Special Report - Session 4
DISTRIBUTED ENERGY RESOURCES AND ENERGY EFFICIENCY

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Introduction

Given the continuing pressures to reduce carbon emissions, improve energy efficiency and develop more sustainable means of producing electricity, the themes of distributed energy resources and the efficient utilisation of electricity continue to grow in importance.

The European Council Climate and Energy Package (March 2007) contains three key targets (to be achieved by 2020) which can be summarises as follows:

- to reduce emissions of greenhouse gases by at least 20%;
- to increase energy efficiency by 20%;
- to achieve a 20% contribution to our energy needs from renewable energy sources.

Electricity distribution has a key role to play in delivering solutions that can be applied to electricity networks thus achieving these objectives.

Of particular importance is identifying the best opportunities brought by new technology and information processing to help connect renewable generation more quickly and cheaper. Of course being cognisant of the need to maintain safety and ensure security of supply.

In a time of unprecedented change, distribution networks have a critical role to play in developing future global low carbon economies. The papers in Session 4 provide an invaluable insight into how we can best meet this challenge.

The 2013 papers cover a broad spectrum of topics relating to distributed generation, distributed energy resources and energy efficiency. The papers cover new techniques for power system modelling, operational control and decision support. Additionally the papers share results from trial and demonstration activities.

The papers have been organised into four blocks as follows:

Block 1 - Planning & Studies

Block 2 - Operation and Control

Block 3 - Customer side developments

Block 4 – Technology

The review and acceptance of the papers has been led by the National Committees, and the Session 4 Chairman and Rapporteurs have worked with the accepted papers to form blocks of papers in broad topic areas in the four blocks. There will always be some debate over allocating papers in this way but it is clear from the report which follows that interesting discussions relating to groups of papers have emerged from this process.

The selection of papers for oral presentation has been made on the basis of the judgement of the Chairman and Rapporteurs according to criteria of quality of results in the paper and the prospects for a high quality presentation at one of the Main Sessions. Papers reporting original outcomes of R&D (with some bias towards academic research) have been allocated to the Research and Innovation Forum (RIF) where several authors will have the opportunity to present their results (supported by their QUAD) in a dynamic discussion environment. Authors presenting papers in a poster session will benefit from organised tours where it is expected that a good level of discussion of the results presented in the papers will emerge.

The Chairman and Rapporteurs have been impressed with the quality of the papers in this session and are particularly pleased with the broad coverage of many topics relating to DER and the efficient utilisation of electrical energy.

Block 1: DG/DER Planning & Studies

Sub block 1: DG/DER Integration Problems and Solutions

Paper 0380 presents an evaluation of technical PV grid integration solutions form the 'PV GRID' project in three categories: Distribution System Operator solutions; Prosumer solutions; and Interactive solutions (that require communications and control across a wide area). The methodology to be used in the project to evaluate the different solutions is presented in terms of financial, technical and regulatory criteria.

Paper 0405 presents the results of the application of a Genetic Algorithm technique to the LV grid configuration problem to overcome voltage problems with PV integration and shows that it is possible to achieve enhanced PV integration while minimizing switching operations and providing potential for investment deferral in the long run as well.

Paper 0558 presents results of analysis of failures of PV inverter anti-islanding systems and finds that the capability and settings of the inverters, inverters connected to the same network and also the characteristics of active loads affect the integrity of the anti-islanding system.

Paper 0754 presents results of a study into the dynamics of DFIG wind farms in system with FACTS devices and that there is evidence of non-linear behaviours that need careful consideration.

Paper 0883 addresses the requirements for better planning for hydro generation integration into distribution networks with identified solutions of better information exchange, agreed generation and network development processes and implementation of technical standards of generation capabilities and control.

Paper 1148 assesses the impact of the significant growth of renewable DG in the Czech power system and identifies possible issues with reverse power flows and changes to network power factors.

Paper 1293 assesses different approaches to reactive power control for LV and MV connected DG and concludes that a cosφ/P technique provides the best results for DNO voltage control purposes. The paper highlights the important issue of reactive power management across different network voltage levels and that this has not been a major issue in the past but with the growing capacity of DG that this will need more attention in future.

Paper 1297 describes the growth in DG in the Italian distribution system and the problems this raises. New technical and regulatory rulings provide the means for the DNO to manage this situation such as inverter controls, widened frequency range of operation and interface protection. The growth in reverse power flows in HV/MV transformers is shown in Figure 1.1.

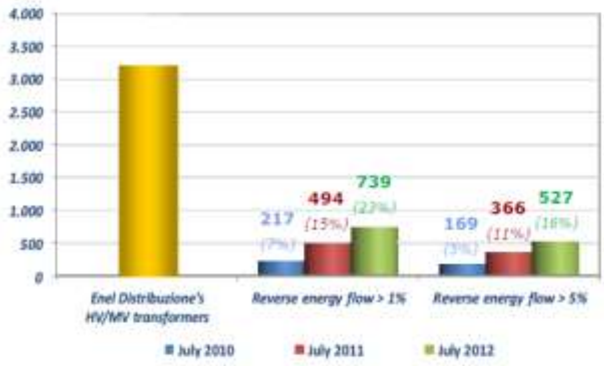

Fig. 1.1: Reverse power flow in HV/MV transformers in Italian distribution system.

Paper 1376 addresses the modelling requirements for DER integration and provides a succinct guide to the use of IEC 61850 for modelling DER.

Paper 1380 addresses the issue of the development of the smart grid as a response to DER integration issues and argues that smart design and engineering decision making is required to achieve an effective, problem focused and incremental development of the smart grid. The ideas of smart points and smart zones in networks is discussed.

Paper 1398 addresses the need for DER to be integrated into DNO enterprise systems as well as the power system and highlights the need for interoperability of systems and the work already undertaken in the power industry in recent years to provide this.

Paper 1504 assesses the effectiveness of network configuration and energy storage to increase DG hosting capacity and finds that network configuration changes can provide up to 20% additional DG hosting capacity while energy storage can enable further extension of hosting capacity but with a high cost.

Sub block 2: Hybrid Energy Systems

Paper 0068 studies a wind-photovoltaic hybrid system and addresses the issue of voltage control. The simulation model addresses wind convertor pitch control and photovoltaic (PV) maximum power point tracking (MPPT) control and the conclusions point to the potential value of the PV power electronics in managing voltage – especially in fault and transient conditions.

Paper 0233 studies a hybrid wind, photovoltaic and battery system in four alternative configurations for the supply of isolated loads and concludes from a case study in Egypt with quite a high variance of supplied unit energy cost depending on the configuration of the system.

Paper 1004 presents am optimisation approach for combined gas and electricity distribution system and DG (CHP) development and shows the economic justification for gas distribution development for an area in Iran.

Sub block 3: Energy Storage

Paper 0300 presents a case study for an electrical energy storage installation to mitigate network thermal overload under contingency conditions. The paper concludes that while there is clearly a significant benefit on maintaining circuits within thermal ratings this is not enough to justify the cost of the energy storage installation on its own.

Paper 0309 studies the value of energy storage for a Swedish utility company in terms of mitigating overloads and curtailed wind power output and in terms of network losses. It is found that the network losses reduction is not sufficient to overcome the additional losses from the storage device and that energy storage would need to work in concert with managed curtailment of renewable generation output in an effective circuit overload management scheme.

Paper 0381 presents a method for optimizing the integration of electrical thermal storage into distribution networks using the multiple objective SPEA2 technique. The results for UK case studies show the benefits to local renewable energy utilization and emissions reduction. Figure 1.2 shows the impact of managing electrical heating with thermal storage from optimizing with wind power production.

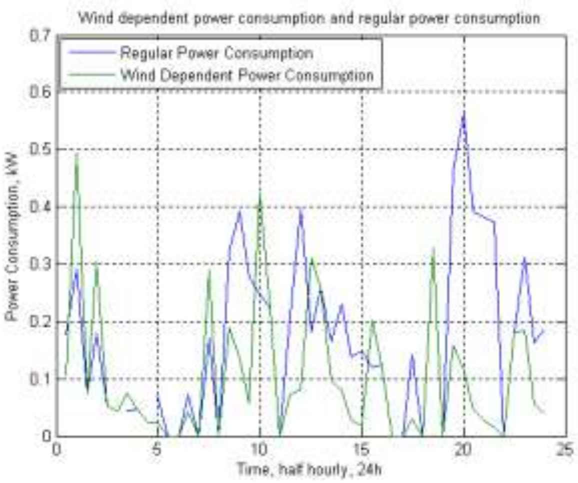

Fig. 1.2: Impact on electrical demand for heating when optimised in accordance with wind power production (paper 0381).

Paper 0510 addresses the issue of evaluating distributed energy storage integration possibilities (domestic versus community/roadside) using genetic algorithms and concludes that the multiple benefits of domestic energy storage (e.g. generation energy capture, peak shaving and loss reduction) provide the possibility of cost effective energy storage installation on this basis.

Paper 0713 presents a technique for energy storage optimal siting and sizing in parallel with consideration of new circuit options and that independently operated multi-function energy storage is preferable to DSO operated energy storage. Figure 1.3 presents the cost comparison of different options from a case study.

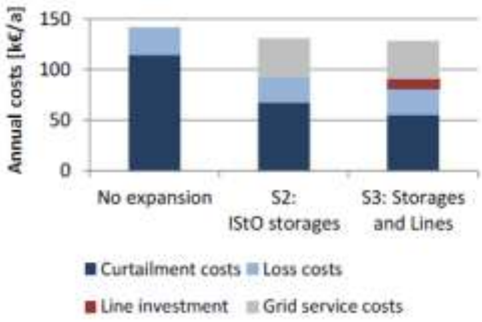

Fig. 1.3: comparison of annual costs for no expansion, independent energy storage expansion and storage/line expansion plans (paper 0713).

Paper 0792 studies the impact of load growth from low carbon demand technology in the coming decades on voltage and thermal limits in distribution networks and examines the potential of energy storage to mitigate capacity and tap changer constraints. There are important trade-offs to be considered in terms of real and reactive power support from energy storage and also in the possible reduction in tap changer operations that can be avoided through the use of energy storage.

Sub block 4: Probabilistic Planning Techniques

Paper 0575 presents a probabilistic approach to LV grid planning based on measured demand and PV production data. Results of analysis of the impact of installing Controllable Distribution Transformers (CDTs) to address high and low voltage events are presented (see example in Fig 1.4 below).

