Special Report - Session 4
DISTRIBUTED ENERGY RESOURCES AND ACTIVE DEMAND INTEGRATION

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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 integration of active demand 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.

As a result of these targets and other goals set by nations across the world, electricity distribution has seen a revolution in the role it plays in the broader system. Whilst many solutions previously considered innovative are now embedded within Distribution System Operator (DSO) businesses, research and development activities continue to be critical to the long term needs of electricity.

Of particular importance is taking the learning from previous studies and demonstration projects and feeding it back into ongoing research programmes. DSOs must ensure new systems and processes are robust enough to maintain security of supply, yet agile enough to allow the speedy connection of distributed generation or active demand.

The Session 4 papers in 2015 cover a broad spectrum of topics relating to distributed generation and distributed energy resources. 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:

Block 1 – Active Demand Integration

Block 2 – Planning and Studies

Block 3 – Innovative Technologies and Solutions

Block 4 – Smart Grid Demonstrators

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 four blocks of papers in broad topic areas. 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 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 the Session 4 scope.

Block 1: Active Demand Integration

Demand Management

Paper 0099 describes a dynamic pricing algorithm that allows customers to take advantage of the volatility of spot prices in order to shift loads towards periods with lower energy costs. Load shifting potential is determined with a preselection algorithm based on measured data. That data is obtained through a two-step questionnaire, with the first part describing the company and the second describing each process.
Optimizing day-ahead consumption patterns according with forecasted spot prices can yield savings on energy costs. A simulation performed for a given production process with a low utilization rate – and a great flexibility to modify consumption patterns resulted in 5.35 % savings on the energy costs.

Paper 0592 presents the results of a demand side management initiative promoted in Iran, involving industrial costumer equipped with smart meters. The interested participants were offered an incentive, provided by the utility, should they be willing to curtail demand during peak load hours, on a 24h notice. The incentive would be valid should the participants accept to curtail peak demand for 100 to 200 hours during a two month interval, on request by the utility.
Results presented by the author show that this mechanism allowed for an average peak demand reduction of 10 MW, providing an economical benefit to the utility associated with delayed investments.

Paper 0620 analyses the potential for residential response to balance variable power generation with electric demand. It presents a residential consumption model and a control algorithm and their impact on the low voltage network. The consumption model differentiates between service appliances (like the dishwasher, washing machine, kettle…), regulated appliance (refrigerator, boiler, heat pump…), passive appliance (multimedia – TV, routers…) and lightning.
Two control algorithms are simulated – a centralized control that adapts consumption of a micro-grid aiming for a certain overall consumption profile, and an algorithm that randomly sets a consumption delay to any given appliance in order to match a reference profile. The performance of a LV network with PV production and demand response is simulated. The results show that local conditions are important to be considering when considering a response control mechanism.

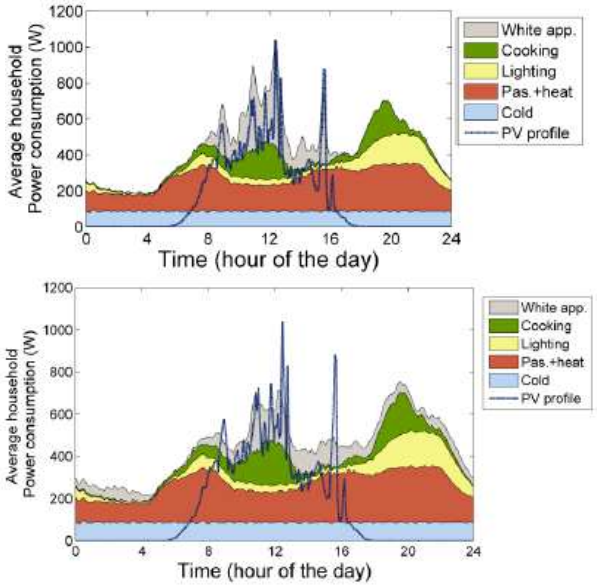


Fig. 1-1: Paper 0620 centralized control heuristic with control on all appliances (above) and random delay selection control heuristic (below)

Paper 0624 presents a case study implemented by an Iranian distributer that made use of smart meters in order to reduce peak consumption on industry, through consumption reduction or peak shifting. Industries that participated on the programme would receive warning signals through the infra-structure, as described by the authors, in order to reduce peak consumption. The plan was offered to 173 industrial units, 87 of which accepted to participate. The paper refers to a 23 MW load reduction during peak hours, as a result of the described method.

Paper 0928 discusses the practical implementation of demand response in Finland. It is based on questionnaires responded by DSOs, retailers, manufacturers of smart meters and designers and other experts of the real estate electricity installations. Questionnaires were complemented with workshops and technical and economic analyses.
The questionnaires allowed to assess the benefits and market place of the DSM perceived by the stakeholders. It also allowed for the identification of the most relevant obstacles to the implementation of DR resources, for each stakeholder.
The authors conclude that there exists a remarkable amount of controllable loads, which can be controlled through smart-meters. Also, there is economical potential for demand response. However, the roles and responsibilities of the different stakeholders in the implementation of DR are not clear.

Paper 1031 describes a dynamic time-of-use pricing trial that took place in the London area, in 2013. High price induced peak reductions for network constraints, alongside the temporal availability of demand response

for supply balancing. By examining both these use cases, potential conflicts were identified between network and system objectives.
Consumers were incentivised to change their electricity consumption through prices changes. The tariff was designed to result in the same revenue as the flat rate tariff, for the average consumer who did not react to price changes. 95 % of households saved money, implying engagement on consumption management. Consequently, a peak demand reduction was observed.
Two kinds of events were tested – constraint management (CM), designed to alleviate peak demand on networks and supply following, designed to scan the response of households to high or low price signals, assessing the response to assist in energy balancing – which can induce higher consumption values associated with high RES production. This two objectives can conflict with each other.

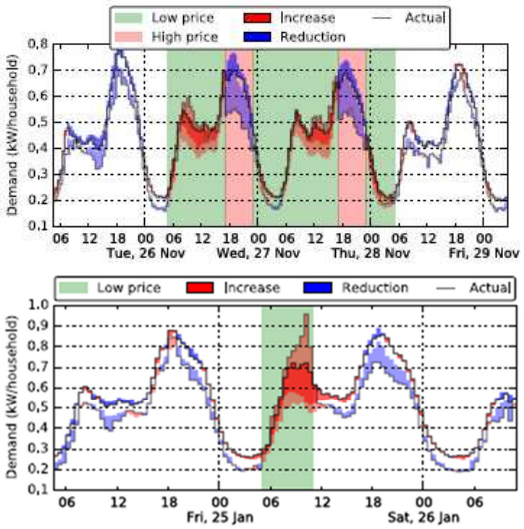


Fig. 1-2: Paper 1031 presents a CM event showing evening peak reduction over two consecutive weekdays. The lighter shaded Increase, Reduction and Actual indicate the response from the most engaged 25% of households (above) and demand increase in response to a low price signal. The lighter shaded Increase, Reduction and Actual indicate the response from the most engaged 25% of households (below)

Paper 1043 describes research project ADVANCED, co-funded by the EU's 7th Framework Programme. This project aims at the development of actionable frameworks enabling residential, commercial and industrial consumers to participate in Active Demand (AD) initiatives. AD initiatives will allow for a great introduction of distributed generation, minimizing reinforcement network investment costs. The project assesses the potential for demand response in France, Germany, Italy and Spain.
Furthermore, the project assesses the impact of the solution on electricity systems, particularly on MV and LV levels. It also describes the main regulatory barriers to the development of an AD solution.

Paper 1105 presents a comparison process for Demand Response (DR) control methods performed by ERDF and Schneider within the framework of French Smart Grid projects. The study assessed mainly tertiary buildings or tertiary uses (heat pump, heat conditioning …). It describes the architecture of an integrated prosumer solution that incorporates a remote smart grid services platform and local onsite energy management systems.
The paper compares the results obtained through the methodologies developed to assess DR benefits, describing the complexity of the analysis that must be made, and concluding that recommended analysis methodology is based on the analysis of individual load curves to assess the response mechanism to DR control.

Paper 1514 presents an analysis of costumer's performance in industrial and commercial (I&C) demand side response (DSR) trials. These segments are particularly appealing for DSR due to large potential available capacity. The trials also take into consideration the costumers' locations, since it also influences their capacity to participate in DSR, given network constraints. 189 DSR events were used, from a wide range of customers. It included generation-led DSR, with on-site diesel generators or CHP engines and demand-led DSR, including HVAC installations and water pumping stations.
Seven event classes associated with the trials, on sites that participated in the Low Carbon London I&C DSR trials, were characterised by site technology and season. Load aggregators submitted portfolios of customers combined into assets of fixed capacity to the DNO, which then dispatched at a predetermined day and time. After the trials, costumers performance was compared with the performance obtained, demonstrating the potential for DSR participation.

Paper 1638 describes a trial, performed under the Linear project, involving 240 households equipped with smart appliances (washing machines, tumble dryers, dishwashers, and domestic hot water tanks), as well as EVs and PV panels. That equipment is able to communicate with a central party and to follow DR control actions, fulfilling four business cases:

1. Portfolio Management – can costumers shift their energy consumption based on the day-ahead market?
2. Wind balancing – is it possible to reduce unbalance costs originated between forecasted and produced wind energy?
3. Transformer ageing – can load spreading over time prevent accelerated transformer ageing?
4. Line voltage management – can voltage deviation issues be prevented in local grids?

The conclusions of the trial show a very slight (< 1 %) increase on the lifetime of transformers, mainly due to a

lack of sufficient flexibility to allow for a greater benefit. The same conclusion is valid concerning line voltage management. Automatic response helping to compensate for wind production performed well on face of wind production underestimations, when consumption had to be increased – up to a 150 W limit per household. When consumption had to be decreased, performance was poor. Also, the response to time off use tariff was weak, if costumers had to check for energy prices. Acceptance of automatic demand response through smart appliances, though, was better.

Electric Vehicles

Paper 0618 provides a description of an architecture developed by ENEL and Siemens to dynamically manage the charging of EVs. The proposed solution includes a software capable of performing load management activities taking into account DSO, RES and EV driver preferences, in order to optimize charging cycles. The solution is aimed at the B2B segment, associated with EV fleet management.

Paper 0635 describes a direct control trial of EV charging. The project My Electric Avenue, established on the UK, includes a control system that directly manages EV charging points on a feeder by disconnecting them when phase currents exceed a threshold. This technology was installed at a cluster site and deployed over 200 EVs. The communications are guaranteed through PLC. The authors also investigate the effectiveness of PLC as a communication medium for distributed control system.
The project demonstrates that the described technologies allow the curtailment of EV charging, managing the current value observed on LV feeders. It also described the reliability of the PLC communication medium, concluding that it is higher closer to the substation. However, the probability of communication rapidly drops at 180 m. Also, reliability vs. distance depends on network topology and time of the day.

Paper 1088 describes an EV charging data collection trial, and analysis the potential for optimising charging profile in order to minimise peak load demand. EV data collected on the described project, associated with the Low Carbon London (LCL) EV trial, is associated with dedicated EV charging stations for commercial and residential EV fleets, from public charging station in London, and from vehicle logger data recording driving, charging and parking events.
Based on the acquired data, the authors proceed with a comparative of the EV demand, analysed for different probability levels, and the load curves associated with optimised charging. They argue that there are opportunities for adopting smart charging approaches to ensure efficient EV integration that results in a small or inexistent impact on peak demand.

