible AC Transmission System) & HVDC in transmission and distribution systems; • Modelling & Control of Power Systems • Power system economics • Integration of renewable generation into electrical power systems • Technologies for smart grids • Energy Efficient Systems.	3 Faculty 6 Researchers 15 PhD students	Engineering & Technology Social Science
Brunel Institute of Power Systems, Brunel University, West London	Brunel Institute of Power Systems (BIPS) in the school of Engineering and Design at Brunel University conducts research in the development of advanced computational software and hardware tools for the analysis, control, operation, management and design of the electricity generation, transmission and distribution systems.	• Algorithms for Network congestion • Condition Monitoring of Power system equipment. • Transmission network steady state and dynamic analysis • Analysis of new energy markets	5 Academic staff 5 researchers, 4 PhD students 2 EngD 2 Visiting scholars Prof. A. Ekwue (PB Power, UK) Prof. M. Bradley (National Grid, UK)	Engineering & Technology
Electricity policy research group, Cambridge University Faculty of Economics	Participates in two main initiatives: Supergen and the 'Towards a Sustainable Energy Economy programme.	• Delivering Secure, Reliable and Diverse Energy in a Liberalised Market • Energy and Emissions in European and Global Contexts • Public Attitudes and Processes of Governance	10 Researchers 40 Associate researchers 18 PhD students	Social Science
The Institute of Energy, Cardiff University	The Institute of Energy has expertise in energy supply, conventional and renewable generation systems, electricity transmission and	• Grid Integration • Smart Grids • Infrastructure Assessment & Modelling	19 Academics 21 Researchers 67 PhD students	Engineering & Technology Social Science

	distribution, as well as the demand-side and efficient utilisation of energy. Interdisciplinary research with Cardiff University school of Psychology.	• Alternative transport • Low Carbon heat & power • Complex fluid & thermal systems • Environmental management & risk • Earthing & probabilistic risk assessment • Transient overvoltages • Insulation systems • Thermoelectric materials • Power magnetics	3 Honorary & visiting staff	
Energy Research Group, School of Engineering and Computing Sciences (ECS), Durham University	Large-scale wind turbines including the application of indirect and direct-drive technology, condition monitoring and reliability, particularly offshore. Embedded generation at the distribution level, including micro-combined heat and power, solar heating and micro-wind, Generator topologies and power electronics for embedded generation. Electrical network research to accommodate the rise of embedded generation The integration and control of new and renewable energy sources into distribution networks.	• Electricity markets • Grid integration of renewable energy • Power system dynamics and stability • Security of supply • Smart grids • Sustainable energy systems	6 Academics 13 Researchers	Engineering & Technology
Institute for Energy Systems, University of Edinburgh	Interdisciplinary research at IES covers the whole supply chain of energy starting from energy and climate change, design of renewable energy converters (mostly marine), design of generators and interfaces for renewables, through to power system control and power system economics.	• Grid integration of renewable energy • Power system control • Power system dynamics • Power system economics	12 Academic staff, 29 research staff 41 postgraduate students 9 Visiting Academics	Engineering & Technology