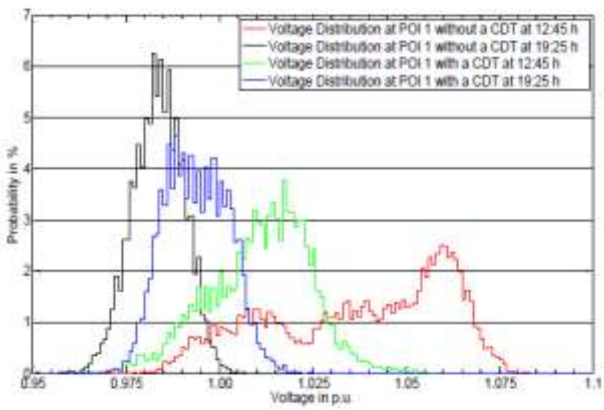

Fig. 1.4: Impact of Controllable Distribution Transformer on voltage probability in LV network (paper 0575).

Paper 0614 compares different methods of estimating generation curtailment under network constraint management schemes. The paper provides guidelines and recommendation on suitable techniques for generation constraint analysis based on available data, network complexity and accuracy of estimate required.

Sub block 5: DC Supply Systems

Paper 0700 picks up the topic of DC supply and utilization at the household level and calculates a >900kWh annual efficiency benefit as well as proposing that the AC-DC conversion could be simply implemented within smart meters and as part of the smart meter roll-outs planned in many countries.

Paper 1053 describes a modified backward-forward sweep algorithm for solving the power flow analysis problem for hybrid AC and DC distribution systems by introducing power conversion algorithms into the established approach.

Sub block 6: DG Network Support

Paper 0732 presents a Genetic Algorithm based approach to the consideration of DG and network reconfiguration to support critical system conditions.

Paper 0849 addresses the need to allocate general distribution reliability improvement to specific DG units when it is possible that DG units can supply power islands after fault reconfiguration. The overall Energy Not Supplied improvement is allocated to each DG unit on the basis of distribution functions.

Paper 1130 looks at the possibility of DG providing reactive power regulation support in LV networks and the results on power losses and voltage regulation for a case study are presented leading to the conclusion that Q injection can lead to lower power losses while not producing significant additional voltage problems because of the predominantly resistive nature of LV networks.

Sub block 7: Asymmetry and Harmonics

Paper 0795 addresses the issue of asymmetry in LV networks with small scale DG operation and highlights the large existing asymmetry in some networks and that even symmetric output three-phase connected LV DG can aggravate the problems of asymmetry such as voltage levels and losses. Figure 1.5 illustrates the extent of asymmetric substation loading in a monitored LV network in Croatia.

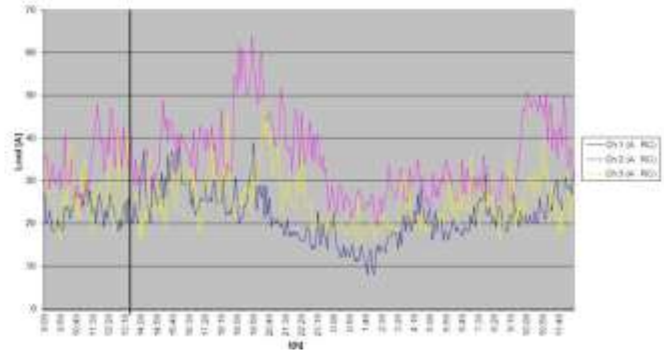

Fig. 1.5: Asymmetric substation loading (paper 0795).

Paper 1020 addresses the issue of power flow approaches for unbalanced networks with DG and proposes various approaches to model unbalance and DG implemented in a radial power flow technique implemented in MATLAB.

Paper 0881 presents a power electronics interface architecture for DER and shows the benefits for power quality in a microgrid through active filtering functionality.

Sub block 8: Protection and Dynamics

Paper 0813 addresses some protection issues with DG integration.

Paper 0859 assesses the contribution of DG units of different technologies to transient performance of test networks and clearly shows the benefit of fault ride through capability of DG units.

Paper 1429 addresses low voltage ride through of hydro generation DG units and the impact of voltage phase angle. The study finds that the voltage angle during fault is important to the ability of the generation to ride through and that this should be considered along with voltage magnitude to give a more accurate test of fault ride through capability. The type and settings of the generator AVR are also shown to be crucial to fault ride through capability.

Sub block 9: Loss Calculation and Minimisation

Paper 0825 addresses the loss minimization objective through a field measurement and simulation programme and proposes several approaches to reducing technical and non-technical losses. Figure 1.6 shows the impact of power factor correction on losses in the studied network in Iran.

Feeder No.	Power Loss (Wh)		Loss Reduction by Improving PF to 0.9
	Existing PF	Improved PF to 0.9	
1	635.32	544.18	14.34%
2	40.45	16.76	58.56%
3	46.15	36.94	19.95 %
4	112.95	108.22	4.18%
5	285.95	242.59	14.93%
6	15.39	8	48%
7	50.71	47.14	7.04%

Fig. 1.6: Simulated impact of power factor on loss minimization in study network (paper 0825).

Paper 0845 addresses the requirement to calculate losses through a fuzzy clustering technique with optimisation and application to a real case study to calculate load factor and loss factor.

Paper 1186 proposes a novel losses correction function to take account of unbalance and short duration peaks based on high resolution measurement data. This allows the DNO to address more accurately the reasons behind higher losses and take investment or operational actions to address losses. Figure 1.7 shows the losses correction factor which effectively raises the losses calculation at higher load periods and reduced the losses calculation at lower load periods.

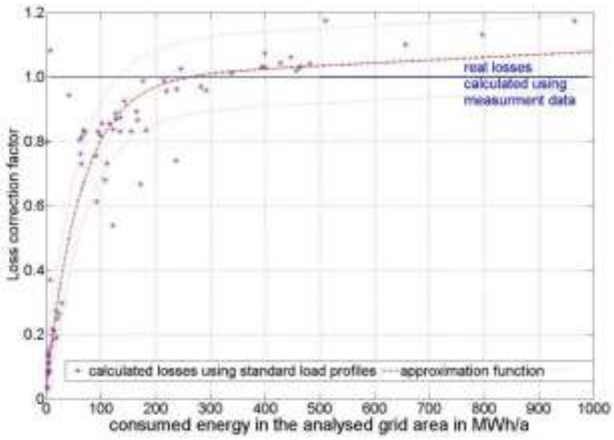

Fig. 1.7: Loss calculation correction factor (paper 1186).

Paper 1478 presents the results of analysis of losses for a large scale aggregated distribution area (northern Germany) with high penetration of PV and wind power. The main outcomes of the analysis point to the need for agreed standard approaches for measuring, simulating and reporting losses across different network voltage levels and including the significant effects of DG. Figure 1.8 shows the results for MV system losses with varying DG penetration.

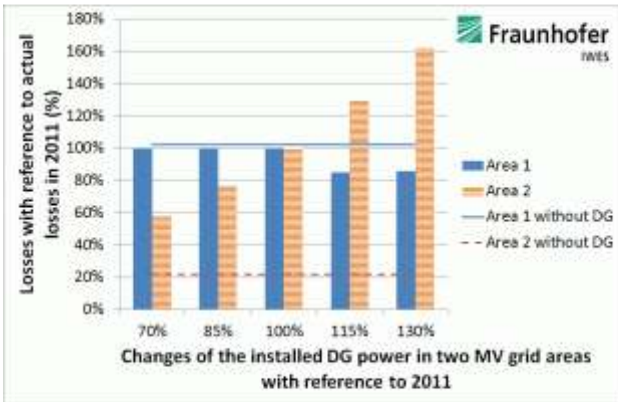

Fig. 1.8: MV system losses variation with DG penetration (paper 1478).

Sub block 10: Demand Response

Paper 0826 presents a stochastic mixed integer optimization for day ahead demand scheduling in a price varying market and shows that prosumers can create value in terms of cost savings through flexibility in demand.

Paper 1024 presents the results of hardware in the loop testing of an agent based approach to managing responsive demand and initiating response to grid frequency events. The tests show that it is possible to marshal demand to provide effective frequency response. Figure 1.9 shows the experimental set up.

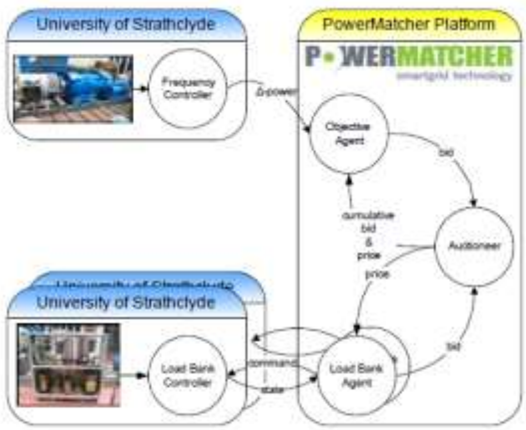

Fig. 1.9: Demand frequency response laboratory test setup (paper 1024).

Paper 1181 addresses the need to take a holistic view of the potential benefit of smart grid implementation and presents results from a wide ranging study in Sweden and draws conclusions that there are significant benefits particularly to end consumers from responsive demand capability. Figure 1.10 shows the cost reduction achieved through different penetrations of responsive demand.

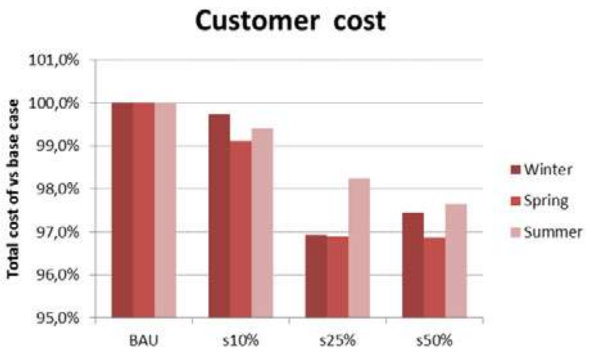

Fig. 1.10: cost savings for different demand response penetrations in Sweden (paper 1181).

Paper 1402 presents results of studies of the potential customer economic benefits of demand response in a spot price market with NordPool as the case study. The paper concludes that there is insufficient benefit for responsive wet appliances but more significant gains to be made in responsive heat demands. Figure 1.11 shows the approach take in the study.

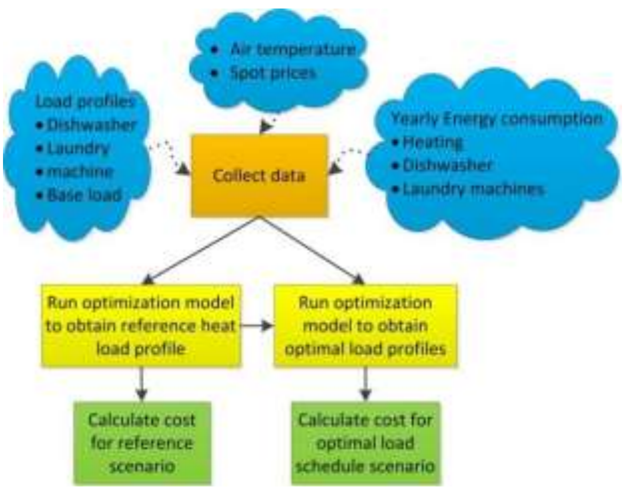

Fig. 1.12: Methodology for evaluation of demand response schemes in spot price based market (paper 1402).