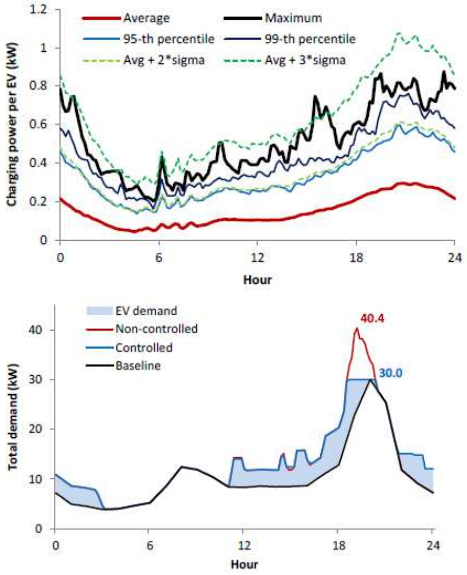


Fig. 1-3: Paper 1088 maximum expected charging profiles per EV for different probability levels (above) and Uncontrolled and optimised charging profile for 10 residential EVs with baseline demand (below)

Paper 1139 presents a probabilistic (Monte Carlo methodology) and deterministic assessment (one single simulation with random allocation of load profiles according to the penetration level) of the impact of electrical vehicle (EV) charging on LV networks. It compares both methods regarding the evaluation of the impact of uncontrolled EV charging on load diagrams.
The authors conclude that the impact assessment is useful to understand the behaviour of one particular LV network with different EV penetrations. However, they claim that the lessons cannot be necessarily extrapolated to a different one, since they can present different problems at different EV penetration levels, when they proceed to use the same methodologies on the nine UK LV networks that are part of the "My Electric Avenue" project. With that insight, the authors argue that the probabilistic assessment is flexible, being able to take into account specific conditions regarding EV penetration and type of costumers.

Paper 1265 describes a solution, developed under the German research programme "Well2Wheel" for energy management of private households with EV, minimizing the impact on network stability (congestion and voltage limits). A VPP in the network control centre pools generation units, flexible loads and energy storages by data exchange and remote control. An algorithm on the VPP calculates variable traffic light tariffs, representative of variable electricity tariffs, which are used to control flexible generation and loads.
The EV charging simulation was performed driving data from private and commercial EVs. The traffic light system allows to shift charging to low load or high renewable generation periods. The authors argue that

intelligent control strategies developed under this project allow for charging processes and time-flexibility energy consumption of private households can support operation efficiency and grid stability.

Smart Metering and AMI

Paper 0174 presents a third generation smart meter that can be customized within several possible configurations. The smart meter is built with several module components that are designed taking into account the most frequent types of failures, allowing for a lower cost and higher maintainability. Furthermore, they allow for costumer management based on a card associated with the meter that allows to change costumer management from address-oriented to customer-oriented, by registering data that holds individual information and facilitates bi-directional communications. The described smart meter takes advantage of ICT and metering technological developments, aimed at reducing both production and operation costs while enhancing the quality of customer service.

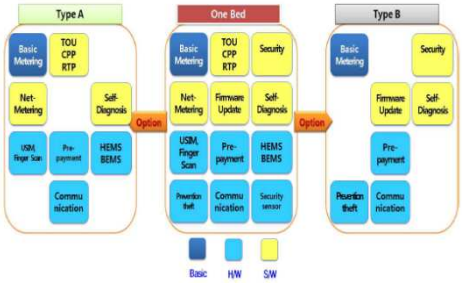


Fig. 1-4: Paper 0174 examples of MULTI Option SMART METER OPTION selection

DER and Network Management

Paper 0400 describes flexible options that will allow for higher penetrations of renewables in power systems. The flexible options described are divided into five categories: (1) supply side – based on conventional generation systems but also on VRES; (2) Demand – associated with flexibility options; (3) Energy Storage – both seen as delivering energy during periods of under supply and absorbing it during periods of over supply; (4) Network – strengthening both transmission and distribution networks will allow for a greater flexibility; and (5) System – improvement of the system operational principles, namely through the tuning of market rules.
Flexibility options are mapped on their characteristics regarding their operational time-frame (short, medium or long term), allowing the authors to propose a roadmap that will allow the existing systems to evolve in order to address the long-term challenges posed by very high penetration levels of VRES.

Paper 0405 analyses the production curves of both PV and wind parks, for several different locations in Germany. Based on that analysis, it demonstrates that the generation facilities only produce maximum power during very short periods. Therefore, it is argued that a large reduction in peak power (70 %) leads to a very small reduction in delivered energy (4 %).

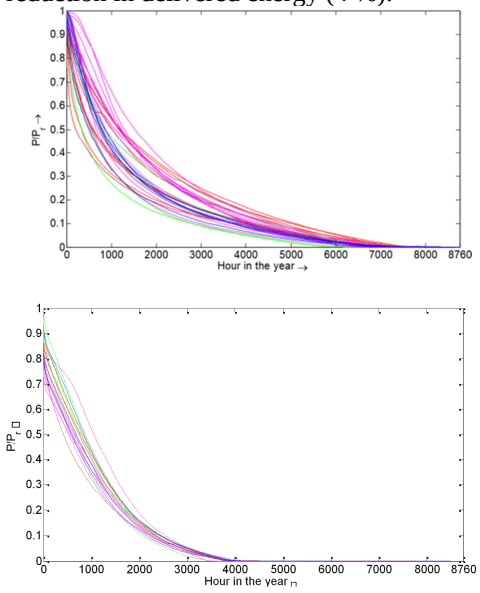


Fig. 1-5: Paper 0405 dependency of wind generation (above) and PV (below) duration curve on location

Paper 0808 discusses the performance of price-based control approaches and the smart measures that avoid demand response concentration of controllable loads on off-peak periods. Case studies involve electrical vehicles (EV) and wet appliances (WA), including dishwasher and washing machines. Should all of the controllable loads initiate their operation either at peak hours or at the same instant of off-peak hours, power flows at the used distribution test feeder would breach its thermal capacity.
Several flexible control solutions were described, as priced-bases control (where a set of location and time-specific pricing is implemented for the several network buses), flexible restrictions (where a relative flexibility signal communicates the fraction of available flexibility they can use at off-peak periods), flexibility pricing (similar to the previous, but with the hard restriction substituted by a price signal that penalises the extent of flexibility used, preventing overuse), randomised flexibility pricing (the price signal mentioned on the previous strategy is randomised, diversifying the flexibility), and measures tuning (the parameters defined on the previous measures are fine-tuned according with the characteristics of the loads. Should the parameters over encourage flexibility, peak demand would be very high in off-peak periods. Should they under encourage, loads will not make use of their flexibility potential. Fine tuning will set the parameters in order to achieve a load diagram as flat as possible).

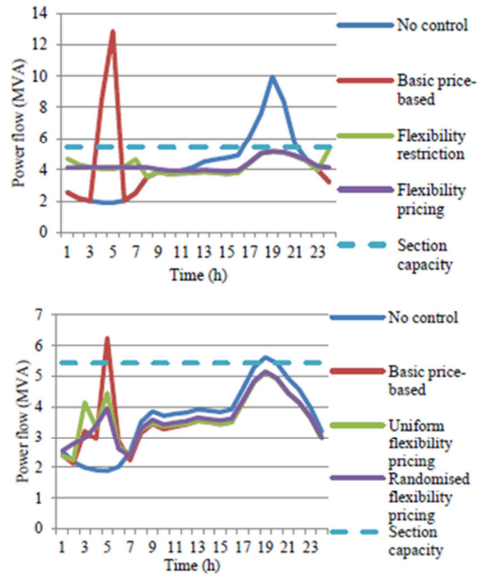


Fig. 1.6: Paper 0808 power flow on top feeder section under different EV control approaches (100% EV penetration scenario, above) and power flow on top feeder section under different WA control approaches (=20h maximum delay scenario, below)

Paper 0971 presents a case study based on an Energy Management System conceived by Enel for the Universal Exposition EXPO 2015 in Milano. The architecture model allows a multi-service suit, including the support to energy management tasks, enabling EMS according to costumer's needs, has an asset management module that configures the devices to be installed (sensors, actuators, meters) and controls the state of the devices connected to the system. It has a site management module, allowing the technicians to easily assess information regarding the power grid.
The core of the system are the energy management and active demand modules, allowing for the monitoring of the parameters of each site and sub-site, down to a single device, and the status of each service (climate control, lighting control, load management). Different scenarios can be selected (Comfort, Energy Efficiency, and Active Demand). The paper also describes the challenges that were associated with installing innovative grid management philosophies on the premises and pavilions, involving the integration of systems not yet available on the market.

Paper 0979 describes the Enel Info+ pilot, deployed in Isernia. This project allowed for the consumers to have simple access to their consumption data, through a device that can be plugged in every socket to collect the data managed by the smart meter, through power line. The pilot tested whether this approach would lead to consumption reduction. The authors registered a net consumption reduction of some percentage points.

Paper 1037 presents a concept of coordinated Distributed Energy Resources (DER), load modulation willing to supply frequency-controlled reserves, provided by a Virtual Power Plant (VPP). The concept described has been tested on an off-grid system. It is a project funded by the European Commission under FP7 (Dream project). According to the authors, Information and Communication Technologies allow to control either DER or loads over the network, in order to obtain frequency-controlled reserves.
The concept was developed with the objective of proposing a solution for the issue of lack of frequency reserve in some locations. Next step intended by the authors will be to convince Utilities and DER owners of its robustness, and the definition of suitable business models that would be fostered by the solution.

Paper 1148 is related with the Reflex project, which aims to examine all aspects of flexibility aggregation, in particular scheduling flexibility to offer bids to a market. It describes an algorithm that forecasts the resources to be used, considering constrains on the number of activations of the resources, recovery time between activations, minimum market bid duration and power, market baselines, flexibility availability, etc. Under the set constraints, it maximises the revenue to be obtained.
The optimization algorithm was tested on a set of 6 office buildings and 2 industrial sites, involving 10 flexible resources in total.

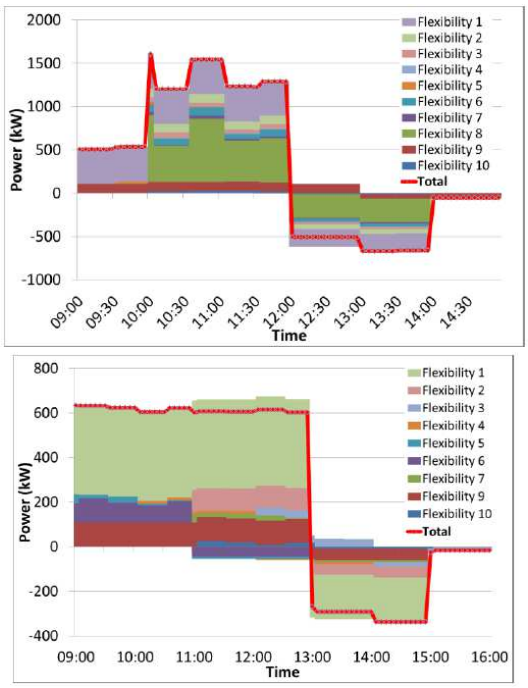


Fig. 1.7: Paper 1148 dispatch schedule and total impact obtained with the expected revenue maximization objective function (above) and dispatch schedule and total impact obtained with the bid duration maximization objective function (below)

Paper 1177 is based on the INTrEPID project, which aims to develop technologies that will enable energy optimization of residential buildings. This project proposes an architecture for a solution fulfilling the needs associated with smart grid applications, fostering interoperability, scalability and the creation of new market opportunities. The architecture uses a middleware layer interconnecting several technological components: supervisory control, energy brokerage, business intelligence, and the indoor home networks.
The solution includes a smart exchanger, a software component that manages the power exchange between the home electric network and the grid. Two control logics were considered. The more basic aims at increasing self-consumption of energy produced by PV modules, balancing production and consumption. The other, more complex, is designed to use storage to compensate between the forecasted PV production profile and the real PV production profile in order to guarantee the expected power output.
INTrEPID has so far been installed on small scale demonstrators and pilots (50 houses).