Department of Geography, University of Exeter	As part of the UKERC Infrastructure and Supply theme, researching the policy and regulation of energy networks in the UK	• Sustainable energy issues • Policies & mechanisms for transition to a low Carbon economy	5 Academic 12 Associates 6 PhD Students	Social Sciences
Department of Electrical and Electronic Engineering, Imperial College London	The Control and Power Group in the Department of Electrical and Electronic Engineering at Imperial College conducts research in several areas of system and control theory, a range of control systems applications, and the analysis and design of power systems and power converters.	• Design & control of power converters to act as interfaces for new and renewable energy • Use of power electronics for power quality & flow improvements in networks. • Application of robust multivariable control to the stabilisation of large power systems & development of active control in distribution systems.	13 Academic staff 35 Researchers 54 Students	Engineering & Technology
The Electrical Energy & Power Systems Group, the University of Manchester	The Electrical Energy and Power Systems (EEPS) group is at the forefront of research and teaching in the field of electric power engineering in the UK and internationally. Our people are in constant contact with industry and at the vanguard of the research trends in electric power engineering.	• Investigating the challenges of integrating renewable and distributed energy sources into the electricity grid. • Power system security and power quality. • Performance enhancement of network equipment plant and asset management. • Power system protection, communication and control. • Sustainable rural electrification for developing countries	11 Academic staff 5 Researchers 62 PhD students	Engineering & Technology
Electrical Power Engineering Group, Southampton University	The Tony Davies High Voltage Laboratory at Southampton is primarily concerned with transmission and distribution engineering with special interest in cables and transformers.	• Condition monitoring of plant, environmental /operational modelling (e.g. rating methods for cables) • High temperature superconducting power apparatus • Liquid dielectrics • Solid dielectrics	7 Academic staff 97 Researchers, 22 Postgraduate students	Engineering & Technology

		• Fundamental studies into space and surface charge.		
Institute for Energy and Environment University of Strathclyde	The Institute evolved from the Centre for Electrical Power Engineering (CEPE), undertakes basic, strategic and applied research in electrical power engineering	• High Voltage Technology and Dielectric Materials Group • Power Systems Analysis Group • Intelligent Systems and Protection Group • Machines and Power Electronics Group • Centre for Economic Renewable Power Delivery	30 Academic staff 56 Researchers 123 PhD students	Engineering & Technology
The Centre for Environmental strategy, University of Surrey	The research at the Centre for Environmental Strategy (CES) applies techno-economic analysis and social science methods, applied to issues in policy and corporate decision-making for resource management and climate change. CES are working to provide evidence-based advice to policy-makers who are seeking to understand and to influence the behaviours and practices of 'energy consumers'. The social, science understandings are being used in research to design, pilot and evaluate the performance of digital network technologies and sensor devices, to improve energy management.	There are currently 9 relevant research projects, funded by the UK Research Councils and the EU. • Opportunities for load management (to support greater integration of intermittent generation and improve network efficiency) are the focus of several projects. • Local energy conversion as part of sustainable urban development. • Modelling energy supply technology choices & related policies against sustainability criteria, seeking smarter integration with other infrastructures.	4 Academic staff 9 Researchers 6 PhD students	Social Science
Sussex Energy Group, SPRU, University of Sussex	A research group supported under the research councils' Towards a Sustainable Energy Economy Programme addressing Paths to Transition. Only partly engaged on transmission and distribution issues.	• How to appraise the options for technology and policy around transitions. • How transitions occur, how technology can be 'shaped', and how technological regimes can be managed.	12 Researchers	Social Science

		• How to govern the complex and uncertain transition processes.		

4. Applied research

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A number of organisations provide applied transmission and distribution network research services in the UK. The key players are concerned with integration of distributed generation into power systems and development of new power system architecture.

Table 4.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Electricity Networks Strategy Group (ENSG)	DECC/OFGEM	The ENSG is jointly chaired by the Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (OFGEM) and its broad aim is to identify, and co-ordinate work to help address key strategic issues that affect the electricity networks in the transition to a low-carbon future.	-	2008 -	
DECC/OFGEM Smart Grid Forum	DECC/OFGEM	The Smart Grid Forum's scope is broad – looking at the services and functionalities that networks will be required to offer as we move towards a low carbon energy sector. It will therefore consider the network companies' challenges and opportunities relating to distributed generation, the electrification of heating and transport and of course the implications of smart metering on demand side management and active network management. It will address commercial and cultural as well as technical changes and the barriers the network companies face in making these changes.	-	2011 -	
Low Carbon Networks Fund (LCNF)	OFGEM	As part of the new price control arrangements that run from 1 April 2010 to 31 March 2015, OFGEM has set up a Low Carbon Networks (LCN) Fund. The Fund allows up to £500m support to projects sponsored by the distribution network operators (DNOs) to try	£500,000 K	2010-2015	