Paper 1452 presents a two objective (customer energy cost and customer satisfaction) approach to demand response in a dynamic pricing environment and while managing network constraints. Figure 1.13 shows the effect of responsive demand on aggregate power demand for the case study.

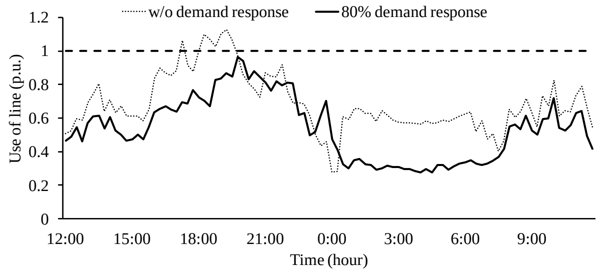

Fig. 1.13: Aggregate response of price responsive customers in shifting demand (paper 1452).

Sub block 11: Active Network Management

Paper 0237 presents results of assessments of the impacts of different commercial arrangements defining network access for DG. The outcomes for generation in a UK case study as the access arrangement is moved away from 'Last In First Out (LIFO)' are significant and are affected by network location of generation, congestion locations and the operation of other generators.

Paper 1073 addresses the question of business models for DSOs that would encourage EV adoption and argues that a DSO centred model would provide the best approach to installing and operating the EV charging infrastructure and grid integration in a timely manner to support EV uptake. Figure 1.14 shows the service concept and the roll in of the infrastructure costs to the DSO.

Fig. 1.14: DSO EV integration service model rolls in the Infrastructure costs (paper 1073).

Paper 1327 presents the results of the application of the Dynamic Optimal Power Flow technique to evaluating the operation of Active Network Management (ANM) schemes. The results show that the technique is able to address the inter-temporal constraints of energy storage and maximise the capture of renewable generation output in constrained networks. Figure 1.15 shows the minimised curtailment of renewable generation after optimal scheduling of energy storage while subject to network constraints. The issue of forecasting is highlighted.

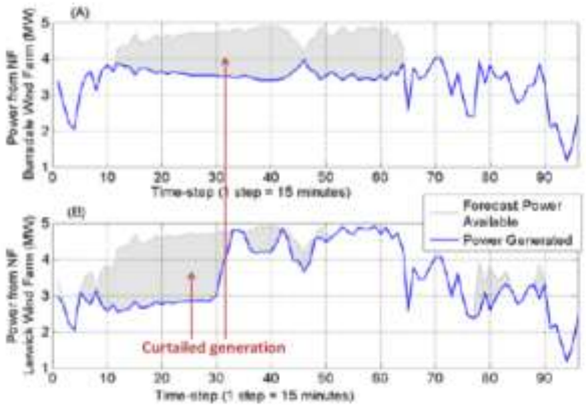

Fig. 1.15: Generation curtailment for two generation locations in case study network after optimal scheduling of energy storage (paper 1327).

Paper 1381 provides details of the power system modelling being undertaken to support the development of active network management (ANM) on Shetland in the UK. The multiple network constraints on this electrically islanded system are discussed and assessed. Figure 1.16 shows the constraints and the concept of the stable region for renewable generation operation.

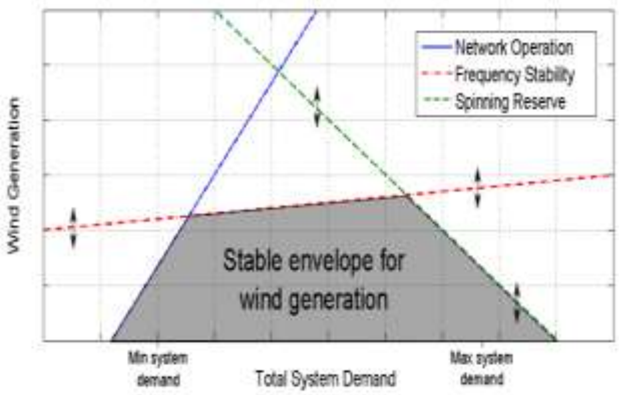

Fig. 1.16: Stable envelope for wind generation operation on Shetland (UK) power system (paper 1381).

Paper 1412 presents results of pseudo real time demonstration of time-dependent receding-horizon OPF technique for the scheduling of network control actions in an active network management scheme with the conclusion that optimising over a fixed time horizon provides a longer term view of required controls and avoids shorter term actions with lesser value.

Sub block 12: Carbon Tracing

Paper 1093 describes the extension of current tracing methods to carbon tracing in distribution networks to final demand. This provides potential for both carbon accounting and public engagement in the carbon content of final supply.

Figure 1.17 illustrates the carbon intensity in supplies, circuits and demand points for a simple example network.

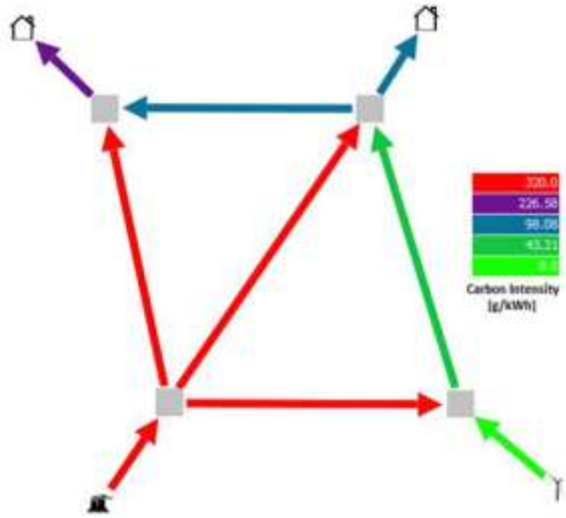

Fig. 1.17: carbon intensity example (g/kWh) (paper 1093).

Sub block 13: DG Monitoring

Paper 1295 reports on the DG monitoring system specification developed in the ENERsip project and some initial testing undertaken. Data acquisition and integration tests have been successfully completed and this paves the way for monitoring of small scale DG to be integrated into a smart grid monitoring and control architecture.

Potential scope of discussion

- Convergence of evidence on effective DER/DG integration solutions.
- Growth in evidence for the value of the role that energy storage can play but accompanying serious difficulties over the cost effectiveness of the technology.
- Roles for probabilistic planning techniques in distribution networks.
- Future for DC supply systems (either behind the customer meter or in the public supply system).
- Requirements for capturing DG network support potential.
- Need for approved methods of calculating losses across voltage levels and with DER/DG impact.
- DNO role in enabling and harnessing the value from Demand Response.
- Future role out of Active Network Management as a tool for DER/DG integration and DNO efficiency.
- Possible DNO uses for Carbon Tracing tools.

Table 1: Papers of Block 1 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0068: The effect of reactive power compensation on voltage profile of hybrid PV-Wind Grid connected power generation system				X
0233: Optimizing Alternative Backup Power Supplies With Wind Generator To Supply Isolated Loads				X
0237: An assessment of 'Principles of Access' for wind generation curtailment in Active Network Management schemes				
0300: Using electrical energy storage to support customers under faulted network conditions				X
0315: Technical dimensioning of an energy storage for a Swedish distribution company	X			
0380: Technical solutions supporting the large scale integration of photovoltaic systems in the future distribution grids				X
0381: The multi-objective optimisation of electrical thermal storage to compensate for the intermittency and variability of renewable generation in distribution networks				X
0405: Reconfiguring distribution grids for more integration of distributed generation				X
0510: Energy Storage/Demand Side Response in LV Networks: Design of Cost Based Planning Tools for Network Operators	X			
0558: Failure analysis of inverter based anti-islanding systems in photovoltaic islanding events				X
0575 Probabilistic Simulation for LV-Grid Optimization with new Network Components			X	
0614 Constraint analysis techniques for active networks				X
0700: Feasibility study of integrating AC to DC in Smart Meter for low voltage DC distribution systems				X
0713: Optimized deployment of storage systems for integration of distributed generation in smart grids				X
0732: Reconfiguration and distributed generation (DG) placement considering critical system condition				
0745: Nonlinear modal analysis of wind farm in stressed wind farms in stressed power systems: effects of DFIG controllers				
0792: Coordinated operation of energy storage and on-load tap changer on a UK 11kV distribution network				X
0795: The issue of asymmetry in low voltage network with distributed generation				X
0813: Simulation of protection functions for connecting distributed generation resources to distribution networks considering vector group of interface transformer				
0825: Distribution loss minimization: a case study in a commercial section in Mashhad				
0826: Demand side operational flexibility - a holistic stochastic optimization model for flexible consumers and prosumers			X	
0845: A new approach for calculating load and loss factor base on consumer data with fuzzy modelling				
0849: Reliability improvement assignment to distributed generation in distribution network				
0881: Seamless control of distributed multi-converter system with high power quality				X
0883: Overall challenges and recommendations concerning the integration of small scale hydro in MV distribution networks				X
1004: Allocating Gas-fired DGs Considering Natural Gas System Constraints				
1020: Impact of distributed generation on unbalanced distribution networks				
1024: Fast demand response in support of the active distribution network				X
1053: Load Flow Calculations in AC/DC Distribution Network Including Weakly Mesh, Distributed Generation and Energy Storage Units				
1073: DSO business model for speeding up EVs mass market	X			
1093: Tracing the carbon intensity of active power flows in distribution networks	X			
1130: Advantages and drawbacks of distributed generators reactive power regulation in the low voltage network				X
1148: Renewable sources and operation of distribution network				X
1181: Smart grid - the business case potential				X
1186: Loss calculation and optimisation in low-voltage networks				X
1293: Reactive power concepts in the future distribution networks				X
1295: Monitoring system for the local distributed generation infrastructures of the smart grid				X
1297: The impact of distributed generation on the Italian distribution network: upgrading of regulatory and technical rules in order to guarantee and improve reliability and efficiency of the electrical system				X
1327: Using Dynamic Optimal Power Flow to inform the design and operation of Active Network Management schemes	X			
1376: Integration of Distributed Energy Resources in Smart Grids				X
1380: The concept of gradual implementation of smart grid through the distributed generation integration				X
1381: Modelling and delivery of an active network management scheme for the Northern Isles new energy solutions project			X	
1398: Using standards to integrate distributed energy resources with distribution management systems				X
1402: Evaluating the customers' benefits of hourly pricing based on day-ahead spot market			X	
1412: A receding-horizon OPF for active network management			X	
1429: Impact of voltage phase angle changes on low-voltage ride-through performance of small scale hydro DG units			X	
1452: Optimal management of residential energy through implementation of real time pricing and demand response				X
1478: Detailed analysis of network losses in a million customer distribution grid with high penetration of distributed generation	X			
1504: Network reconfiguration and storage systems for the hosting capacity improvement				X

Block 2: DG/DER Operation and Control

Sub block 1: Results from trial projects

Paper 0230 presents the main learning from 13 utility DER integration programmes and outlines the factors for success of consumer participation and the level of participation and actual power response that can be expected – the financial value of participation is shown to be quite low. The results from various conservation voltage reduction (CVR) trials show demand reduction of 1.2-1.7%.