Paper 1258 describes the Couperus project, in The Hague, where 300 apartments are heated with heat pumps. This building was operated as a Virtual Power Plant (VPP) for ten months (by controlling 150 heat pumps), balancing the consumption with a nearby wind-farm production in order to provide a peak-shaving service to the local distribution substation. The VPP operated with a conservative value for the bandwidth of the temperature variation inside the building (0.4 ºC), in order to guarantee that the comfort within would be preserved.
The trial results demonstrated that operating within an indoor temperature bandwidth of 0.4 ºC did not originated complaints regarding comfort, but allowed to use 21 % of the total power of the heat pumps for imbalance reduction during a large period of time in spring, summer and autumn. Peak shaving capability was demonstrated.

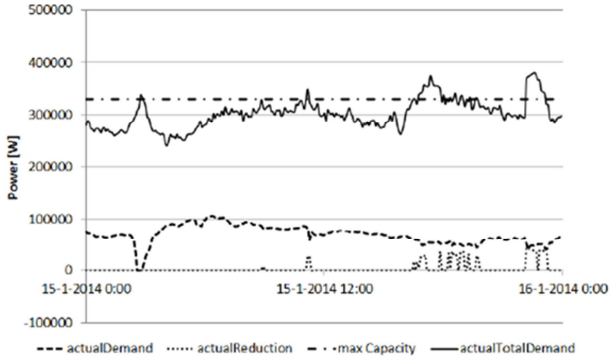


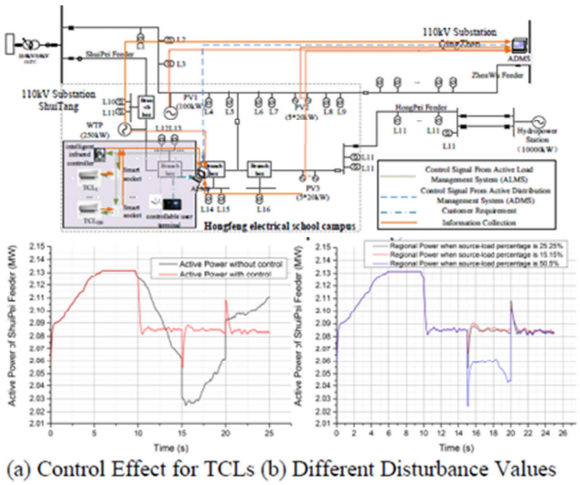
Fig. 1-8: Paper 1258 peak shaving 150 of 300 heat pumps in the VPP Couperus on January 15th 2014 showing the maximum capacity of the substation, the actual total demand, the actual demand of the heat pumps controlled and the actual reduction achieved.

Paper 1303 investigates the potential of heat pumps to increase the self-consumption of households and to lower the occurring voltage rise within a LV distribution grid, lowering the occurring voltage rise associated with PV production. Results demonstrate that heat pumps are able to increase the self-consumption of households, particularly during winter.
Even though the paper also includes the analysis associated with controlling hot water systems, which present a much lower load than heat pumps but much more constant throughout the year, the effects of dispersed heat pumps on the self-consumption of households, the peak PV infeed into the grid and the voltage rise in electrical distribution grids are of low impact.

Paper 1306 describes a flexibility market facilitation mechanism developed by ERDF and Schneider Electric. It includes an Aggregator Portal designed to be a facilitator between aggregators' systems and ERDF's information system. Aggregators registered on the portal upload their portfolios, which can be assessed regarding the risk of the DR activations' characteristics, for each site. The aggregator might then define activation schemes of DR on a daily basis, submitting them through the portal for technical approval. The Portal can, then, automatically send the activation scheme to ERDF, allowing to estimate the impacts of DR activation.

After DR activation, the aggregator declares into the Portal the flexibility program sold in flexibility markets or mechanisms. For each DR cluster, ERDF benchmarks with a cluster of non-flexible loads, establishing a baseline that can be compared with the load diagram of the aggregators' cluster. These neutral load curve are certified by the DSO as a neutral stakeholder and published into the Portal.

Paper 1504 describes thoroughly an active management strategy considering fluctuation characteristics of intermittent energy, presenting the flowcharts and basic equations developed for the modelling methodology and strategy proposed. A strategy for an active distribution network (AND) where thermostatically controlled loads are used on a multi-layer control strategy for power stabilisation and load shifting, allowing the integration of more DG.
A demonstration of the application of active load management was performed in Qinzhen, China, involving 300 kW of PV and 250 kW of wind turbines. Several simulation results allowed the authors to validate the proposed voltage control strategy.



(a) Control Effect for TCLs (b) Different Disturbance Values

Fig. 1-9: Paper 1504 demonstration Project of AND Active Load Management (above) and Active Power of Feeder under Different Conditions (below)

Paper 1622 assesses the value of demand side participation in frequency regulation, based on 2020 and 2030 scenarios concerning wind generation penetration in GB. Based on the least-cost annual generation scheduling, considering the need of energy and reserve and frequency regulation systems, the value of demand side response (DSR) is quantified by the comparison of the system operation costs with and without the contribution of DSR into frequency provision response.
High penetration of wind production will displace conventional generation and reduce the number of synchronised plants, causing the aggregated system inertia to decrease, and requiring increased demand for frequency response. The authors argue that DSR is capable of providing primary frequency response, gradually reducing demand as the frequency drops, but could not contribute to system inertia in a manner similar to synchronous rotating machines. Conventional generators will remain the only source of inertia, i.e. resistance to rapid frequency changes.

Potential scope of discussion

There are several papers describing describing demand management trials. How big is the potential for different costumer to contribute for peak load reduction and how can the benefits for all the involved parties be measured, in order to assess the value associated with demand response?

There are several papers associated with EV demand management. What is the expected impact of EV demand in the next 10 years and how can the trade-off between the complexity of demand systems and savings for the electrical energy system be measured?

Table 1: Papers of Block 1 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
99	Optimal use of demand response potentials in medium-sized industry using dynamic electricity tariffs				X
174	The 3rd Generation Smart Meter Development Strategy in KEPCO				X
400	Flexibility Roadmap for a near 100% Renewable Energy System				X
405	Optimal integration of renewable energy sources by limiting peak generation	X			X
592	Demand management program for large industrial consumers by using the AMI system				
618	Load Management: A Demand Response B2B service for EV Fleet Operators				X
620	Residential demand management and distribution grid impact assessment	X			X
624	Peak Shaving in MEEDC Incorporating Major Industrial Consumers				
635	Direct Control of EV Charging on Feeders with EV Clusters				X
808	Price-based control of flexible loads for distribution network management	X			X
928	Practical implementation of demand response in Finland				X
971	EXPO 2015 Smart City: an innovative system offering energy efficiency services and enabling active demand				X
979	Smart info as a key enabler for widespread active demand: Enel Info+ from pilot to large scale				X
1031	Experimental validation of residential consumer responsiveness to dynamic time-of-use pricing	X			X
1037	Distributed and Coordinated Demand Response for the supply of Frequency Containment Reserve (FCR)				X
1043	The conclusions of the ADVANCED project on the impact of active demand on the electrical system and its actors				X
1088	Characteristic demand profiles of residential and commercial EV users and opportunities for smart charging				X
1105	Comparison process for demand response methodology				X
1139	Probabilistic Impact Assessment of EV Charging on Residential UK LV Networks			X	X
1148	Scheduling of DER flexibility in a market environment: lessons learnt from the Reflexe demonstration project				X
1177	Intelligent systems for energy prosumer buildings at district level			X	X
1258	Imbalance reduction and peak shaving of a VPP with 150 heat pumps	X			X
1265	Energy Management of Private Households with Electric Vehicles as Active Consumers in the German Research Project “Well2Wheel”				X
1303	Voltage Support in Distribution Grids Using Heat Pumps				X
1306	Flexibility Market Facilitation through DSO Aggregator Portal				X
1504	Active Load Management Strategy Considering Fluctuation Characteristics of Intermittent Energy			X	X
1514	Analysis of Customers' Performance in Industrial and Commercial Demand Side Response Trials				X
1622	Value of Demand Side Participation in Frequency Regulation				X
1638	Flanders' LINEAR pilot project - implementing residential demand-response algorithms				X

Block 2: Planning and Studies

DG/DER Integration and Network Planning

Paper 0289 describes an algorithm for network losses reduction and enhancing the voltage profile through siting DG units at optimal locations and optimal sizes. The benefit of the DGs integration is quantified. The losses reduction is between 18-28% with optimal size of DG penetration of about 25% of the slack bus capacity. The paper also includes discussion that is relevant for uptake of DG in developing countries.

Paper 0449 presents a general process to address the challenges in distribution systems posed by the integration of renewable generation, changing load patterns and the modifications in the electricity market sector. A use case describing interactions among different players that fits the process is also presented. An example of computations conducted in long-term horizon is included to illustrate some initial results.

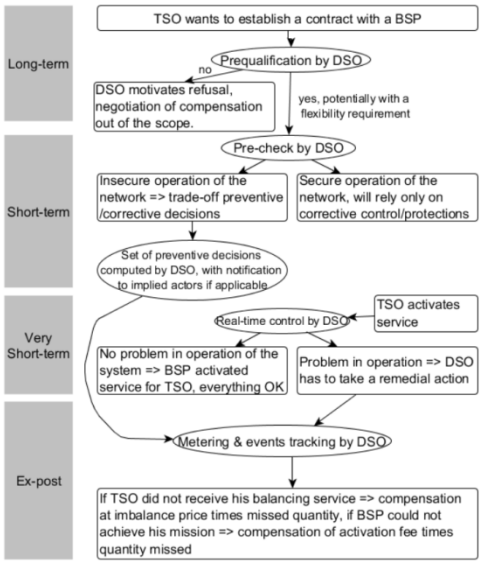


Fig. 2-1: Paper 0449 Use case where TSO buys and uses flexibility from a BSP active in a DSO

Paper 0601 shows a set of developed use cases for testing the maximization of PV hosting capacity concepts using smart meters and new sensors/instrumentation in substations. It suggests that the most promising option to solve the voltage quality problems is to maximize local active power consumption. However, use cases utilising reactive power control options are found not be very effective due to the high R/X ratio typical for LV feeders.