		out new technology, operating and commercial arrangements. The objective of the projects is to help all DNOs understand what they need to do to provide security of supply at value for money as Great Britain (GB) moves to a low carbon economy.			
Centre for Sustainable Electricity and Distributed Generation (SEDG)	DECC	The Centre for Sustainable Electricity and Distributed Generation (SEDG), a collaborative venture building on extensive on-going research at the Universities of Cardiff, Strathclyde & Imperial college London, was established in order to bridge the gap between academic research and the needs of industry to meet the 2020 targets on renewable energy for the UK.	-	2010 -	
Technology Strategy Board	BIS	The Technology Strategy Board (TSB) is the UK's national innovation agency. Our goal is to accelerate economic growth by stimulating and supporting business-led innovation. The TSB understand business, and our people come mainly from business. We work right across government, business and the research community - removing the barriers to innovation, bringing organisations together to focus on opportunities, and investing in the development of new technology-based products and services for future markets	-	2011 – 2015	
Energy Technologies Institute (ETI)	UK government (BIS, DECC, Department of Transport) and private companies (E.ON, Shell,	The ETI is an innovative and unique Limited Liability Partnership between international industrial companies (with a strong focus on energy) and the UK government. The ETI bridges the gulf between laboratory proven technologies and full scale commercially tested systems. The objective is to take the	-	2007-2017	

	BP, Rolls-Royce, EDF and Caterpillar)	most challenging large-scale energy projects to full system demonstration, so de-risking their future development.			

Table 4.2: Key Research Providers

Name	Description	Sub-topics covered	No of staff	Sector
NaREC	A company providing testing facilities, consultancy and R&D in the new and renewable energy field.	- Marine, PV, Wind turbine blades, Generation, Transmission & distribution equipment	55	R&D science and engineering
EA Technology	Provider of Consultancy, Technical Services, Products and Training for Power Asset Management underpinned by research and development for electricity companies in the UK and internationally	- Plant & Equipment – lifetime, performance, innovative solutions, fault location - Failure Analysis & Materials - Network Issues - Distributed Generation – Demand side measures & energy efficiency - Risk Management at strategic, system and equipment level - Condition Monitoring & innovative instrumentation - Dissemination of R&D results	100	Consulting engineers
Senergy Econnect	Specialists in the grid integration of renewables	- For R&D: load management, active network management, innovation in regulation, generator control, network	56 of which 5 currently in R&D	Consulting engineers

		control		
DNV-GL	The DNV-GL company now incorporates KEMA and is a provider of services to the energy value chain, including business & technical consultancy, operational support, measurements & inspection, and testing & certification.	- Independent electric power equipment testing services. - Technical, management and regulatory strategy and planning. - Engineering feasibility studies (offshore Wind, interconnector, storage). - Process and performance optimisation, implementation and evaluation.	30 (UK)	Consulting engineers

5. Development and Demonstration Funding

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Development and demonstration activities are stimulated by initiatives from OFGEM, the gas and electricity markets regulator. These are the Innovation Financial Incentives (IFIs) and the innovation and demonstration features of the recently launched RIIO framework (Revenue = Incentives + Innovation + Outputs). The schemes are intended to address the lack of innovative activity in the gas and electricity transmission and distribution sector. Both schemes allow T&D companies to recover the cost of innovative activity from their customers, up to a certain level.