Paper 0659 describes the second generation of development of the Orkney smart grid / active network management project including enhanced communications, real time thermal ratings of overhead 33kV lines, energy storage, demand management, distribution state estimation and small scale generation integration.

Paper 1286 presents results from a micro-grid islanding trial in the Thailand distribution network and reports that protection, control, balancing and resynchronizing were possible for a range of pre-island and in-island operating conditions.

Paper 1389 presents results from Norwegian smart grid trial projects with an emphasis on smart meters and the associated ICT infrastructure. The issue of risks and threats to this infrastructure are discussed along with various lessons learned from the trial and implementation activities. Figure 2.1 illustrates the smart meter and ICT architecture being trialled.

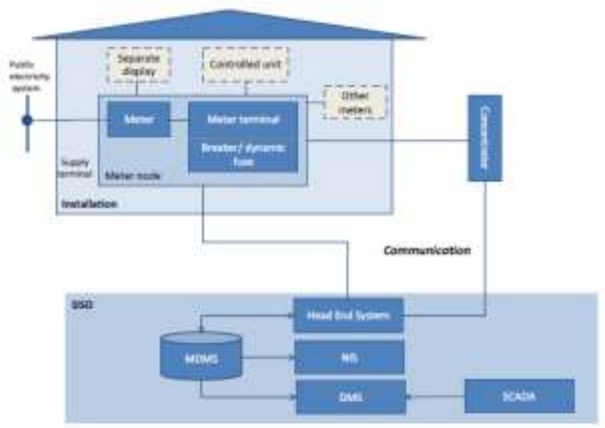

Fig. 2.1: Smart Meter and ICT infrastructure in Norwegian trials (paper 1389).

Sub block 2: Price based DER dispatch and control

Paper 0051 presents a constrained mixed integer nonlinear multi-objective optimization approach to the DG/DER dispatch problem in microgrids with the objectives of minimizing operating cost and the net emissions in the microgrid. The results of an LV network case study who the trade-offs between the objectives and the role of generation, energy storage and demand response in the microgrid.

Paper 0057 presents a relative price based self-dispatch algorithm for micro-CHP units as would be implemented in a local CHP controller. The CHP operation is heat led with thermal storage and the relative price of electricity is assessed in relation to historic market data. The benefit of reduced operation cost and the value of power production regulation is also shown.

Paper 0267 presents the results of experiments with price based control of wind, solar, heat demand and energy storage units controlled in response to the dynamic prices in the NordPool and a local power exchange price and the simplicity of the approach is illustrated. The setting of the price deadband is shown to have a flipping effect on the control of the DER units.

Sub block 3: Virtual Power Plant and Aggregation

Paper 0309 presents the results of an software agent approach to scheduling and dispatch within a commercial Virtual Power Plant (VPP) and demonstrates the strength of the approach while highlighting the key factors in successful operation of CHP units, EVs and Heat Pumps within the VPP. For example pre-emptive filling (Heat Pumps) and emptying (CHP buffers) of thermal energy stores ahead of high market price periods and charging of EVs at low price periods.

Paper 0785 presents the results of an approach to optimize the grid and market interaction of DG within a VPP framework. Figure 2.2 shows the results of a grid and market optimized curtailment of DG.

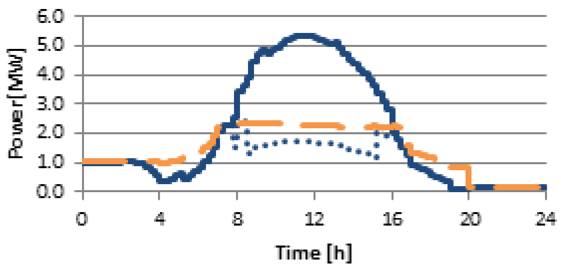

Fig. 2.2: DG grid infeed before curtailment (solid line) and optimised VPP management of DG (dashed line) in comparison to standard curtailment measures (dotted line) (paper 0785).

Paper 0901 suggests the different aggregation functions required for DER and reviews the different meta-heuristic techniques available to support the provision of aggregation in line with the conceptual architecture illustrated in Figure

2.3.

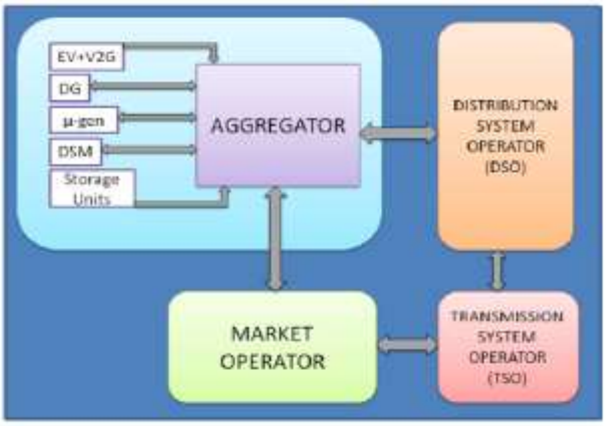

Fig. 2.3: Aggregation concept (paper 0901).

Sub block 4: Smart grid control architectures

Paper 0316 describes different aspects of the RiesLing project featuring MV voltage estimation from LV measurements, LV voltage control, communication and Grid state estimation and forecasting. Fig 2.4 illustrates the ultimate grid state forecasting objective of the project.

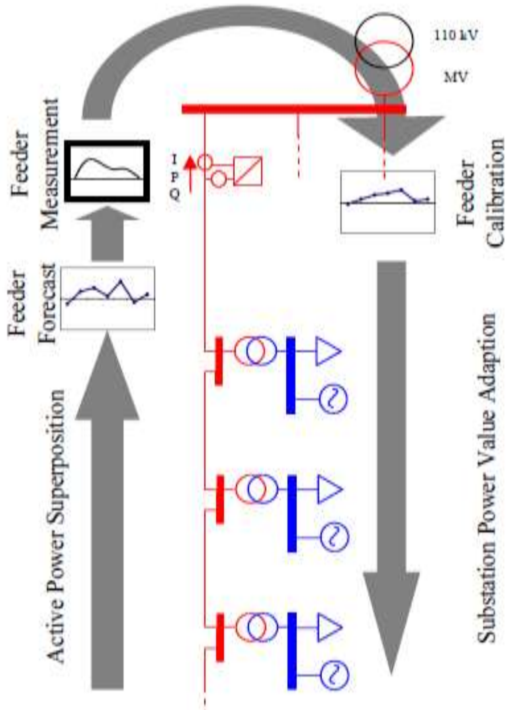

Fig. 2.4: RiesLing - Power flow forecast and calibration process (paper 0316).

Paper 0822 proposes a self-organising and location aware agent control approach and illustrates this with a demonstration of EV charging demand response to feeder voltage level.

Paper 1268 addresses the need to control EV charging while at the same time tackling PV integration issues through a proposed Low Voltage Grid Controller that estimates available power (from PV and network and for EV charging) and schedules EV charging. The high level architecture is illustrated in Figure 2.5.

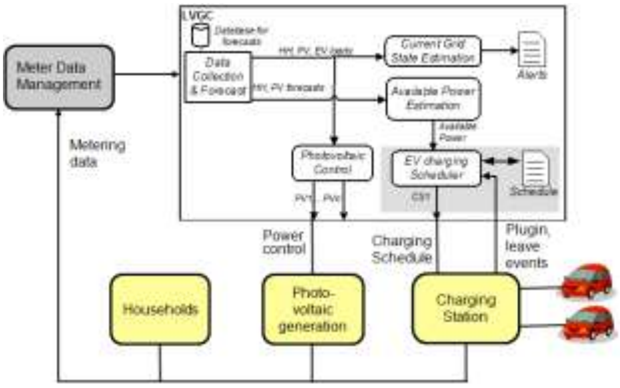

Fig. 2.5: Low Voltage Grid Controller architecture (paper 1268).

Paper 1278 proposes an approach to control DER in distribution networks to manage risks, costs and system reliability. The approach is based on aggregating DER and network assets, probabilistically assessing them and the using a multi-agent system to deliver autonomous control.

Sub block 5: Market integration of DER

Paper 0424 outlines a regional dynamic price based market proposal to aid the integration of DER and argues that this provides better market access fro DER, efficiency, investment signals, less communication infrastructure requirements and flexible response from consumers. The proposals would require a market operated by DSOs which would be a significant shift from current approaches. Figure 2.6 illustrates the regional market concept.

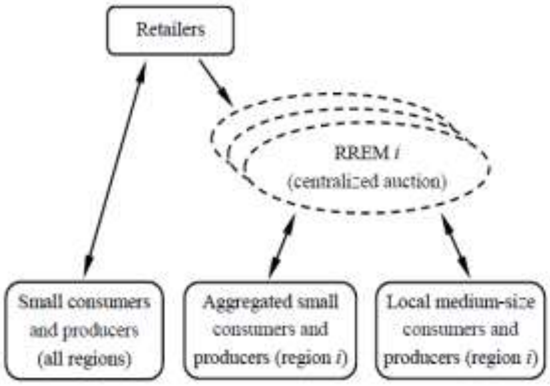

Fig. 2.6: Regional retail energy market conceptual design (paper 0424).

Paper 1126 addresses the impact of flexible demand integrated into electricity markets on overall system demand. Figure 2.7 illustrates the potential demand profile change in a future UK power system case study of various elements of flexible demand development.

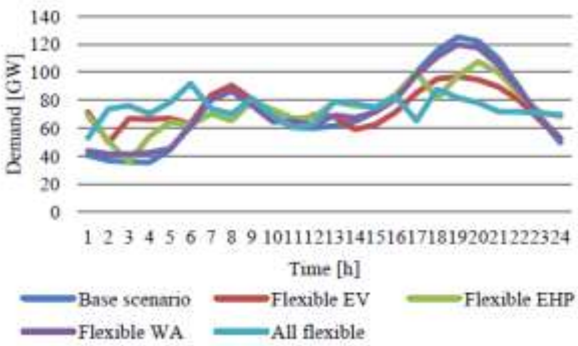

Fig. 2.7: Impact of flexible demand on UK system demand profile (paper 1126).