Paper 0662 presents a demonstration of the potential for improving network operation and increasing DER hosting capacity of existing distribution networks through the application of optimal coordinated control of voltage deviations, losses, DER energy curtailments, application of different network control devices etc. The method is applied to a distribution network with on-load tap changers, shunt capacitors and DG. The possible advantages include improved voltage regulation, increased accommodation of DER without violating technical constraints, reduced losses and wear of control devices. The potential benefits have been quantified using a MV study case network, where both optimal control and conventional regulation have been applied.

Paper 1169 proposes an integral bi-level planning approach which co-optimizes the allocation of renewable distributed generation (RDG) and energy storage (ES) in a context of active distribution networks. The model takes the maximum expectation of net benefit of RDG as the upper-level objective, and the maximisation of total renewable energy contribution as the lower-level objective. The impact of potential network contingencies on RDG efficacy is especially taken into account. The problem is solved by using a hybrid algorithm, which combines harmony search and probabilistic optimal power flow. The case studies have been carried out on a 33-bus distribution network, and the results demonstrate the effectiveness of the proposed method.

Paper 1314 investigates the impact of integrating EV in the operation of a real distribution network (Canary Islands) including diesel and wind generation. A Mixed Integer Linear Programming is formulated and applied with the goal of minimising the overall operation costs. Results are presented in technical (power losses, voltage behaviour, EV behaviour) and economic (generation cost, substation price signals) terms. There is a potential to decrease the island's network operation costs. However, increase in power losses and reduced voltage stability and security, driven by high penetration of EV is also discussed.

Paper 1332 highlights the effectiveness of the centralised and decentralised control systems in order to increase the hosting capacity of Smart Grids, by comparing the outcomes of the centralised and the distributed approach in the active management. For this purpose, a multi-agent system is developed and compared with a centralised demand side management approach. The proposed optimization algorithms allow designing valid and effective demand response program, able to contribute to voltage control of distribution networks. The outcome is the difference between the solutions obtained with the two different control systems and a comparison between the system costs in both cases, with particular reference to LV systems.

Paper 1414 proposes a method for the simulation of errors in renewable energy sources generation forecasting (photovoltaic and wind) for use in power system planning studies. The proposed methodology includes simulation of photovoltaic plant and wind farm power production, with a sufficient spatial and temporal resolution (few km

and hourly time step), generation of forecast errors using historic data of numerical weather predictions considering intra-hourly variations. For the case of France with a very high penetration of renewable energy (i.e. more than 30 GW of wind power and 60GW of PV) the results show that the worst event won't exceed a few GW for the total forecast error calculated an hour in advance.

Paper 1475 presents the prospects of development of LV DC electricity distribution energy efficiency (EE) using quantitative results and discusses the system development challenges. It shows that the future LV DC system might improve the EE. The inclusion of directly connected energy storage to the system can further improve the EE of the system and might present clear advantage over AC microgrid.

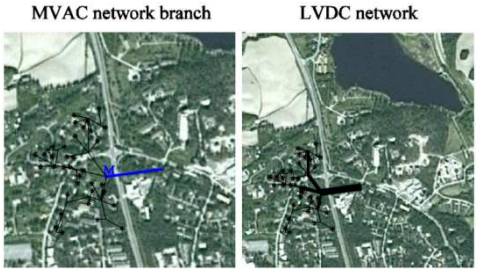


Fig. 2-1: Paper 1475 Case network 2 (city network)

Paper 1568 presents a general framework which identifies the Hosting Capacity (HC) of distribution networks and attempts to maximize the reactive power control of wind turbines, capacitor switching and demand response actions. It is demonstrated that DR and optimal switching of capacitor banks are effective tools for a DNO to increase the HC of RESs. In order to quantify the benefits of the recommended method, the evaluations are carried out by applying it on IEEE 33-bus distribution network.

Impact of DER on Network Operation

Paper 0019 describes an approach for the inclusion of the influence of photovoltaics on annual network losses forecast enabling an efficient purchase of electricity to cover these losses. A cascade model, by dividing electricity network in different voltage levels, is used to estimate technical losses by creating typical PV generation profile based on global radiation data and a typical PV-unit. For each network level a relationship between the relative network losses and PV penetration level is established enabling forecasting of future network losses based on both the expected power consumption and the expected PV penetration level and ultimately enabling optimisation of electricity purchase strategy.

Paper 0137 describes the experience in distribution network operation under a high penetration level of renewable generation exceeding the maximum load three to six times. It describes measures taken to improve system operation stability: grid extension/reinforcement, reduction of planning reserves, intelligent control of reactive power, dynamic line rating, network switching to optimise topology for maximum feed-in power, transformer control, use of storage and generation curtailment.

Paper 0355 shows technical implications of micro-generation integration in low voltage distribution grids. It proposes connection design scenarios as: maximum consumption and minimum production, and vice versa. Two field solar micro-generation tests at two locations from the public transformer station are performed. It concludes that the voltage constraint violations might occur on feeders longer than 200 meters.

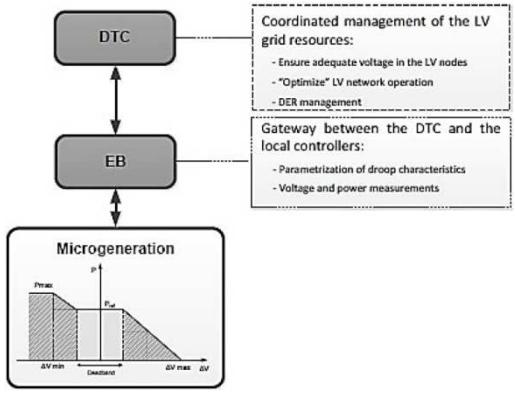


Fig. 2-2: Paper 0355 General overview of the LV grid control

Paper 0965 presents the steps taken by a DSO on constructing a coherent strategy for Smart Grid implementation. The paper also presents a study showing that significant penetration of DG can increase energy losses. Results show that, in case of studied network, the optimal penetration level is somewhere between 23%-50%. It concludes that the penetration level of distributed generation should be optimised rather than maximized because, at some point, the technical loses no longer decrease, but increase sharply.

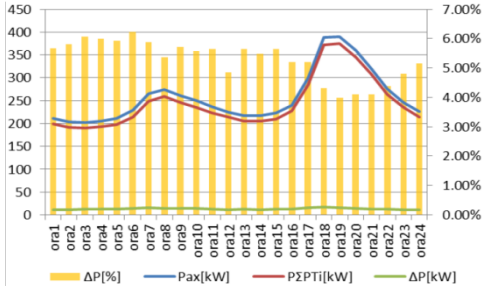


Fig. 2-3: Paper 0965 Calculated power losses

Paper 1365 presents a hybrid formulation to estimate and

identify Technical and Non-Technical Losses (TL and NTL, respectively) in distribution systems. It is based on the application of unbalanced Weighted Least Squares State Estimation (WLS-SE) and the anomaly detection (AD) technique. The results of the application of the proposed method to a test and real distribution system have shown promising results for both NTL and TL estimation and irregular consumers identification. The additional information provided by the AD method to the state estimator resulted in a decrease in the TL error estimation, which represents an improvement on the losses estimation. For this test system, the performance of the AD method for NTL identification has also shown satisfactory results. The authors expect that the proposed method could provide indication regarding the actions to be taken by utilities to reduce both TL and NTL.

Paper 0375 presents results from a study on variations in voltage magnitude at a timescale less than 10 minutes, driven by the variations in wind and solar production. The voltage variations are recorded in several low and medium-voltage sites. It is concluded that several solar panels connected to the same low-voltage feeder may lead to a noticeable increase in voltage variations. The voltage variations do change in character by the introduction of wind and solar power.

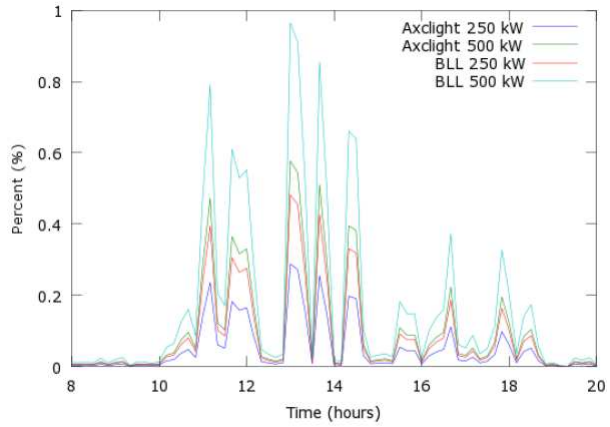


Fig. 2-4: Paper 0375 10-minute VSV-levels for different PV park capacities and cables

Paper 0393 statistically models the loads to derive probabilistic voltage and reverse power flow profiles of LV feeders with and without PV. It proposes a modified Herman-Beta method as well suited for the efficient calculation of voltage variations in standard open-access platforms.

Paper 1080 statistically quantifies the limit of Conservation Voltage Reduction schemes, due to voltage constraints, adopting a Monte Carlo approach on LV feeders during winter. The percentage of BS EN 50160 non-compliant supply voltage at customer connections for different values of voltage on the primary side of the LV transformer is quantified. Results show that to maintain this percentage below 1% the voltage on the primary side of every LV transformer should be maintained between 0.94 and 1 pu. The analysis is carried out on a real UK MV network where the maximum voltage reduction for a specific day is also quantified.

Paper 1082 investigates the impact of different control options of PV inverters in unbalanced low voltage networks on the network performance: voltage levels, voltage unbalance, neutral conductor loading and losses. The paper demonstrates that under unbalanced conditions, the maximum voltage, the phase spreading and the phase voltage imbalance factor can be reduced to a greater extent with the unsymmetrical control using the individual phase voltages than with the symmetrical controls. However, this results in a higher voltage imbalance factor under heavily unbalanced conditions and, in some cases, the normative 2 %- limit can even be exceeded.

Paper 1145 describes a new approach to control the voltage at the level of the MV/LV substations for a better integration of distributed production using a Regulated Distribution Transformer with embedded intelligence. It also describes how the solution has been extensively tested on several different network topologies with many different customer profiles. The main benefits of each solution described in this paper are summarised in the following table.

Benefits: / Solutions	System simplicity	Optimize cost	Upstream fluctuation (wind farms)	Downstream fluctuation (PV)	Inhomogeneous LV network
Traditional local regulation	***	***	**	*	*
Centralized regulation (DMS)	*	**	***	*	*
Remote point regulation	*	*	**	***	**
Solar sensor regulation	***	***	**	***	*
Line drop compensation	***	***	**	***	*
Monitoring of LV feeders	**	**	**	***	***

Islanding Mode of Operation

Paper 0598 compares the transient stability of the system when a three-phase to ground fault occurs of an islanded micro-grid with different forms of DGs. It shows that the presence of DG improves the dynamic performance of the micro-grid, and when the DG source is the unit with the energy storage, this improvement is potentially very significant as this device can absorb power rush caused by the fault and it will supply a reactive compensation to recover the voltage after the fault. The micro-grid with both storage unit and DFIG based wind turbine show stable transient performance.

Paper 0780 evaluates the effect of the DG on the uncontrolled islanding events in LV network, considering different LV load dynamic characteristics and inverter-based models. P/f and Q/V capabilities and regulation required by the DERs stated by the most relevant standards have also been considered. Field measurements and simulations in different environments are reported. The paper concludes that further investigation of dynamic characteristics of loads in providing fast voltage support, power system stabilization including synthetic inertia etc., would be needed in order to fully understand the dynamic phenomena of islanding operation.