Table 5.1 Development and Demonstration Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Innovation financial incentives (IFIs)	Distribution companies, allowed by OFGEM.	Funding for the technical development of any aspect of distribution system asset management. (Note : In April 2013, OFGEM replaced the Innovation Funding Incentive (IFI) with the Network Innovation Allowance (NIA) for operators of the gas and electricity transmission networks and gas distribution networks – see below). The total IFI spend of all the Distribution Network Operators (DNOs): In 2010/11 was £12.3 m. Companies have established a website to share learning from projects: Details of IFI projects are available on the ENA's Smarter Networks' Portal.	Up to 0.5% of a company's annual turnover	2005 - 2015	
Network Innovation Competitions (NIC): As part of RIIO	Transmission and Distribution companies (gas and electricity) allowed by	The NICs are annual competitions for electricity and gas, where network companies compete for funding for research, development and trialling for new technology, operating and commercial arrangements. Funding will be provided for the best innovation	For electricity network projects: £27 million annually (£3 million set aside for successful	2013-2021	

	OFGEM	projects which help all network operators understand what they need to do to provide environmental benefits and security of supply at value for money as Great Britain (GB) moves to a low carbon economy.	delivery of projects awarded each year)		
Network Innovation Allowance (NIA): as part of RIIO	Transmission and Distribution companies (gas and electricity) allowed by OFGEM	The NIA is an allowance each RIIO network licensee receives to fund smaller scale innovative projects which have the potential to deliver network benefits to customers.	0.5 -1% of a company's annual (allowed) turnover	2013-2021	
Innovation Roll-out Mechanism: As part of RIIO	Transmission and Distribution companies (gas and electricity) allowed by OFGEM	An Innovation Roll-out Mechanism (IRM) – to fund the roll-out of proven innovations which will contribute to the development in Great Britain (GB) of a low carbon energy sector or broader environmental benefits.	-	2013-2021	

6. Research Facilities and Other Assets

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There has been an increase in R&D/testing/certification facilities for electricity transmission and distribution plant in the UK over the past few years. Three main facilities (Manchester, NaREC & Strathclyde) have been extended to include significant research facilities in Bath, Cardiff, Imperial College & Southampton Universities, as detailed below.

Table 6.1: Research Facilities and Assets

Name	Description	Type of asset	Number of supporting staff	Annual Operating Budget
Centre for Sustainable Power Distribution, University of Bath	Real Time Digital Simulator (RTDS)	Major item of equipment	7 Academics 3 Researchers 13 PhD students 2 visiting Fellows	
The Institute of Energy, Cardiff University	Real Time Digital Simulator (RTDS) High Voltage laboratory	Laboratory. Major item of equipment.	5 Academics 3 Researchers 6 PhD students	
Department of Electrical and Electronic Engineering, Imperial College London Control & Power research group	A range of control systems applications, and the analysis and design of power systems and power converters.	Laboratory. Major item of equipment.	20 Academics 88 Researchers (Associates & Students)	
The Electrical Energy & Power systems group, the University of Manchester	High voltage laboratory	Laboratory. Major item of equipment.	200 Academics 100 Researchers 300 PhD students	
NaREC National Renewable Energy Centre limited	Marine test facilities PV Technology centre – R&D and niche manufacturing	Laboratory. Test facility.	>100 staff	
Electrical Power Engineering Group, Southampton University	Transmission and distribution engineering with special interest in cables and transformers.	Laboratory.	7 Academic staff 9 Researchers, 24 Postgraduate students	
Institute for Energy and Environment University of Strathclyde	Protection & distributed generation laboratories (Sustainable Electricity & Distributed Generation - SEDG) Real Time Digital Simulator (RTDS)	Laboratory. Major item of equipment.	30 academic staff 19 Visiting staff 130 research staff and students	

7. Networks

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There are three significant consortium networks in the area of electricity transmission and distribution.

Table 7.1 Networks

Network	Date Established	Description	Membership Profile	Activities
AURA-NMS	2006	The aim of the project is to develop a distributed control system to deliver: • Real-time automated reconfiguration (regional network) • Economically, efficiently & effectively integrate large amounts of small scale distributed generation taking into account legacy infrastructure & renewal programmes. • Network optimisation (considering DG & electrical energy storage)	• This is a Strategic Partnership between; • DF Energy Networks, • ABB, • EPSRC • SP Power systems. • Imperial College London • Cardiff University • University of Bath • University of Durham • University of Edinburgh • University of Loughborough • University of Manchester • University of Strathclyde.	Research into Network Control, Communications, Power System Economics, Distribution Automation, Control Applications and Network Analysis.
Hubnet	2011	The creation of a "hub" will catalyse and focus the research on energy networks in the UK: • A programme of fundamental research • A pool of research student places	University of Bristol • Cardiff University • Imperial College London • University of Manchester • University of Nottingham • University of Southampton • University of Strathclyde	HubNet is a diverse multi-pronged programme aimed at driving forward ground breaking research which will highlight the route by which energy networks will develop over the coming years and decades as the