Sub block 6: Voltage control

Paper 0494 presents the results of field trials of different DG reactive power voltage control approaches in EDF distribution networks. The results show the impact of different scheme options such as control droops, deadbands, integrating the local control into the DG controllers and modified reference signals to avoid interaction with substation voltage control equipment. Figure 2.8 shows the Q control to avoid overvoltage problems when DG connection point voltage rises as a result of higher generation output.

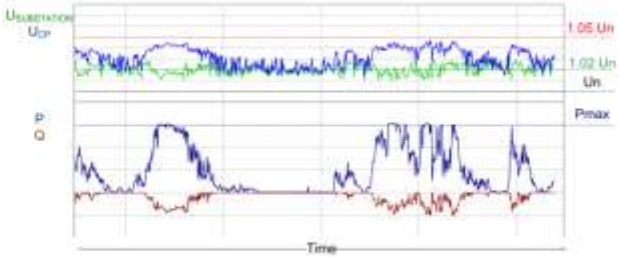

Fig. 2.8: DG voltage control (regulating Q) with droop and deadband (paper 0494).

Paper 0711 proposed a combined power flow and voltage control based on forecasting the effect of MV/LV tap changer control and if not feasible then using energy storage to resolve voltage and thermal capacity violations based on a look-up table approach.

Paper 1007 develops the concept of voltage sensitivity to active power flows and injections as the basis for a voltage control in a commercial VPP architecture. Nodes with similar voltage sensitivities are clustered together for voltage control purposes to identify required DG set points.

Paper 1396 compares different approaches to voltage control in networks with high PV penetration and also investigates the use of energy storage combined with PV to resolve curtailment, energy self-use and voltage control issues. Figure 2.9 illustrates the effect of different modes of PV and energy storage control.

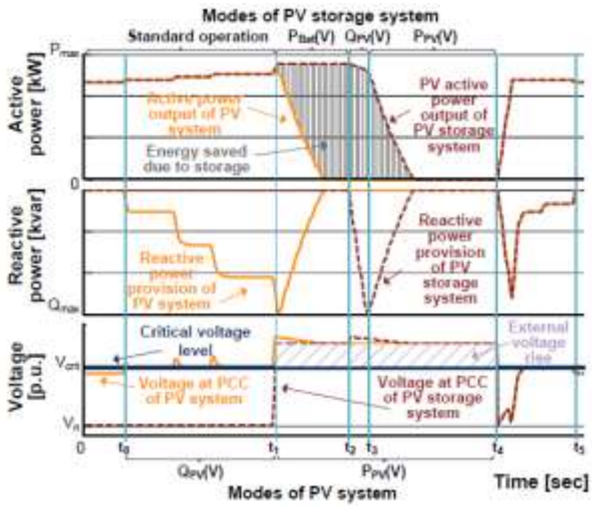

Fig. 2.9: comparison of voltage control strategies for PV and PV storage systems (paper 1396).

Paper 1460 presents the results of an OPF based Volt-VAr Optimisation approach which has receding priority for eliminating voltage violations, minimizing switching operations and minimizing active power losses.

Sub block 7: Distribution System Analysis for Network Management

Paper 0652 describes how distribution system analysis is being used to support distribution network control in three major smart grid programmes in Europe and North America. The integration of the distribution system analysis techniques is illustrated in Fig 2.10.

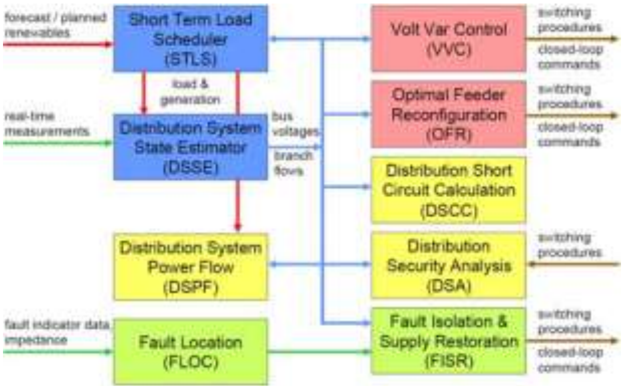

Fig. 2.10: Distribution Network analysis applications (paper 0652).

Paper 1100 describes the implementation of a Weighted Least Squares approach to distribution state estimation (DSE) based on DNO requirements and prior to trial deployment in the Orkney (UK) distribution network. The importance of error estimation is highlighted and the implications for use of DSE in active network management (ANM) are discussed.

Sub block 8: Energy Storage

Paper 1116 presents a comparison of different strategies for using energy storage to peak shave and control voltage in LV networks without the need to forecast energy demand. The performance of the different strategies is assessed using indices of peak shaving and voltage control that aggregate performance over any period of numbers of days. The results are promising for the proposed battery power optimisation control approach.

Paper 1291 assesses the multiple roles and value of energy storage in distribution systems and concludes with the summary results shown in Figure 2.11.

Application	*Economical value*	*Annual benefit*
Peak shaving for industrial loads	Savings in grid connection costs	4 %
Primary reserve control	Earnings	130,000 to 180,000 €
Increased utilization of RES	Savings in supply costs	12.5 %
Optimization of networks utilization	Avoided expansion costs	Individual case assessment
Operation of island-based networks	Savings in supply costs	35 %
(RES-) Energy trading	Additional earnings	5 %

Fig. 2.11: Value of Energy Storage in Distribution Networks (paper 1291).

Paper 1307 presents the proposed power electronics interface for a flywheel energy storage system to support system operation in variable and transient states as a result of renewable energy operation.

Paper 1320 presents results of an assessment of the potential for hydrogen based energy storage to provide essential coupling between electricity, heat and gas networks. The paper draws out the difference in application between urban and rural areas in terms of capacity of installed equipment and role of the storage. This same urban to rural difference is also highlighted in the use of PV for voltage management in LV networks.

Paper 0852 addresses the potential of energy storage and demand response to defer network capacity investments through an optimisation approach where energy storage location and capacity is optimised and where wet appliance operation can be shifted in time. The findings are that Demand Response of wet appliances provides good potential capacity investment deferral (several years) with good overall economic value. Energy storage is found to be less preferred on economic and practical grounds.

Sub block 9: Loss of Mains Protection

Paper 0460 presents a network information systems (NIS) approach to loss of mains protection risk assessment and argues that effective identification of non-detection zones (NDZ) and therefore at risk operating modes for LOM protection can be enhanced through smart meter, customer information system and network information system data.

Sub block 10: Ancillary Services from DER

Paper 1281 reports on the REserviceS project and the evaluation of ancillary services that could be provided by DER in different European regulatory jurisdictions. The possible ancillary services include real power regulation, reactive power regulation and frequency support.

Sub block 11: Hybrid energy system planning and operation

Paper 0993 presents an optimization approach to electricity and heat network development and operation and applies this to a German city area case study which seems to show that the case for district-based versus individual heat pump based systems is finely balanced in terms of lifetime costs.

Potential scope of discussion

- Broader applicability of the outcomes of the major trial and demonstration projects.
- Implications of the trials of VPPs and proposals for market integration of DER/DG.
- Convergence of thinking on smart grid and active network control architectures.
- Reasons for lack of consensus on approaches to Voltage Control across DNOs and countries.
- Roles of Power System Analysis and State Estimation in future smart grid management and control.
- Means of management and control (and supporting business models) for energy storage in distribution systems

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0051: Multi-objective dispatch of distributed generations in a grid-connected micro-grid considering demand response actions				
0057: A real time control model for micro combined heat and power system operation			X	
0230: Understanding and applying research results from over 13 case studies integrating DER from EPRI's smart grid demonstration initiative.	X			
0267: Use of local dynamic electricity prices for indirect control of DER power units			X	
0309: Real-time trade dispatch of a commercial VPP with residential customers in the PowerMatchingCity SmartGrid living lab				X
0316: The RiesLing project - Pilot project for innovative Hardware and Software Solutions for Smart Grid Requirements	X			
0424: An alternative approach for market integration of distributed energy resources				X
0460: Network information system based loss of mains risk management				X
0494: Field demonstration of local voltage regulation on ERDF MV network.	X			
0652: Next generation network analysis applications for secure and economic integration of distributed renewable generation in distribution grids				X
0659: Second Generation Active Network Management on Orkney	X			
0674: Impact of electric vehicle charging on residential distribution networks: an Irish demonstration initiative			X	
0711: Coordinated voltage and power flow control in distribution networks				X
0785: Grid and market related integration of renewable generation under consideration of virtual power plants				X
0822: Leveraging location awareness for distributed energy resources: self-organising energy communities				X
0852: Application of demand side response and energy storage to enhance the utilisation of the existing distribution network capacity			X	
0901: Optimization of aggregation procedures in a smart grid environment				X
0993: Optimization model for the energy supply in city quarters			X	
1007: Transaction areas for local voltage control in distribution networks				X
1100: Requirements-driven distribution state estimation				X
1116: Real-time control for services provided by battery energy storage systems in a residential low voltage grid with large amount of PV				X
1126: Investigation of the impact of flexible loads' participation in electricity markets				X
1268: Controlling EV charging and PV generation in a low voltage grid				X
1278: Distributed optimization-based control of electrical distribution systems with active distributed resources			X	
1281: Evaluation of ancillary services provision capabilities from distributed energy supply				X
1286: Microgrid islanding operation experience	X			
1291: Application possibilities and economical aspects of electric storage devices in distribution networks				X
1307: Voltage and frequency control in smart distribution systems in presence of DER using flywheel energy storage system				
1320: Optimal distributed hybrid storage and voltage support of photovoltaic systems			X	
1389: Experiences from Norwegian Smart Grid Pilot Projects	X			
1396: Voltage control using PV storage systems in distribution systems				X
1460: Volt/var optimization of the Korean smart distribution management system				X

Block 3: Customer side developments

This block brings together papers around the general theme of customer side developments including those in the areas of general demand response, energy efficiency, electric vehicles, load modelling and forecasting and ICT architecture. The papers in this block report on alternative concepts, analysis approaches and modelling exercises associated with demand side response including designs and field trial results.

Sub block 1: Demand response

Paper 0140 proposes a demand response scheme for effective levelling of domestic demand. In order to avoid the concentration of demand response at the same time periods, this scheme employs controlled randomisation of the response to the signals sent by the suppliers. As shown in figures 3-1 and 3-2, this scheme achieves sufficient flattening of the domestic demand.