Paper 0941 analyses approaches for detection of islanding mode of operation. It demonstrates weaknesses of passive methods for anti-islanding with conventional under/over voltage (UOV) and under/over frequency (UOF) protection, particularly when the frequency threshold is increased. The implementation of proposed frequency shift based control enables the protection to deliver improved anti-islanding performance compared to the passive method by increasing detection to 87.5%. The implementation of zero crossing detection to measure the frequency changes is demonstrated to provide the best performance (100% detection) of the anti-islanding with proposed frequency and voltage shift control activated, but it still could send false tripping command (13.3%).

Paper 1367 proposes an optimal fuzzy logic controller (FLC) for active power management in micro grid (MG). A new topology is presented to minimize frequency deviation in hybrid isolated micro grids, which involve wind turbines (WT), photovoltaic (PV), fuel cell (FC) battery energy storage system (BESS) and ultra-capacitor (UC). According to the proposed topology, WT and PV are primary power sources of the system, FC is used to provide long-term energy balance and finally UC and BESS are employed as buffer storage for the short-term compensation.

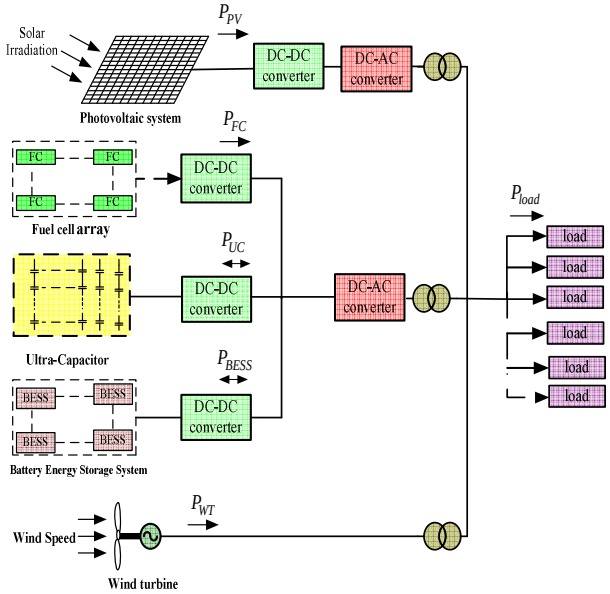


Fig 2-6.The New Scheme of the Standalone network

Virtual Power Plant and provision of ancillary services

Paper 0145 describes several open loop VPP operational strategies and simulates the impacts on a distribution grid. The following strategies are analysed: decoupled VPP, self-consumption optimization, schedule optimization, feed-in damping and primary control. Impact on grid is analysed in term of losses, voltage profile and utilization. In conclusion this paper opens a question of possible closed loop strategy with the possibility for providing ancillary services.

Paper 0390 tackles the question of what makes a particular smart grid project scalable and replicable. Technical, economic and regulatory & stakeholder-related factors that affect the scalability and replicability of smart grid projects are derived through the analysis of complex systems and smart grid projects. A case study is performed on on-going European and national smart grid projects in order to validate the key performance factors.

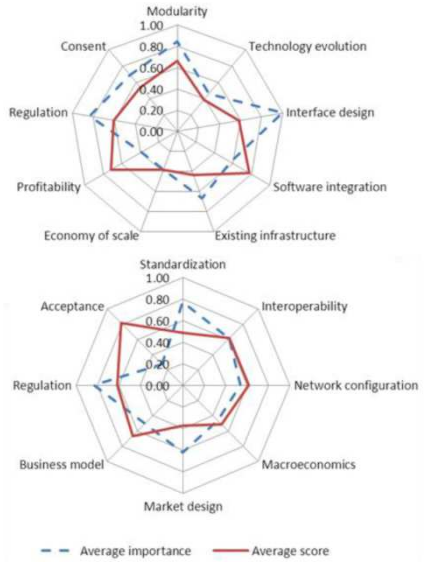


Fig. 2-7: Paper 0390 Average Score and Importance on factor level

Paper 0675 analyses the impact of grid supportive inverters on distribution feeders through hosting capacity. Three distinct smart inverter functions are selected and hosting capacity calculations are performed with solar PV operating with each control function. Paper demonstrates that smart inverter functions could significantly increase hosting capacity of large-scale PV.

Paper 1345 propose an autonomous DC microgrid system with distributed power exchange control to increase the utilization of renewables and to minimise energy curtailment in the event of a large-scale disruptions. Each house included in this system can continue to provide power to appliances from their batteries and solar panels even in the event of disconnection from the transmission system. In the paper, this system is called "Open Energy System" (OES). A year around analysis of an interconnected microgrid system is carried out using SRR and SOR and compared it to direct PV systems as well as standalone nanogrid systems. Furthermore, the OES system is analysed as a VPP feeding in electricity to the utility grid. Because of its modular open architecture it can develop gradually, one subsystem at the time, thus reducing infrastructural investment.

Paper 0654 summarizes the hosting capacity approach and gives some recent developments: including uncertainty in location and size of production units; curtailment to connect more production than according to the initial hosting capacity. For both developments it is shown that the transparency of the approach still holds but also that the results may be strongly location dependent. It is also shown that the hosting-capacity approach can be used to obtain rough estimations, rules-of-thumbs, and to make a first assessment in case more detailed studies are not feasible due to lack of availability of relevant data.

Paper 0721 discusses the potential for the supply of the ancillary services by generating units connected to the distribution grid, while considering the impact on local distribution networks. The communication between the DSO and TSO is argued to be necessary to manage the potential conflicts in delivery of ancillary services to support system balancing at the national level and local network constraints. It concludes that the basic requirement for efficient system operation in the future is to involve the DSOs in coordinating the control of demand-supply balance and network security.

Paper 0763 presents and evaluates different control strategies for a vanadium redox flow battery energy storage system (VRB). This energy storage device is integrated in the distribution network to prove its operation as demand balancing tool. A comparative study is carried out to analyse the impact of the control strategies developed in the charging/discharging patterns and state of charge of the battery. The simulation results show that the control strategies developed enable efficient energy usage, reduce the end user cost of energy and minimise the distribution networks equipment stress.

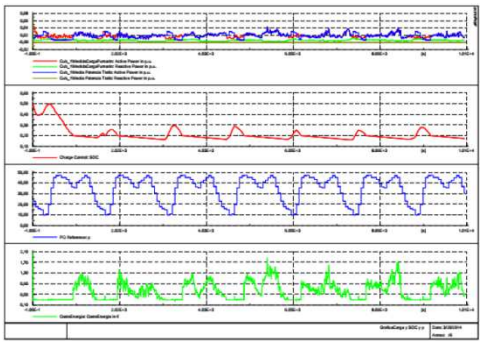


Fig. 2-8: Paper 0763 Modelling result for a strategy taking into account price signals

Paper 0964 presents the results of a case study in which power exchange between several MV-networks and the overlay HV-network is analysed. It is based on a remote control of the MV connected generators' power factors and the tap position of the HV/MV-transformers in order to minimise voltage deviations. An algorithm based on successive reactive power control is used for assessing the performance of the network across the entire year including consideration of energy losses.

Paper 1217 emphasizes the contributions of dedicated scheduling applications in order to enhance the reliability, performance and life expectation of the storage assets, based on the Nice Grid case, a Smart Grid pilot project. The supervision system for distributed Battery Energy Storage System (BESS) is able to provide coordination across a range of operation modes. The system coordinates several distinct business applications, which can be expressed as optimisation problems with distinct

objectives, constraints and time horizons. This study shows how innovative solutions of BESS management systems can facilitate the integration of the BESS into network system operation.

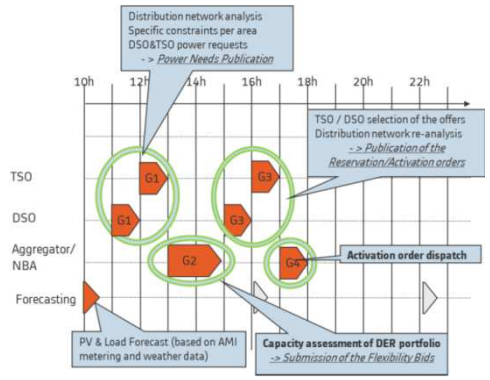


Fig. 2-9: Paper 1217 day-ahead process for DER flexibility scheduling

Paper 1340 describes a concept developed for the evaluation of innovative control concepts for frequency and voltage control, which consists of a network model, a distributed generation model and a control model. Various control strategies, for devices connected to the distribution grid to provide active and reactive power for frequency and voltage control, are investigated. It is shown that the combination of a centralised and a decentralised approach to can be effective in providing primary frequency control. The analyses of the voltage control concepts show that a centralised as well as a hybrid voltage scheme can be realised. The dynamic investigations demonstrate the application conventional and innovative solutions for the provision of ancillary service.

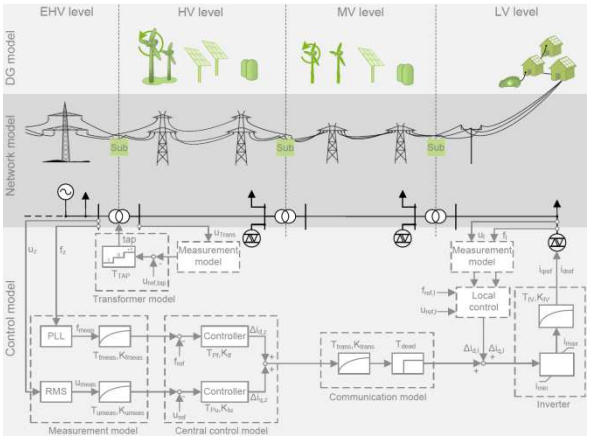


Fig. 2-10: Paper 1340 Simulation framework for DG (exemplarily for units connected to the low-voltage level)

Paper 1571 determines the optimum placement and size of energy storage sources (ESS) in electricity distribution networks using an optimization method. The simulation results demonstrate the considerable reliability improvement and loss reduction. An objective function includes SAIDI, SAIFI, ENS and energy losses. Then, genetic optimization algorithm is implemented to solve the nonlinear multi-objective problem. Simulation is carried out on two real and IEEE 33-bus test networks. Three scenarios that include the installation of one unit, two units and four units of ESS are analysed for each of the above networks. The results indicate that EES could significantly improve the network reliability and loss performance. It is noted that the effectiveness of the reliability improvement are reduced by increasing the number of sources. In other words, for installation of two units and more, the effects on reducing the mentioned indices decrease.

Paper 1611 proposes an analytical approach for adequacy studies of distribution networks in presence of vehicle-to-grid programs offered by parking decks. In this regard, a multi-state model is developed for assisting EVs in the parking to be used in emergency conditions. Both EVs characteristics and driving behaviours are considered in obtaining the assistance model of parking decks. Furthermore, reliability studies of distribution systems have been revisited taking into account this new auxiliary unit. It discusses how different reliability indices might be affected while results show significant improvement in the reliability performance of a distribution system enabled by EVs.