		• An ambition to help define the key research questions • A programme of events to help form a stronger research community.	• University of Warwick	vision of a low carbon energy system and economy becomes a reality.
Sustainable Electricity & Distributed Generation (SEDG) Centre	2006	The Centre undertakes research projects to bridge the gap between academic research & the needs of industry to work towards meeting the 2020 renewable energy targets. The Centre investigates transmission and active distribution networks & the devices and systems that are connected to them. Development & evaluation of new concepts & solutions are also undertaken.	• University of Strathclyde • Cardiff University • Imperial College London	Fundamental research aimed at achieving cost effective integration of renewable generation and Distributed Generation (DG) into operation and development of the UK electricity system.

8. UK Participation in EU Framework Programmes

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The participation of UK universities and industry in EU funded transmission and distribution research activities is summarised in Table 8.1 below. The universities of Manchester, Cardiff, Imperial College London and Strathclyde are all active, as is a large manufacturer (Areva T&D) and generation/network companies (RWE NPower, E.ON (UK), EDF Energy Networks).

Table 8.1: EU Framework Programmes

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
GARPUR: Generally Accepted Reliability Principle with Uncertainty modelling and through probabilistic Risk assessment	Power system reliability management means to take decisions under increasing uncertainty. It aims to maintain power system performance at a desired level, while minimizing the socio-economic costs of keeping the power system at that performance level. GARPUR designs, develops, and assesses system reliability criteria and management while maximizing social welfare as they are implemented over the next decades at a pan-European level. The new management methodologies	FP7-ENERGY - 2013.7.2.1	Collaborative project (generic)	University of Strathclyde	Sintef Energi AS 19 Partners	€10864 k	€7767 k	2013-09-01 - 2017-08-31 (48 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	encompass multiple business activities that, in turn, ensure coherent decision-making at the respective time horizons. These methodologies also involve mathematical and computational models to predict the location, duration and amount of power supply interruptions.								
ELECTRA**:** European Liaison on Electricity Committed Towards long-term Research Activities for Smart Grids.	The ELECTRA Integrated Research Programme on Smart Grids (ELECTRA) brings together the partners of the EERA Joint Programme on Smart Grids (JP SG) to reinforce and accelerate Europe's medium to long term research cooperation in this area. Together, the JP SG and ELECTRA will establish significant coherence across national research efforts. The whole-sale deployment of	FP7-ENERGY-ENERGY.2013.10.1.8	CPCSA	University of Strathclyde	Ricerca Sul Sistema Energetico - RSE SPA 20 Partners	€13126k	€9990k	2013-12-01 - 2017-11-30 (48 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	RES connected to the network at all voltage levels will require radically new approaches for real time control that can accommodate the coordinated operation of millions of devices, of various technologies, at many different scales and voltage levels, dispersed across EU grid.								
INSPIRE-GRID: Improved and eNhanced Stakeholders Participation In Reinforcement of Electricity Grid	The basic assumption of the project is that the difficult public acceptance of Electric Power System (EPS) infrastructures are due to several reasons: i) the lack of trustworthiness in the relationship between Transmission System Operators (TSOs) and the stakeholders and general public; ii) the difficulty in comparing the new EPS infrastructures benefits, which are on a global, with the	FP7-ENERGY-ENERGY.2013.7.2.4	Collaborative project (generic)	National Grid Electricity Transmission PLC	Ricerca Sul Sistema Energetico - RSE SPA 9 Partners	€3496 k	€2572 k	2013-10-01 - 2016-9-30 (36 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	impacts, which are mostly "local". The overarching goal of this project is to develop a methodology to manage the consultation in order to engage the stakeholders in the decision making process and to improve support of development of future grid infrastructure.								
DIGESPO: Distributed CHP generation from Small Size Concentrated Solar Power	The DiGeSPo project concept is the development of a modular 1-3 kWe, 3-9 kWth micro Combined Heat and Power (m-CHP) system based on innovative Concentrated Solar Power (CSP) and Stirling engine technology. This CSP m-CHP will provide electrical power, heating and cooling for single and multiple domestic	FP7-ENERGY ENERGY.2009.2.5.1 Key components for Concentrated Solar Power	Collaborative project (generic)	Sustainable Engine Systems Ltd	Fondazione Bruno Kessler 6 Partners	€4540 k	€3280 k	2010-01-01 - 2012-12-31 (36 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	dwellings and other small commercial, industrial and public buildings.								