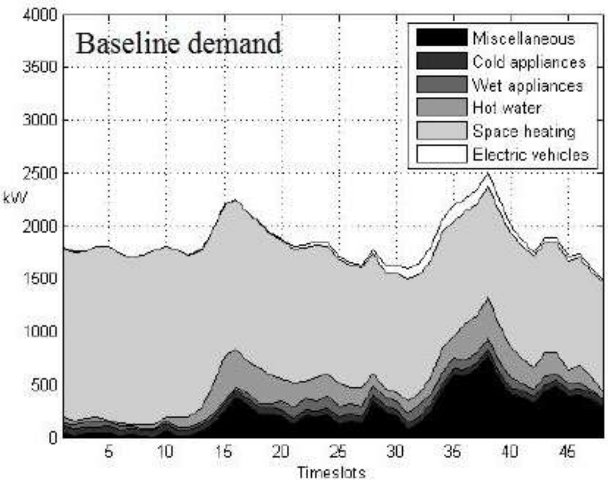

Fig. 3-1: Baseline demand profile (paper 0140).

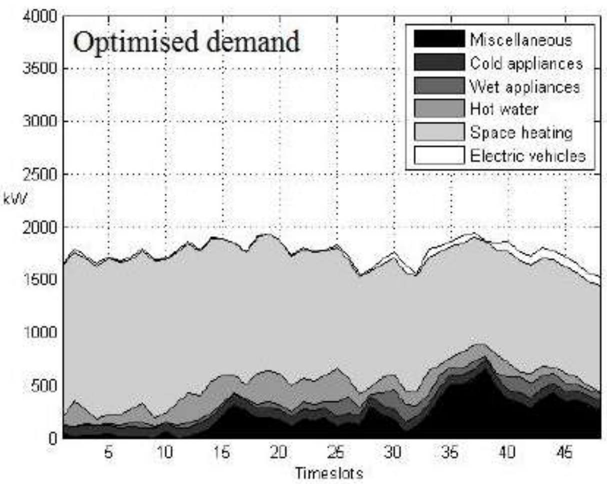

Fig. 3-2: Optimised demand profile (paper 0140).

Paper 0224 describes the application of a modified maximum rectangle algorithm to determine the optimal starting times for charging electric cars and night storage heating devices to flatten the load curve. In the presented simulations, the proposed approach exhibits a small error (<5%) with respect to the global optimum, but also much lower computational requirements.

Paper 0799 develops an optimisation model to adjust the hourly demand of a consumer in response to hourly electricity prices and the production of local renewable energy resources, with the objective of minimizing the energy cost of the consumer. Price uncertainty and uncertainties in making prediction about renewable energy production are modelled through robust optimization techniques.

Paper 0846 outlines an economic model of demand response and examines the effects of demand response on greenhouse gases emission, load factor and loss factor for different self and cross elasticities, and incentive values for load reduction. The analysis carried out shows that demand response can increase load factors of low carbon sources, such as nuclear and renewable generation, and hence contribute to reduction of emissions.

In paper 0959, the operation of a load aggregator is simulated on the Swedish island of Gotland with different wind penetration conditions, in order to test two different business models, one oriented to price following and the other oriented to wind following. The results confirm that in the present conditions the price following strategy is the one that leads to higher profits, but generates some power quality issues and also increases the network power losses.

Paper 1139 explores the results and the lessons learned from a six home trial of new domestic demand side management equipment associated with immersion and storage heaters in Shetland Islands. The results demonstrate that the controlled demand devices do not always follow the scheduled set points due to the individual energy requirements of the occupants.

Paper 0506 describes the development of a Home Energy Controller (HEC), which not only coordinates (smart) appliances in a building to exploit local optimization potentials, but also offers flexibility to the distribution network operator to maintain a efficiently functioning grid, by issuing suitable incentives and steering signals for demand response actions.

Paper 1277 addresses the problem of avoiding voltage constraints in Austrian low voltage grids by making use of the load shifting potentials in households. In the current stage of the study, the composition of different household types, the numbers of different devices in each type, and their flexibility limits have been defined.

Paper 1407 presents two demand response problems in the French islands, aiming to reduce the risk of failure during peak periods without requiring the investment in additional peaking power plants that would only be needed for relatively few hours during the year. The first involves curtailment of energy commitments for a hundred of hours per year, and the second deploys automatic-load-shedding in residential houses.

Two papers deal with dynamic demand response for frequency regulation. Paper 0435 introduces a hybrid controller for frequency response by thermostatic loads. The performance of the proposed controller is compared against other approaches proposed in the literature, with respect to the ability to provide a sufficient reduction in power consumption at short notice, the capability to delay and control the payback of energy, and the ability to avoid synchronization of the duty cycles. Advantages of the proposed hybrid controller are presented in figures 3-3 and 3-4

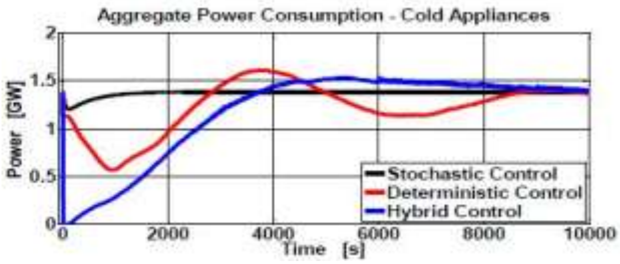

Fig. 3-3: Power consumption of dynamic demand appliances after a system disturbance (paper 0435).

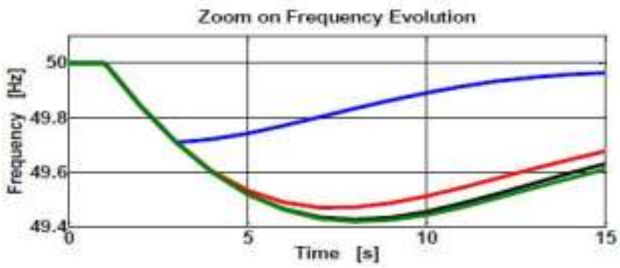

Fig. 3-4: Frequency evolution after a system disturbance (paper 0435).

Paper 0507 investigates a control algorithm for frequency response by refrigerators. In contrast with numerous control schemes in the literature, the proposed controller maintains the load diversity of a population of refrigerators, by randomising the trigger frequency of each individual refrigerator.

Sub block 2: Electric vehicles (EV)

Paper 0648 addresses the problem of minimizing the electricity cost of EV operation, accounting for both temporal and spatial dimensions. The latter is achieved by adopting a minimum cost-flow approach, where the mapping of the mobility pattern is assessed via time-variable flows between the individual network nodes.
Paper 0661 introduces a simulation model for the plug and charge, the unidirectional, and the bidirectional price controlled charging strategies and compares them with respect to profitability and technical constraints, as shown in figure 3-5. It is reported that the additional charging cycles of the bidirectional price controlled charging strategy lead to excess aging and a shortened lifetime of the battery, and that the associated costs render this strategy less profitable under current technological parameters.

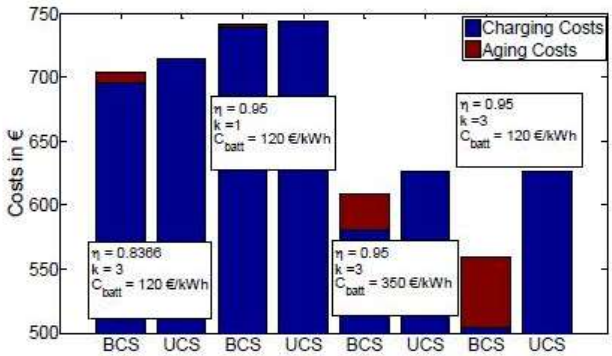

Fig. 3-5: Cost comparison between unidirectional (UCS) and bidirectional (BCS) charging strategies (paper 0661).

Sub block 3: Energy efficiency

Paper 0094 presents a decision support system for integrated management of energy efficient buildings, intending to assist building operators to meet their needs in a more efficient, less costly, and less CO2 intensive manner. This tool provides management of conflicting goals such as cost minimisation, meeting energy efficiency and CO2 emission reduction requirements, as well as risk management.
Paper 0288 outlines a deployment architecture for meeting the sustainability requirements of Stockholm City. Key features of this initiative are (a) limit the energy consumption of each residential building and (b) produce a minimum percentage of the demand requirements by renewable generation.
Paper 0576 presents a series of measures taken by a distribution network operator in Portugal to improve the energy efficiency of street lighting, including the adoption of Light Emitting Diodes and Light Flux Regulators, as well as the deployment of intelligent management systems. As illustrated in figure 3-6, these measures have effectively stopped the annual growth of street lighting energy consumption.

Fig. 3-6: Street lighting power consumption evolution between from 2005 to 2012 (paper 0576).

Paper 0812 uses a detailed bottom up model to compare the impacts of the substitution of more efficient compact fluorescent lights for traditional incandescent types and the substitution of emerging light emitting diode technology for existing halogen fittings on reducing system capacity requirements, with the respective impacts of load shifting of wet appliances. The analysis demonstrates that the substitution of lighting technology has a significant potential for peak reduction (figure 3-7).

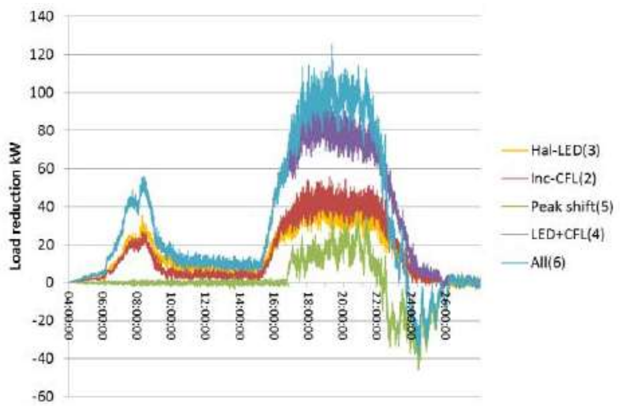

Fig. 3-7: Comparative benefits of peak reducing measures (paper 0812).

Sub block 4: Load modelling and forecasting

Paper 0254 takes previous work on load profiling at MV and LV levels and uses it to generate load profile compositions for learning the composition of customers that make up an LV feeder load and how it evolves over time. An approach for tracking changes to the load composition on residential feeders is shown to identify anomalous conditions or abrupt changes in the behaviour of the loads to be detected.

In paper 0308, a novel method of energy disaggregation is proposed, based on motif mining and the incorporation of on and off durations of the electrical devices. The results of the novel method are promising and allow a very high accuracy in detection of the electrical power consumption of the selected electrical appliances.

Paper 0884 investigates a methodology that characterizes the load profile of each electricity consumer, according to its daily load curves for each period. This approach has been based on field assessments of consumer behaviour and ownership of equipment and appliances.

Paper 1436 proposes a method to analyse and locate the demand side integration potential of urban areas using Geographic Information Systems (GIS)-based digital city maps in combination with usage-based characteristic data on the typical power installed in buildings for HVAC. Because of the inherent connection to a GIS based data set, the results can be easily displayed in maps, as illustrated in figure 3-8, corresponding to the results of a feasibility study in Hamburg, Germany.

Fig. 3-8: Map section of Hamburg displaying the demand side integration potential for HVAC in office-like buildings (paper 1436).