Hardware based network Analysis

Paper 0724 explains how distribution grid renewable integration and protection studies are conducted using a digital real-time simulator. Distribution grids are difficult to simulate in real-time because of the network. The SSN solver is an Electromagnetic Transient solver used to compute the time-domain solution of these large distribution networks in real-time. A real-life distribution grid is used to analyse the real-time performance of the SSN solver and to verify the protection schemes and protocols as well as to study the smart grid concepts required to run the grid effectively and reliably.

Paper 0827 investigates the angular stability of distribution systems, with multiple synchronous and asynchronous generating technologies, including increasing levels of penetration of wind and photovoltaic. A methodology to develop a reduced equivalent dynamic model, as well as a stability analysis of distribution systems is proposed considering a range of operating conditions and the characteristics of the traditional distribution systems. Given the inherent characteristic of R >> X, especially in rural feeders, even in systems with low penetration of distributed generation penetration, stability may be compromised. The proposed methodology indicates the need to represent the large distribution systems through smaller equivalent networks. The application of the methodology in a real system confirmed the need to evaluate the critical events in the

feeder trunk, but also the peripheral events, evaluating the operating times of the protection fuses. It is evident the need for Distributed Generation contributing reactive power support, in order to optimize voltage levels, especially during contingencies.

Potential scope of discussion

- State of the art and future approaches for effective DER/DG integration, including requirements for capturing DER/DG distribution network management potential
- Role and value of energy storage and business case for the provision of local and national level services
- Role of probabilistic techniques in assessing distribution network operational risks
- Understanding of the case for operating future distribution networks in islanding mode including role of new modelling to inform this proposition (hardware based network analysis)
- Role and business case for application of DC in LV and HV distribution networks
- Understanding the impact of DER/DG on network losses across different voltage levels including alternative loss reduction strategies.
- Interaction between DSOs and TSOs in facilitating application DER/DG to support distribution and transmission networks
- Technical, economic and regulatory factors that affect the scalability and replicability of smart grid projects

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0019: Impact of PV on distribution network losses				X
0137: Too much "Energiewende"? - How to handle massive growing DER				X
0145: Operational strategies of a Virtual Power Plant and their impacts on the distribution grid				X
0289: Technical and Economic Assessment of Integrating DG Resources into a Realistic Egyptian Distribution Network				X
0355: Technical Implications of Microgeneration Integration in Low Voltage Distribution Grids	X			X
0375: Very short variations in voltage (timescale less than 10 minutes) due to variations in wind and solar power			X	X
0390: Improving Scalability and Replicability of Smart Grid Projects	X			X
0393: Voltage profiles on LV residential feeders with PVEG using a practical, probabilistic approach				X
0449: A process to address electricity distribution sector challenges: The GREDOR project approach				X
0598: Fault Analysis of an Islanded Microgrid with Doubly Fed Induction Generator Based Wind Turbine				X
0601: Use cases for efficient network integration of Smart home PV				X
0654: The transparent hosting-capacity approach – overview, applications and developments				X
0662: Optimal centralized coordinated control for enhancing DER integration in MV distribution networks				X
0675: Smart Grid Inverters to Support Photovoltaics in Distribution Systems				X
0721: Study of Possible Provision of Control Power with Renewable Energy Facilities, with Respect to Restrictions in Distribution Systems				X
0724: Renewable integration and protection studies on a 700-node distribution grid using a real-time simulator and a delay-free parallel solver				X
0763: Price-based control strategies for electric energy storage system in distribution networks	X			X
0780: Generators and loads models to investigate uncontrolled islanding on active distribution networks				X
0827: Methodology for Analysis of Angle Stability in Distribution System with Distributed Generation				X
0941: Setting and Algorithm Simulation of PV Anti-Islanding Protection in Case of Increased Frequency Threshold				X
0964: Flexible reactive power exchange between distribution and transmission networks: Case study				X
0965: IMPACT OF DISTRIBUTED GENERATION ON DISTRIBUTION NETWORKS			X	X
1080: A Monte Carlo Assessment of Customer Voltage Constraints in the Context of CVR Schemes				X
1082: On the effectiveness of voltage control with photovoltaic inverters in unbalanced low voltage networks				X
1145: New approach to regulate low voltage distribution network				X
1169: Integrated Planning for Maximizing Renewable Energy Harvesting in Distribution Systems				X
1217: Coordinated Control of Dispersed Battery Energy Storage Systems for Services to Network Operators	X			X
1314: Technical and economic Impact of integrating EV in an insular distribution grid				X
1332: Decentralized and Centralized Approach in the Active Management of Distribution Networks: a comparison through business cases				X
1340: Distributed Provision of Ancillary Services	X			X
1345: The Open Energy System with Autonomous DC Microgrid				X
1365: Hybrid Formulation for Technical and Non-Technical Losses Estimation and Identification in Distribution Networks: Application in a Brazilian Power System				X
1367: A New Technique on Frequency Control in Micro Grid in an Isolated State with Improvement of fuzzy Controller by PSO Algorithm				
1414: Evaluation of the level of forecast errors and sub hourly variability of PV and wind generation in a future with a large renewable penetration				X
1475: Prospect of development of a LVDC electricity distribution system energy efficiency			X	X
1568: Distribution Network Hosting Capacity Maximization using Demand Response				X
1571: Electrical Energy Storage Resource Placement in Distribution Network to Improve Reliability and Loss Reduction				
1611: An Investigation of Reliability Impacts of V2G-Capable Vehicles in Municipal Parking Decks				

Block 3: Innovative Technologies and Solutions

Energy Storage

Paper 0081 investigates the impact of different storage use-cases on a low-voltage grid. It shows that storage systems for increasing the level of self-sufficiency in combination with photovoltaic systems can additionally offload the grid when being operated according to smart control algorithms.
Paper 0204 presents a sensor-less PV MPPT algorithm. It analyses the effectiveness of the set to nearly track the maximum available PV power without using any sensors in DC side. Finally the solution is promising but has a slower response time compared with the same set using sensors.

Paper 0298 investigates the mitigation of grid overloads and voltage deviations by the use of storage devices in low and medium voltage distribution grids with a high penetration of renewable sources, electric vehicle chargers and heat pumps. By using the proposed method, storage devices can satisfactorily take care of voltage deviations and overloads if they are located properly.

Paper 0525 presents that applying distributed storage technologies can avoid exceeding different grid limits. Hence, they enable a massive integration of regenerative generation units in distributed grids. A rather high capacity to power ratio for batteries is preferred for this matter. The decentralized coupling between the electrical and thermal system through heat pumps avoids transportation losses.

Paper 0792 proposes a functional architecture and an underlying optimisation method that aims at potentiating the participation of photovoltaic sources in spot and secondary reserve markets through an optimal utilisation of distributed storage capacity.

Paper 0983 presents the results of simulations exploring the role and performance of energy storage providing voltage regulation support in LV grids with high PV penetration. The studies find that the proposed approach is potentially valuable and that the assumed battery life and other specifics of the case study network have a strong bearing on the conclusions.

Paper 0988 also tackles the topic of energy storage in distribution systems with PV but from the perspective of power output uncertainty and generation export smoothing. Simulation results show the potential value provided by battery energy storage systems of different ratings.

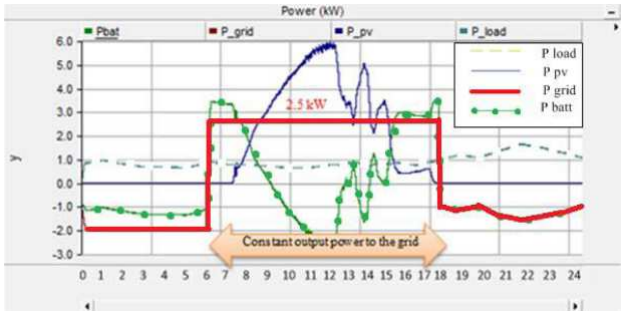


Fig. 3-1: Paper 0988 battery energy storage in grid power smoothing mode.

Paper 1424 presents the results of the development and application of an energy storage design methodology for the size, technology and control strategy for energy management. The objectives of the proposed methodology are supply reliability enhancement, energy trading cost saving and loss reduction in power distribution systems. Results show a range of outcomes for the best storage selection for a case study in rural Thailand.

Paper 1490 presents results of simulations on an MV/LV test grid of an Energy Storage System (ESS) control approach to provide multi-service regulation (i.e. different reserve and regulation services simultaneously). The results are a useful foundation for further work on regulatory and economic options for ESS including incentive schemes, energy tariffs and ancillary services remuneration.

DER and Network Management

Paper 0250 presents a reference architecture for the management and control of the distribution system designed in course of the EU project SuSTAINABLE deployed in a test site in Evora, Portugal. The architecture contains the main information flows foreseen concerning data between the several control layers and identifies control signals between the several network devices.

Paper 0251 describes a multi-temporal voltage control functionality that results from the combination of a solar power forecast method and an Optimal Power Flow (OPF) algorithm. It shows that an OPF fed by forecasts with high accuracy can solve voltage problems, while minimizing RES curtailment and control actions.

In paper 383 an approach to find the optimal capacity of non-firm windfarms that can be connected to the Isle of Anglesey distribution network (Wales) with angle constraint active management (ACAM) is described.

Paper 0485 presents a software architecture model aiding the integration of different components for active distribution grid to applications. The architecture has been defined using UML from a large collection of use cases specifications, class diagrams and sequence diagrams.

Paper 0532 presents a voltage controller able to manage complex optimization in order to get a proper interaction between the microgrid and the power system. It is shown that in the experimental testing the optimization goals are respected: voltage, currents and power factor at the PCC.

Paper 0940 presents laboratory test results of a composite load, state, and topology estimation process for distribution grids for situations where there are few measurements available. The advantage of the proposed methodology is that it is simple, computationally effective and is based on the widely accepted WLS estimation.

Paper 1028 presents results of solutions built within the Nice Grid smart grid demonstration project addressing Voltage Profile Management and Power Flow Management on distribution feeders with issues covered including modelling, shared data, and specifications of the calculation engine for steady-state network analysis.

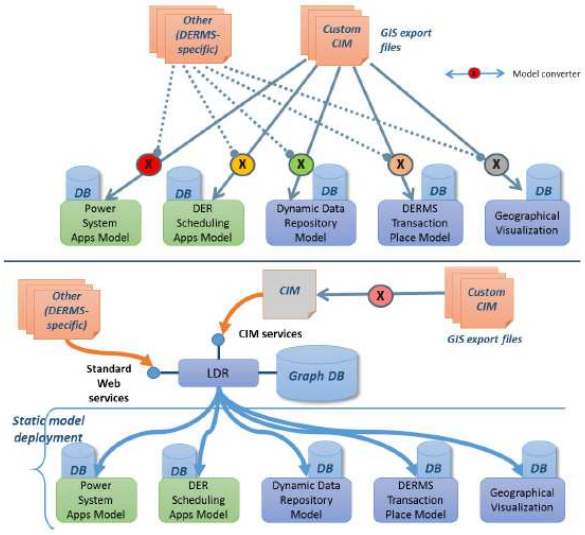


Fig. 3-2: Paper 1028 - DERMS Static Data deployment principles in Nice Grid.

Paper 1125 discusses the concepts of distributed agent-based operation of the distribution system. The potential benefits of scalability, modularity and robustness are discussed. The prototypal system has been tested in an integrated simulation environment and will be implemented on a test site in a French distribution grid as part of the European project DREAM.