ESTORAGE: Solution for cost-effective integration of renewable intermittent generation by demonstrating the feasibility of flexible large-scale energy storage with innovative market and grid control approach.	The objective of eStorage is to develop cost-effective solutions for the widespread deployment of flexible, reliable, GWh-scale storage across EU, and to enhance grid management systems to allow the integration of large share of renewable. The key issue we plan to address is the need for power regulation during low demand periods, when only inflexible baseload generation and intermittent renewable generation are operating. In contrast to conventional generation, a storage plant able to regulate its consumption could help to avoid	FP7-ENERGY ENERGY.2011.7.3-2	Collaborative project (generic)	Imperial College of Science, Technology and Medicine	Alstom Hydro France 6 Partners	€22119 k	€1275 6 k	2012-10-01 - 2017-09-30 (60 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	curtailing wind.								
CLUSTERDESIGN: A Toolbox for Offshore Wind Farm Cluster Design	In the future, the best-performing wind farms will be designed with an integrated approach. This means they must integrate wind farm clusters and grid connection design with new intelligent mechanisms for wind turbine, farm and cluster control in the design phase. The objective of the project is to develop toolbox for such an integrated offshore wind farm clusters design. This will be achieved by combination of the following different design optimisation tools elements as advanced wake models, turbine load models, grid interconnection models and by incorporating the operation of the offshore clusters as a	FP7-ENERGY-ENERGY.2011.2.3-2 Development of design tools for Offshore Wind farm clusters	Collaborative project (generic)	Imperial College of Science, Technology and Medicine	3e N.V. 5 Partners	€5207 k	€3583 k	2011-12-01 - 2016-05-31 (55 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	virtual offshore power plant.								
ITESLA: Innovative Tools for Electrical System Security within Large Areas	7 Transmission System Operators (Belgium, France, Greece, Norway, Portugal, Spain and United Kingdom) and CORESO, a TSO coordination centre, together with 13 RTD performers propose a 4 year R&D project to develop and to validate an open interoperable toolbox which will bring support, by 2015, to future operations of the pan-European electricity transmission network, thus favouring increased coordination/harmonisation of operating procedures among network operators. The resulting tools meets 3 goals: i) to provide a risk based security	FP7-ENERGY-ENERGY.2011.7.2-1 Innovative tools for the future coordinated and stable operation of the pan-European electricity transmission system	Collaborative project (generic)	Imperial College of Science, Technology and Medicine National Grid Electricity Transmission PLC	Rte Edf Transport SA 20 Partners	€19381 k	€1322 9 k	2012-01-01 - 2015-12-31 (48 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	assessment accounting for uncertainties. ii) to construct more realistic states of any system iii) to assess system security using time domain simulations								
EERA-DTOC: EERA Design Tools for Offshore Wind Farm Cluster	The European Energy Research Alliance (EERA) together with some high-impact industry partners addresses the call proposing an integrated and validated design tool combining the state-of-the-art wake, yield and electrical models available in the consortium, as a plug-in architecture with possibility for third party models. The concept of the EERA-DTOC project is to combine expertise in a common integrated software	FP7-ENERGY-ENERGY.2011.2.3-2 Development of design tools for Offshore Wind farm clusters	Collaborative project (generic)	Renewable Energy Systems Limited University of Strathclyde The Carbon Trust	Danmarks Tekniske Universitet 21 Partners	€3998 k	€2900 k	2012-01-01 - 2015-06-30 (43 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	tool for the optimised design of offshore wind farms and wind farm clusters acting as wind power plants.								
MARINET: Marine Renewables Infrastructure Network for Emerging Energy Technologies	Offshore Renewable Conversion systems are mostly at the pre-commercial stage of development. They comprise wave energy and tidal stream converters as well as offshore wind turbines. The aim of this project is to coordinate research and development at all scales and to allow access for researchers and developers into facilities which are not available universally in Europe. The linking together of facilities at different scales together with the incorporation of test facilities for components such as power take-off systems, grid	FP7-INFRASTRUCTURES-INFRA-2010-1.1.23 Research Infrastructures for offshore renewable energy devices: ocean-, current-, wave- and wind energy	Combination of CP and CSA	National Renewable Energy Centre Limited European Marine Energy Centre Ltd University of Plymouth The University of Exeter The Queen's University of Belfast The University of Edinburgh University	University College Cork, National University of Ireland, Cork 27 Partners	€11093k	€9000k	2011-04-01 - 2015-03-31 (42 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	integration, moorings, environmental tests will ensure a focusing of activities in this area.			of Strathclyde					