Paper 0907 explores the use of three advanced methods to build a next hour consumption forecasting model, including the Autoregressive Integrated Moving Average (ARIMA), Artificial Neural Networks (ANN) and Support Vector Machines (SVM). ANN exhibited superior accuracy in a simulation test employing consumption data of a Norwegian university, but it is reported that priority is placed on ARIMA due to its transparency.

Paper 1208 discusses two approaches for predicting the thermal behaviour of self adapting buildings, the state space model and the neural network approach, as well as different algorithms for optimization of HVAC schedules. It is reported that neural network models need a wider range of training data, but also need minimum information about the physical characteristics of the building.

Sub block 5: ICT architecture

Paper 0199 examines ICT architecture for smart EV charging, implemented for demonstration purposes by a distribution network operator in the Netherlands. The main properties of this architecture include flexibility to deal with future changes regarding the market model for public EV charging, and addressing privacy concerns of EV users.

Paper 241 investigates the privacy, security and flexibility aspects of ICT architecture for a Smart Grid project with consumer interaction in the Netherlands. The main high-level requirements regarding flexibility that are identified include interoperability, scalability and loose coupling, implying that each component has, or makes use of, little or no knowledge of the implementation of other components.

Potential scope of discussion

Demand response in dealt with in a large number of papers in this block, with a particular focus on methodologies for minimization of consumers' costs, effective flattening of the domestic demand profile and the provision of frequency response. There is a consensus that the unavoidable uncertainties in prices and renewable generation should be factored in the developed demand response and that carefully-tuned techniques are required to avoid the synchronization of demand response according to the price or frequency signals. Although the modelling approaches developed are effective, questions remain about the development of suitable business models to support their commercial consistency and the required upgrades in the smart metering and ICT infrastructure to support practical implementation.

Energy efficiency is the subject of several papers in this block, with a particular interest in energy efficient lighting technologies and commercial buildings observed. Topics for discussion include the design of large scale demonstrators for comprehensively capturing the value of energy efficiency measures, commercial arrangements to support wide deployment of energy efficient technologies, and the interdependence and trade-offs between the performance of energy efficiency and demand response schemes.

Table 3: Papers of Block 3 assigned to the Session

Accurate load modelling and forecasting is addressed in a number of papers, with specific challenges including the characterization of consumers load profiles, dynamic learning of consumers composition, energy disaggregation of load appliances and the application of neural networks for high-accuracy load predictions. In addition to the comparison of the performance of alternative forecasting techniques, the discussion could include questions on integration of the proposed advanced techniques in the automation management systems of distribution network operators and the smart metering equipment at customers' premises.

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0094: Decision support system for distributed energy resources and efficient utilisation of energy in buildings				X
0140: Levelling of heating and vehicle demand in distribution networks using randomised device control				X
0199: A flexible and privacy friendly ICT architecture for Smart Charging of Electric Vehicles		X		
0224: Improved load management algorithm for future network requirements			X	
0241: A flexible, privacy enhanced and secured ICT architecture for a Smart Grid project with active consumers in the city of Zwolle (The Netherlands)				X
0254**:** Feeder load composition tracking for Smart Metered low voltage circuits				X
0288: Active house deployment architecture for residential electricity customers' active interaction with the smart grid		X		
0308: Appliance-specific energy consumption feedback for domestic consumers using load disaggregation methods				X
0435: Controlling The Synchronization And Payback Associated With The Provision Of Frequency Services By Dynamic Demand				X
0506**:** Controlling and optimizing of energy streams in local buildings in a field test				X
0507: Primary frequency response in the Great Britain power system from dynamically controlled refrigerators		X		
0576: Efficient and Adaptive LED Public Lighting Integrated in Évora Smart Grid		X		
0648: Optimal operation of mobile storages by network flow algorithms considering spatiotemporal effects			X	
0661: Analysis of the potential of unidirectional and bidirectional price controlled charging strategies				X
0799**:** Real time demand response using renewable energy resources and energy storage in smart consumers				
0812: Network benefits of energy efficient lighting				X
0846: Evaluating the Impact of Load Management Programs on the Greenhouse gases Emission				
0884: Load modeling based on field survey of electric appliances ownership and consumption habits		X		
0907: Load forecasting in a Smart Grid oriented building				X
0959: Technical analysis of an aggregator's operation for the Gotland power system				X
1139: Domestic demand side management trial and extension				X
1208: Self-Adapting building models and optimized HVAC scheduling for demand side management			X	
1277: Active and anticipatory Demand-Side-Management in households			X	
1407: Demand Side Management in the French Islands		X		
1436: Analysis and location of Demand Side Integration Potentials in urban space using GIS based digital city maps			X	

Block 4: DG/DER technology

The scope of this block covers technologies and solutions that would enhance the capabilities of the system to integrate increased amounts of distributed generation and load growth as well as DG/DER technologies.

Sub block 1: Energy storage

Paper 0180 proposes a scheme for optimising the internal air circulation of an integrated storage system. It is demonstrated that the losses during a high power discharge/charge cycle can be effectively absorbed by the thermal inertia of the storage device, and that by placing the system partially underground, would have a very modest environmental impact while enhancing temperature stability.
Paper 0568 discusses findings of a demonstration project with a 1 MW battery energy storage system in Zurich, Switzerland. A model predictive control algorithm was developed for peak shaving in an office building, considering costs for grid operation as well as for battery degradation. Future tests will involve voltage regulation at the coupling point of the office-building, participation in the primary frequency regulation market and operation of the building compound in island mode.
Paper 0583 provides a detailed technical description and explores the benefits of a smart storage unit operated by a distribution network operator in a Dutch low voltage distribution network. The storage unit enables applications such as the increase of local PV consumption, improvement of reliability and flexibility, reduction of losses, and increase of the utilization of local network infrastructure.
Paper 0599 investigates two use cases of domestic scale electrochemical battery storage, one involving voltage regulation (complemented with reduction of outage duration and arbitrage in the energy market), and one involving primary frequency response (with the same complementary services). Figures 4-1 and 4-2 illustrate the breakdown of the value of the various services in these use cases. The issue of simultaneous provision of two or more services at the same time is discussed and the definition of a priority function between the services is proposed to address it.

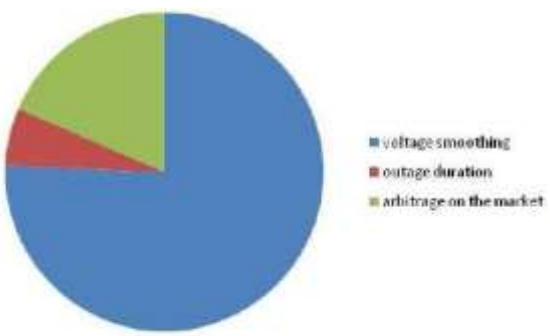

Fig. 4-1: Breakdown of the value of services in the use case around voltage regulation (paper 0599).

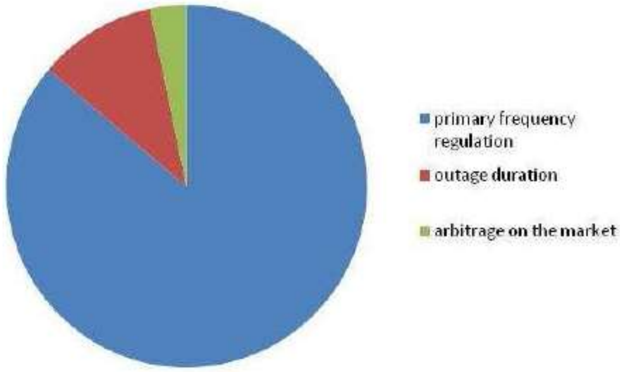

Fig. 4-2: Breakdown of the value of services in the use case around frequency response (paper 0599).

Paper 0620 presents a system to virtually aggregate numerous and diverse batteries in order to contribute to power grid operation. Functions of the aggregated entity include frequency regulation, peak shifting, and reserve contribution.
Paper 0797 examines theoretical models of smart distributed storage devices located at customer premises for powering local DC lighting and electronic loads, and explores business models and field data from deployments of example Smart DC/Storage systems. A particular focus is set on the management of DC household appliance loads to reduce peak load electricity usage, as illustrated in figure 4-3.

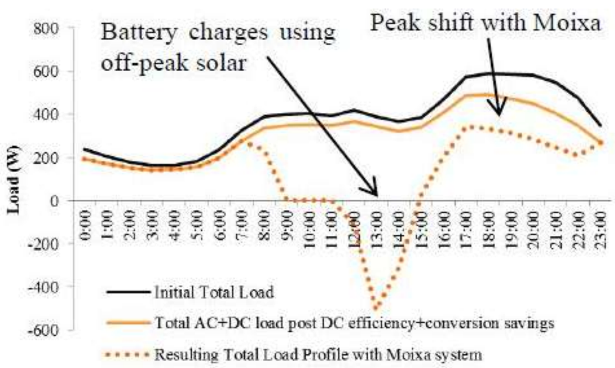

Fig. 4-3: Peak load management through DC/storage system (paper 0797).

Paper 0904 explores the potential benefits of distributed energy storage in enabling wider deployment of distributed generation, improving the load factor, mitigating voltage constraints and reducing power losses, and stresses the increased value of this technology when located in close proximity to renewable resources.
Paper 1165 presents a pilot project involving the deployment of large-scale electro-thermal energy storage in Zurich, Switzerland. Different potential services are identified, including increase of the distribution network utilization, price arbitrage, and electricity production from external heat sources. Interdependencies of the different services are identified, as shown in figure 4-4, and the need

to determine the optimal combination of the possible services is highlighted.

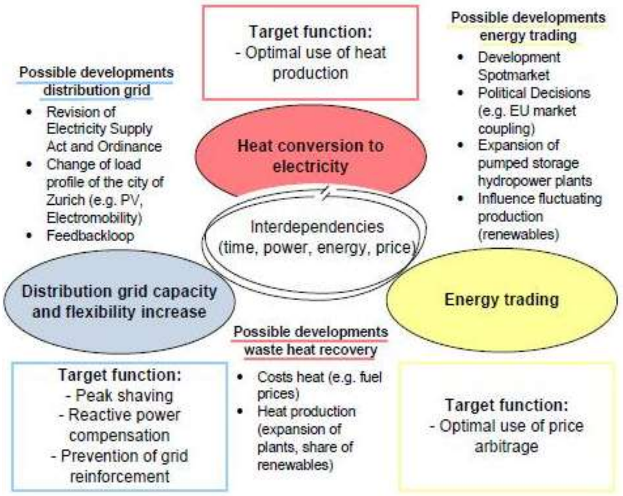

Fig. 4-4: Interdependencies of different storage services (paper 1165).