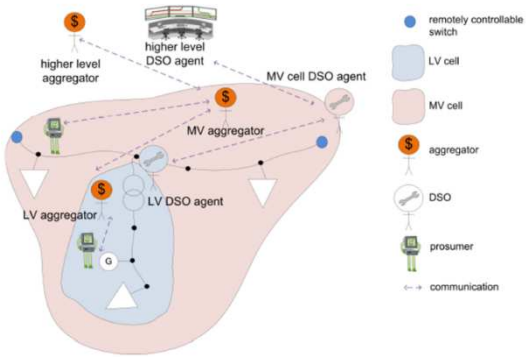


Fig. 3-3: Paper 1125 - Schematic representation of the proposed agent structure within a distributed control system in the DREAM project.

Paper 1519 presents results from the 'Smart Grid Solar' project which focuses on LV networks with a high penetration of photovoltaics (PV), solutions for voltage control and P/Q-management with by a storage device dimensioned and located especially for this purpose. The results show how and when it is possible to keep the network voltage profile within limits by means of reactive power management when the primary control of voltage through active power is constrained by P-rating.

Paper 1609 proposes a hierarchical control architecture for active networks that integrates centralised and decentralised approaches. A centralised EMS schedules the active resources for the next day while the intraday real time optimisation adjusts the day-ahead schedule to meet technical constraints. Results are presented for simulated test cases on Italian test network models from the ATLANTIDE project.

Testing

Paper 0318 defines a more holistic approach for the testing and validation process of active systems applied within power systems, which combines the dynamic behaviour of the equipment under test with the overall power system response. It presents methods such as co-simulation and power hardware in the loop.

Photovoltaics Grid integration and Inverters

In paper 0588, two dynamic reactive power control RMS-models for photovoltaic inverters are developed from and evaluated with laboratory measurements. Amongst others it can be shown, that a high gain mostly leads to unwanted results, while larger time constants can both be smoothing or inducing, depending on the

other parameters.

Paper 1559 presents results of the application of a streamlined methodology to assess the PV hosting capacity of distribution networks. The methodology balances the twin objectives of speed and accuracy and favourable comparisons with more detailed and time consuming analysis are presented.

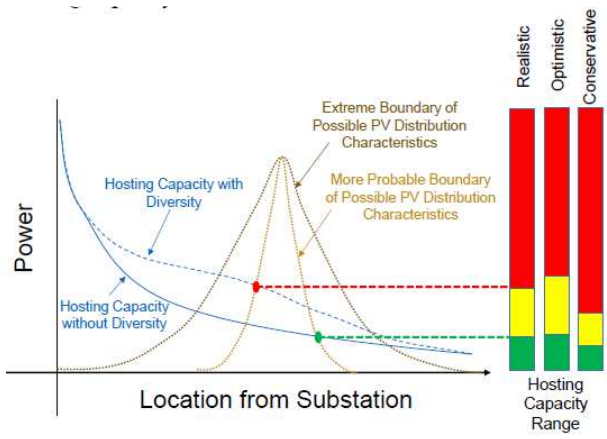


Fig. 3-4: Paper 1559 – Results from streamlined PV hosting capacity analysis.

Electric Vehicles

Paper 0681 describes smart charging methods and discusses the economic efficiency of electric vehicle charging optimization methods. With the smart charging optimization, the economic efficiency of a charging event can be increased for customer, electricity retailer and distribution system operator.

Paper 0932 shows how to overcome significant reverse power flow in the system during noon time causing voltage-rise problem by using the Plug-in Electric Vehicles (PEVs) storage in an LV distribution network. Results of the simulation show that the proposed strategy helps in mitigating voltage rise and the potentially destabilizing effects of intermittent solar PVs and also provides support to the grid during the evening peak.

Microgrids and VPPs

Paper 1267 presents an approach to Load Shedding to address P and Q power imbalance at the creation of power islands in a microgrid context. An evolutionary algorithmic approach to Load Shedding is developed and tested for a small (20MW) simulated 33kV system islanded at the connection to the 132kV system.

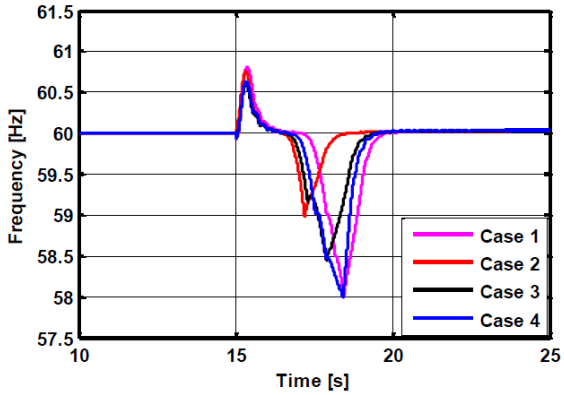


Fig. 3-5: Paper 1267 – Load Shedding impact on frequency at on islanding event.

Paper 1495 describes proof of concept testing of a Virtual Power Plan, local grid controller and Building Energy Management System market/auction approach to grid services provision. Results show that it is possible for buildings to change their behavior in response to incentives offered in advance. Internal processes like heat storage usage offer flexibilities that may be used for grid stability without interfering with user requirements if sufficient time between prediction and the occurrence of a problem exists.

Smart Metering and AMI

Paper 0782 shows how to integrate low voltage network supervision over existing advanced metering infrastructure (AMI) deployments. The paper concludes that LV network supervision solutions are a cost-effective alternative to increase the distribution grid capacity due to better control and monitoring of the LV grid. Several other applications such as LV network supervision can be integrated on top of AMI.

Alternative Power Distribution System Architectures

Paper 1137 sets out proposals for Active Customer Interfaces (ACI) as part of the ICT architecture for LV DC power systems. ACI is presented as an essential enabling element for customer load control as part of demand-side-management-related functionality.

Geographical Information Systems

Paper 1136 presents the case for alternative approaches to geographical location of assets to enhance accuracy. There are potential applications in power distribution Geographical Information Systems (GIS) asset information systems.

Synchrophasors / Phasor Measurement Units

Paper 1421 proposes applications of synchrophasor based protection, automation and control solutions to enhance the grid integration of DER – especially in the areas of power quality and ride-through requirements.

Potential scope of discussion

With several papers in the area of energy storage, what are the real prospects and timescales for energy storage being deployed to support network management objectives?

With several papers proposing different philosophies of network management in this block, is the divergence in competing approaches healthy or does this point towards lack of clarity on network objectives or the supporting technologies?

Does the relative lack of papers in VPPs and Microgrids show that these are now mature topics or else not fully accepted for commercial exploitation yet?

Are the capabilities of power electronics (e.g. PV inverters) still an untapped resource in distribution network control and operation?

Table 3: Papers of Block 3 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
81	Combined Operation of a Battery Storage System on Distribution Grid Level - Impact on the Grid and Economic Benefit		X		X
204	Realization of DC- bus sensor-less MPPT technique for a single-stage PV grid-connected inverter				X
250	Advanced System Architecture and Algorithms for Smart Distribution Grids: The SuSTAINABLE Approach				X
251	The Impact of Solar Power Forecast Errors on Voltage Control in Smart Distribution Grids			X	X
298	Mitigation of overload and voltage deviations using storage			X	X
318	A holistic approach to power system testing & validation				X
383	Benefit Quantification of Applying Angle Constraint Active Management on 33 kV Isle of Anglesey Network				X
485	The DREAM innovative software architecture for high DG-RES distribution grids				X
525	The importance of distributed storage and conversion technologies in distributed networks on an example of "Symbiose"				X
532	Perspective functions of LV microgrids: simulations and tests on the RSE's test facility			X	X
588	A representative model of the reactive power control system applied in solar inverters				X
681	Case Study: Economic Efficiency of Smart Charging in LUT Green Campus				X
782	Beyond AMI: LV network supervision over existing AMI deployments				X
792	Distributed Energy Storage potentiating the participation of PV sources in electricity markets				X
932	Meeting the Renewable Energy Target by the Integration of Solar PV and Storage in Distribution Network				X
940	Distribution Grid State Estimation using Load Pseudomeasurements and Topology Identification Techniques		X		X
983	Participation of storage devices for steady-state voltage management in LV grid with PV integration		X		X
0988	Improving of Uncertain Power Generation of Rooftop Solar PV Using Battery Storage				X
1028	Effective Distributed Resources Management System for Local Voltage Support				X
1125	Agent-based distribution grid operation based on a traffic light concept				X
1136	Use of consumer grade 3D visualisation technologies in asset management				X
1137	Finland				X
1145	New approach to regulate low voltage distribution network				X
1267	Analysis of selective load shedding applied to the operation of the intentional Islanding of distributed synchronous generators				X
1421	The Role of Synchrophasors in the Integration of Distributed Energy Resources				X
1424	Optimal Energy Storage System Design for Energy Management of PEA Distribution Systems				X
1490	Energy Storage Systems on distribution networks to provide multi-services regulation		X		X
1495	Proof-of-Concept for Market Based Grid Quality Assurance				X
1519	Positioning and Requirements on Voltage Controlled Energy Storage Systems in LV Power Networks with Distributed Power Generation				X
1559	Streamlined Method for Determining Distribution System Hosting Capacity		X		X
1609	Cooperative centralised and decentralised energy management systems for active networks				X

Block 4: Smart Grid Demonstrators

The scope of this block covers results from real world smart grid demonstration projects or from advanced studies in readiness for field trials in specific locations. .

Sub block 1: Integration of Distributed Generation

Paper 0021presents a scheme to facilitate the connection of Photovoltaic Power Plants. It analyses the response of the power plant under extreme conditions within the grid including faults and potential islanding. It is demonstrated that the tests provide assurance (to power plant and DSO) of safe operation under all conditions. The paper presents new insights into the actual interaction of PV power plants and the distribution grid.

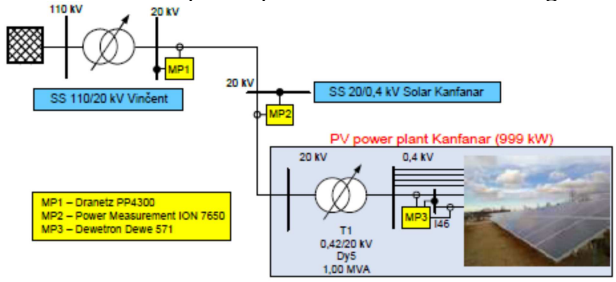


Fig. 4-1: Metering of PV Power Plant and Grid (Paper 0021)

Paper 0704 discusses findings from the modelling phase of a future demonstration project on Russky Island. The study sets out the modelling approach used to simulate the integration of Photovoltaic Power Plant and Energy Storage on the island. The simplified model is used to investigate the integration of active load. The possibility of using the active load under emergency situations is explored. The paper concludes that the simulation technique is highly effective and that the Russky Island will shortly become a demonstration location for such fuzzy logic and other intelligent control methods.

Paper 0806 provides a detailed technical description and explores the benefits of combining LV grid sensors and smart meter information to improve DSO awareness of grid status. The objective of the monitoring is to improve voltage regulation in circumstance of how or high PV generation output. The paper concludes that at times of high PV output/low demand voltage rise is a significant issue causing some generation to be shed. Future tests will attempt to demonstrate how individual PV invertors can be used to actively assist in substation coordinated voltage regulation to minimise export limitations.