SESAME: Securing the European Electricity Supply Against Malicious and accidental threats	Threats for the supply of electricity have changed dramatically throughout the last decade and include not only natural and accidental ones but threat of malicious attacks. Such attacks may affect large portions of the European grid, make repair difficult and cause huge societal impact. The complex level of interconnectivity of electricity distribution/transmission/generation compared to the supply through other energy carriers makes the development of a highly focused toolkit for its protection an	FP7-SECURITY-SEC-2010.2.3-2 Assessment framework and tools to identify vulnerabilities of energy grids and energy plants, and to protect them against cascading effects	Collaborative project (generic)	Heriot-Watt University RS Consulting Limited	Politecnico Di Torino 8 Partners	€3993 k	€2754 k	2011-05-01 - 2014-08-31 (40 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	essential task. SESAME develops a Decision Support System (DSS) for the protection of the European power system and applies it to two regional electricity grids, Austria and Romania.								
AFTER: A Framework for electrical power sysTems vulnerability identification, dEfense and Restoration	AFTER project addresses the challenges posed by the need for vulnerability evaluation and contingency planning of the energy grids and energy plants considering also the relevant ICT systems used in protection and control. Project emphasis is on cascading events that cause catastrophic outages of the electric power systems. In particular, two major objectives are	FP7-SECURITY-SEC-2010.2.3-2 Assessment framework and tools to identify vulnerabilities of energy grids and energy plants, and to protect them against cascading effects	Collaborative project (generic)	The City University	Ricerca Sul Sistema Energetico - RSE SPA 12 Partners	€5050 k	€3474 k	2011-09-01 - 2014-08-31 (36 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	addressed: The first is to develop a methodology and tool for the integrated, global vulnerability analysis and risk assessment of the interconnected Electrical Power Systems considering their interdependencies.								
E-HIGHWAY 2050: Modular Development Plan of the Pan-European Transmission System 2050	Transmission System Operators together with technology manufacturers propose a 3-year R&D project to develop and to apply a methodology for the long-term development of the Pan-European transmission network. The project aims at delivering a top-down methodology to support the planning from 2020 to 2050. First, it implements a set of future power scenarios, including	FP7-ENERGY-ENERGY.2012.7.2.1 Planning for European Electricity Highways to ensure the reliable delivery of renewable electricity and pan-European market integration	Collaborative project (generic)	Brunel University Third Generation Environmentalism Limited Põyry Management Consulting (Uk) Ltd Europacable Services Limited Collingwood Environmental Planning	Rte Reseau de Transport d'Electricite SA 27 Partners	€13046k	€8991K	2012-09-01 - 2015-12-31 (39 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	generation units, the possible use of electricity storage and demand-side management solutions. Grid architectures options and a modular development plan are then proposed, including electricity highways, on the basis of power flow calculations, network stability analysis, socio-economic and network governance considerations.			Limited					
SUSTAINABLE: Smart Distribution System OperaTion for MAximizing the INtegration of RenewABLE Generation	The SuSTAINABLE project will develop and demonstrate a new operation paradigm, leveraging information from smart meters and short-term localized predictions to manage distribution systems in a more efficient and cost-effective way, enabling a large-scale deployment of variable distributed	ENERGY.2012.7.1.1 Integration of variable distributed resources in distribution networks	Collaborative project (generic)	The University of Manchester	EDP Distribuicao Energia SA 7 Partners	€5726 k	€3871 k	2013-01-01 - 2015-12-31 (36 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	resources. A cloud based principle is used, where the distribution system operator -collects information from smart metering infrastructure and other distributed sensors; -processes the information using tools such as distribution state-estimation etc; -communicates settings to power quality mitigation devices, protection relays and actuators, distribution components and distributed flexible resources; -assesses market strategy as a provider of ancillary and balancing services.								
DISCERN: Distributed	As the patterns of power generation and	FP7-ENERGY-	Collaborative project	Scottish and	RWE Deutschland	€7914 k	€4799 k	2013-02-01 -	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
Intelligence for Cost-Effective and Reliable Distribution Network Operation	distribution are rapidly changing in Europe towards a highly dispersed and volatile system, Distribution System Operators need to completely change traditional ways of grid operations. The aim of this project to assess the optimal level of intelligence in the distribution network and to determine the replicable technological options that will allow a cost-effective and reliable enhancement of observability and controllability of future distribution networks in Europe. DISCERN will build on five demonstration projects operated by major European DSOs. The involved demonstration sites unite a variety of technological	ENERGY.2012.7.1.2 Enhancing electricity networks through use of distributed intelligence	(generic)	Southern Energy PLC	Aktiengesellschaft 10 Partners			2016-01-31 (36 months)	