Paper 1172 describes the overall setup and main components of a pilot project in a Swedish distribution network involving a battery energy storage system. The main applications of the battery installation include peak shaving (illustrated in figure 4-5), power factor correction, losses reduction and harmonic mitigation.

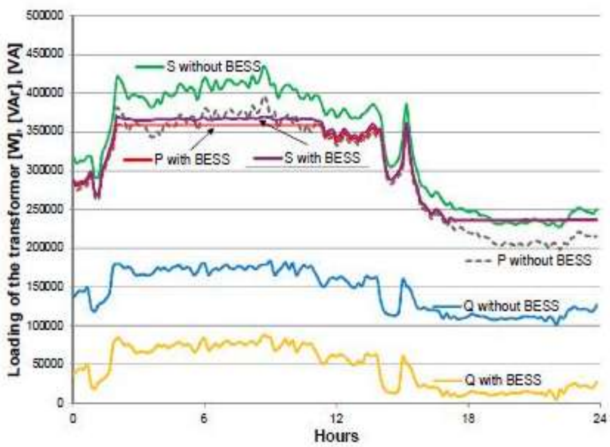

Fig. 4-5: Peak shaving through battery energy storage system (BESS) (paper 1172).

In paper 1335, the usage of a storage device to integrate a large amount of wind power into a German MV distribution network is discussed, and it is demonstrated that impacts of wind generation connection such as harmonics, flicker, overloading, and voltage issues can be simultaneously mitigated by storage. A case study reports that a storage device of 2MW and an energy capacity of 500 kWh is required to make the connection of a 16MW wind generator comply with the German MV grid code.

Sub block 2: PV generation

Paper 0139 presents the components and testing procedures for grid-connected photovoltaic inverters (PVI). The testing procedures include the protection function test, the EMC test, the conversion efficiency test, the harmonic current, the anti-island protection test, and the grid protection test.
Paper 0856 investigates the performance of two short-term PV forecasting models based on historical data a 200 kWc solar plant located in the south-east of France. It is reported that satisfactory performances can be expected from the proposed models, when calibrated with no more than one or two weeks of training data.
Paper 1221 discusses a collaborative initiative to develop standard functions and a standard language for grid integration of smart solar and storage inverters. It also presents three of the advanced inverter control standard functions that were identified using simulation of a North American distribution network containing large solar PV installations, and demonstrates their satisfying voltage performance.

Sub block 3: Wind generation

Paper 0153 introduces a fuzzy logic power system stabilizer (FLPSS) for wind generation systems that overcomes the conventional power system stabilizer (CPSS) demerits in damping multimodal oscillations, and can cope with a wider range of operating conditions. The results also show that the FLPSS can work cooperatively with the CPSS.
Paper 0232 studies the dynamic performance of a controller for a wind-turbine synchronous generator supplying an infinite bus through a transmission line. This controller is examined for various disturbances in wind speed, load and short circuit faults, and its benefits with respect to the open loop control approach are discussed.

Sub block 4: CHP generation

Paper 0142 presents experience from grid code compliance testing and studies of a combined heat and power plant in Sweden. The grid code requirements concern interference tolerance, voltage control, output control, frequency control, shutdown and start-up de-energization, communication and controllability, verification and documentation.
Paper 0260 identifies the crucial steps and questions the common practice of stability analysis of gas-engine-driven units. Events and operating conditions that may be critical and have not been considered so far for stability investigation are highlighted. Generator modeling is explained within the framework of conventional stability investigation.

Sub block 5: Active distribution network management

under DG/DER presence

Paper 0044 proposes a method for the detection of islanding in worst loading conditions according to IEEE1547 and UL1741 standards. The proposed method exhibits high speed, can effectively address issues associated with timely diagnosis, misdiagnosis and poor reliability, and can be used in both anti-islanding detection protection and micro-grid applications.
Paper 0750 describes the technology and functionalities associated with a Distribution Automation (DA) pilot project in Portugal. The developed DA schemes process real-time information from sensors and smart meters, and achieve reduction of the outage and repair times, optimisation of the voltage profiles and improved asset management.
Paper 1145 introduces a new active management scheme, where renewable generators are constrained based on voltage angle difference signals produced by Phasor Measurement Units, and a set of angle constraints derived through offline network simulations (illustrated in figure 4-6). The proposed scheme requires fewer measuring devices, simpler control logic, and lower implementation and testing costs than existing solutions. The progress of a related pilot project in North Wales is reported.

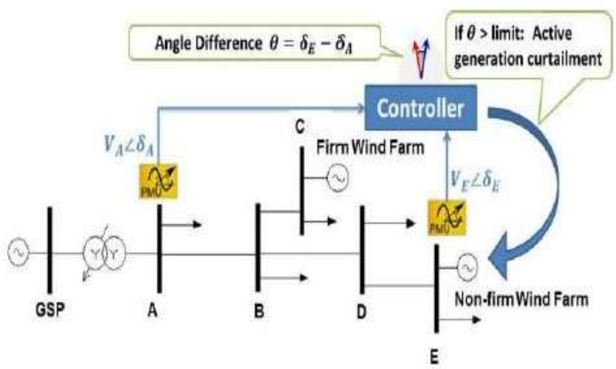

Fig. 4-6: Proposed active management scheme (paper 1145).

Sub block 6: DER connection infrastructure

Paper 0476 highlights the role of the standardization of conductive AC charging infrastructure for the rollout of electric vehicles. The current status of the standardization and the compatibility of different standards are discussed, and it is concluded that standardization is already sufficient.
Paper 0551 investigates a smart switch panel (SSP) for the interconnection between DNOs and small scale DERs. The presented device reduces required installation spaces and costs, supplies power continuously in cases of distribution network failures, and enables trading of electricity and ancillary services with the DNO and other customers.

Sub block 7: Energy management and smart metering

Paper 0867 describes an application of Wireless Sensor Networks in monitoring and controlling energy in residential and commercial buildings. In the application layer, user friendly software is designed to control and monitor all nodes in the wireless network through GPRS or LAN. Each user can remotely connect to this network and all nodes can control electrical devices without management from the coordinator node side.
Paper 0876 reports the results of a pilot test involving the deployment of in-home displays in 91 households in Norway. Customers of the test group exhibited a significantly higher tendency to reduce their electricity consumption due to updated feedback, with respect to the respective behaviour observed in a control group of 42 households.
Paper 1203 presents a large-scale trial by an Italian DNO, involving the deployment of an energy monitoring and displaying device aiming to increase understanding and control of the customers' energy usage. The device can be plugged in every domestic socket to start data collection from the smart meter through the power line, and personal computers can be connected to the device to enable consumers to view how much electricity is currently being used and to process the preceding load curves.
Paper 1499 explores the solutions adopted in an Italian project to demonstrate the feasibility of optimized management and planning tools to an industrial district. The project involves a LV Virtual Power Plant and a MV storage compensation system performing several functions for easing the integration of large share of renewables and supplying services to the grid. The first results indicate that very interesting performances and services can be achieved for both the grid and the renewable plant owners.

Sub block 8: DER coordination technologies

Paper 1440 proposes control algorithms for the coordination of a very large number (several tens of thousands) of distributed consumers with electric heat pumps and night storage heaters. In order to deal with the computation scalability and reliability challenges of the problem, an agent-based approach involving decentralized control and scheduling is adopted.
Paper 1470 describes recent results from two field trials and three large simulation studies using a market-ready DER coordination technology based on dynamic pricing. The results show that this technology improves the wholesale market position of energy trade and supply businesses, contributes to active management of distribution networks, raises the system's accommodation ceiling for renewable power generation, and is scalable to mass-application levels.

Potential scope of discussion

A large number of papers in this block deal with energy storage technologies and their valued services, with a particular focus on peak shaving, increased utilisation of the distribution network, increased capability of DG accommodation, voltage and frequency regulation, power losses reduction, and market arbitrage. Although the benefits of storage technologies have been sufficiently demonstrated through both simulation studies and field trials, questions remain regarding the optimization of the simultaneous provision of multiple services, the quantification of the overall economic value of storage technologies, and the development of commercial arrangements recognizing the multiple added values.

Distributed generation technologies, including PV, wind, and CHP, constitute the topic of many papers, with specific challenges including the standardization and performance of power electronic inverters, the testing of grid codes compliance, and the development of stability analysis procedures and controllers. The standardization of the testing procedures for DG inverters and controllers and the identification of the major barriers for establishing uniform and consistent grid compliance codes are important topics of discussion.

Energy management is the subject of several papers in this block, with a special interest in energy monitoring, displaying and control at the domestic level. Despite the promising results of relevant field trials concerning consumers response, challenges associated with the standardization of the relevant equipment and development of suitable business models for its massive rollout would be worth further discussion.

Table 4: Papers of Block 4 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0044: A new active islanding detection method of DG				
0139: The design of performance test system for grid-connected photovoltaic inverters				X
0142: Practical experiences of grid code compliance testing and studies in heat and power plants in Sweden				X
0153: Fuzzy Stabilizers Design for Renewable Energy based Distribution Networks				X
0180: Thermal optimization of an integrated LV battery energy storage station				X
0232: Operation Assessment Of a Wind Generator With a Conventional Power System				X
0260: Low voltage ride through capability of gas engine driven units				X
0476: Standardization of conductive AC charging infrastructure for electric vehicles				X
0551: Optimal interconnection device between DNO and small scale DERs of customer			X	
0568: Preliminary Findings of a 1 MW Battery Energy Storage Demonstration Project		X		
0583: Smart storage in the Enexis LV distribution grid		X		
0599: Multi-Services Storage Plant At A Domestic Customer's Premises: Effect Of Simultaneous Requests				X
0620: Battery SCADA demonstration system in YSCP				X
0750: Distribution Automation on LV and MV using Distributed Intelligence				X
0797: Local smart DC networks and distributed storage for reducing and shifting peak load				X
0856: The impact of available data history on the performance of photovoltaic generation forecasting models			X	
0867: Design and implementation of building energy monitoring system using wireless sensor networks				
0876: In-home displays at household customers. Results from a Norwegian pilot study.		X		
0904: Energy storage can enable wider deployment of distributed generation				X
1145: PMU-based angle constraint active management on 33kV distribution network		X		
1165: Feasibility study of an electro-thermal energy storage in the city of Zurich				X
1172: Practical Grid Benefits of Battery Energy Storage System in Falköping Distribution Grid		X		
1203: Enel Info+ project: a demo to evaluate the impact of the consciousness on the customer energy consumptions		X		
1221: Advanced inverter controls for distributed resources			X	
1335: Using Storage to Integrate Renewables into the Distribution System - A Case Study				X
1440: Determination of load schedules and load shifting potentials of a high number of electrical consumers using mass simulation				X
1470: Intelligent energy management using PowerMatcher: recent results from field deployments and simulation studies				X
1499: Experience on energy management in an industrial district				X