Project	Objectives	Action Line	Type of Action	Uk Participants	Co-Ordinator And Partners	Total Funding	EU Funding	Duration	Annual Spend
	approaches addressing different challenges.								

9. International Initiatives

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The International Energy Agency has created a Multilateral Technology Initiative (formerly known as an Implementing Agreement) in integrating wind power into the electricity transmission and distribution systems. The UK is playing a significant role in addressing this issue.

A European Union Distributed Energy Resources laboratory is also operational.

Table 9.1: International Activities

Name	Type	Description	UK Contact Point
IEA Annex XXV Wind integration activities	IEA Implementing agreement	The ultimate objective is to provide information to facilitate the highest economically feasible wind energy penetration within electricity power systems worldwide. This task supports this goal by analysing and further developing the methodology to assess the impact of wind power on power systems. The Task has established an international forum for exchange of knowledge and experiences related to power system operation with large amounts of wind power. The challenge is to create coherence between parallel activities with Transmission System Operators and other research and development work worldwide.	Prof Goran Strbac – Imperial College London Tel: +44 (0)20 7594 6169 g.strbac@imperial.ac.uk
DER lab	International Network	The European project DERri provides "free of charge" access to 13 major European facilities in the field of Distributed Energy Resources. Laboratory access, as well as costs of travel and accommodation (according to the eligibility criteria), are funded by the European Union. The facilities and the services offered, the rules and procedures for the submission and selection of proposals are described in the DERri web site at www.der-ri.net	Prof Graham Ault University of Strathclyde Tel. +44 (0)141 548 2878 g.ault@eee.strath.ac.uk