Paper 1170 presents findings from the EU FP7 funded NICE Grid project. The Project deals with PV integration in LV networks. It implements a local flexibility mechanism to solve grid constraints employing devices on the grid and within residential properties. The author shares preliminary findings from trials in 2013 and 2014. The technique demonstrated is proving to be highly effective with the paper concluding that residential consumers are able to shift usage into times of excess PV generation.

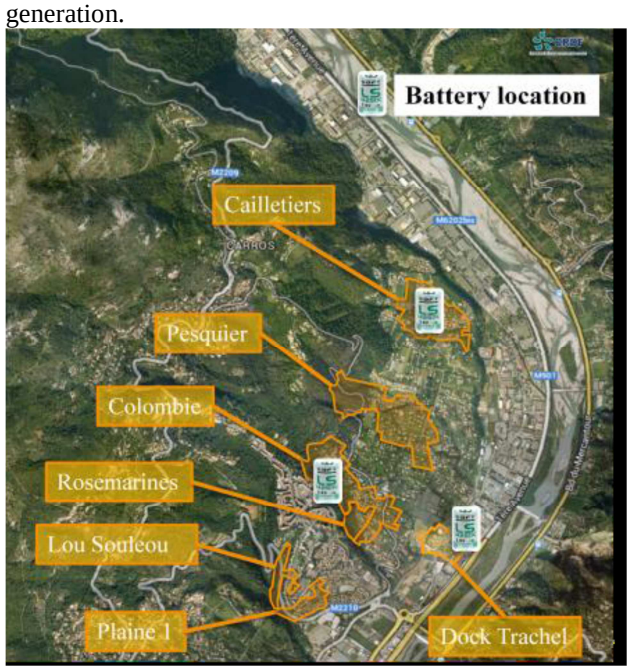


Fig. 4-2: Seven Solar Districts in the NICE Grid

Paper 1327 examines the network impact of solar PV and heat pumps on an urban distribution network. The paper explains the bottom up modelling approach used to assess the impact of the two low carbon technologies. The paper conclude that for heat pumps the primary concern is distribution transformer overload. The issues with solar PV on the other hand are voltage rise. The paper asserts that current UK DSO Engineering Recommendations may need to be reviewed.

Paper 1524 explores the potential benefits using distributed energy resources across Corsica to prevent blackouts. In particular the use of a 90kW biomass fuelled power plant and localised smart grid has been studied. The paper explores means to mitigate technical issues such as dynamic balancing whilst maintaining power quality. It explains the approach to islanding and re-coupling including the requirement to adjust protection schemes. Further lab tests are planned prior to the commissioning of the actual biomass fuelled generators in 2016.

Sub block 2: Integration of Active Demand

Paper 0106 presents details of the Open Smart Charging Protocol (OSCP) for electric vehicles developed on a successful field project in the Netherlands. The methodology builds on papers published at the CIRED 2011 and 2013 conferences which set out use cases, now demonstrated in the real world.. The OSCP facilitates the smart charging of EVs using a standardised messaging structure to state the current capacity of the grid. The paper concludes that the OSCP approach is effective and further can be simply implemented within vehicles of

charging infrastructure. Further it is noted that smart charging can be achieved without inconvenience to drivers of electric vehicles.

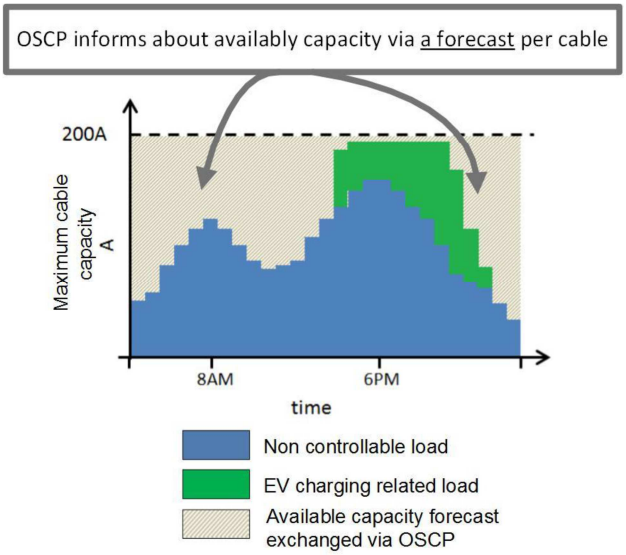


Fig. 4-3: Smart Charging of Electric Vehicles using OSCP (Paper 0106)

Paper 0505 investigates the performance of end user flexibility for consumers with second homes in Norway. Within the Hvaler region holiday houses are mainly used in the summer and for holidays such as Christmas. However, even when unoccupied the load can be substantial due to essential heating. The DeVID project demonstrated a local demand response concept utilising this heating load.

Paper 1124 discusses a collaborative initiative to develop a new approach and presents first results from a demand response trial in the Netherlands. Based around an industrial site the study used power flow data to estimate the loading at a HV/MV transformer. The companies selected to take part in the trial offered demand flexibility to prevent overloading of the transformer at times of high demand. Overall the project successfully demonstrated that demand response involving companies is effective.

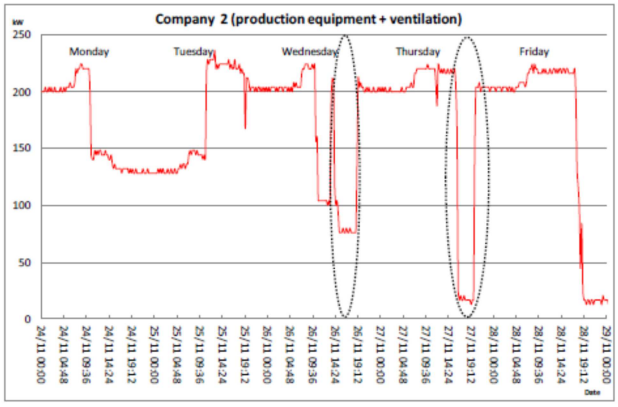


Fig. 4-4: Demand response pilot results (Paper 1124)

Paper 1362 explores the extent to which e-mobility incentives are appropriate on island territories. The paper highlights two projects aimed at optimising the economic and environmental impact of electric vehicles on Corsica and Reunion. The paper concludes that the environmental benefits of electric vehicles in such locations is highly dependent on the fuel mix for island generation. Thus alternative solutions such as smart charging and use of renewable energy/storage charge stations are necessary.

Paper 1613 summaries a series of research projects centred on the Salzburg region in Austria. These projects deal with the integration of renewables, electric cars, residential customer flexibility and building systems. The paper uses evidence from the research projects to highlight the increasing complexity of the distribution grid and asserts a need for comprehensive monitoring and new ICT systems

Paper 1634 summarises the main lessons learnt relating to active demand integration based on the EU funded large-scale ADDRESS project. The results include those from real world tests in Italy, France and Spain. The paper summarises recommendations from the project including their applicability to different market participants such as aggregators, consumers, DSOs and ICT providers.

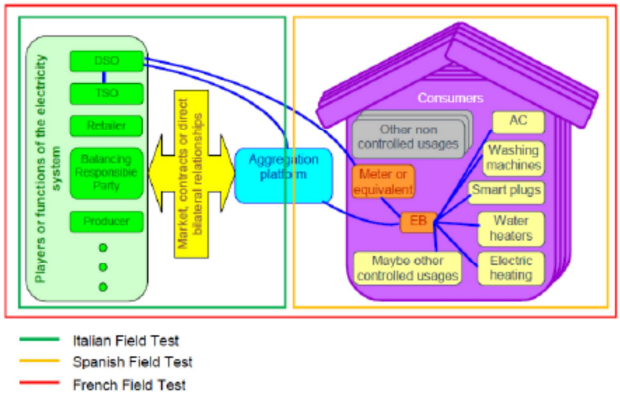


Fig. 4-5: ADDRESS Project domains (Paper 1634)

Sub block 3: Energy Storage

Paper 0244 introduces the concept and goals for EDP's first energy storage project located within the Inovgrid in Portugal. It describes the simulation approach used to determine the optimum size and location of the Electrical Energy Storage (EES). The paper also explains the technical tests carried out, the results of which support the hypothesis that EES are effective in contributing to DSO technical goals. Further it is able to provide such DSO support whilst assuring supply reliability to an end customer through backup power availability.

Paper 0333 studies the dynamic performance of a vanadium redox flow battery on an island network. The project is demonstrating the storage device on the Isle of Gigha which is situated of the UK's Kintyre peninsula. Preliminary results show that a containerised solution is well suited to such a location. Further project phases will

explore the economic benefits accruing to local residents in further detail.

Paper 0738 focuses on a 2MW/1.3MWh lithium ion battery commissioned during the early part of 2015 in France. It sets out sample results from factory tests which are informing the final installation and commissioning. Importantly the paper recognises the importance of the control system architecture in addition to the electrical integration issues.

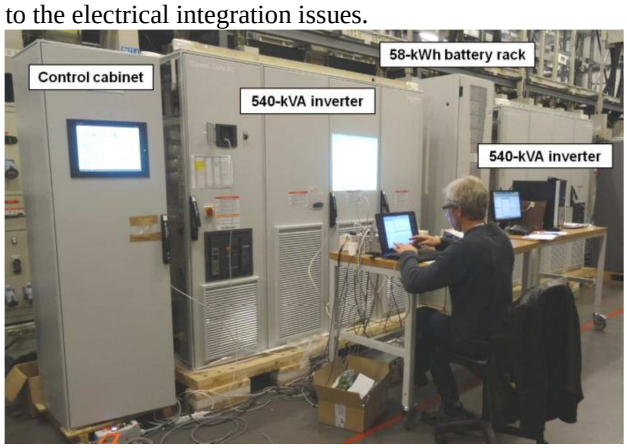


Fig. 4-6: Factory testing of electrical storage (Paper 0738)

Paper 0750 looks at another redox flow battery demonstration. This Spanish project had the objective of better understanding of new components for future generations of batteries as well has practical experience of integrating energy storage into distribution grids.

Paper 0824 presents the findings from a Low Carbon Network Funded (LCNF) project in the UK involving Europe's largest electrical energy storage project. The 10MWh/7.5MVA unit optimises performance across technical and economic objectives. The economic objectives are critical due to the high costs of battery storage compared to conventional solutions. The paper concludes that sophisticated forecasting can be used to schedule the battery for a variety of commercial services to DSO, TSO and others. Thus providing a route to achieve wide scale adoption.

Fig. 4-7: Large scale LCNF storage demonstrator (Paper 0824)

Paper 0142 deals with voltage regulation in low voltage networks with invertor connected photovoltaic and energy storage. It explores an effective control strategy to improve voltage profile and maximise the integration of renewables. It concludes that based on simulation experience that reactive power control can be effectively deployed to compensative for voltage rise, without reducing active power export.

Sub block 4: Control Systems for Active Networks

Paper 0447 summarises the results from field tests of a smarter distribution management system (S-DMS). The test network in South Korea included distributed energy resources (DER) including STATCOM and Energy Storage Systems. The architecture for the S-DMS is described together with the logic used for reconfiguring the network or controlling DER.

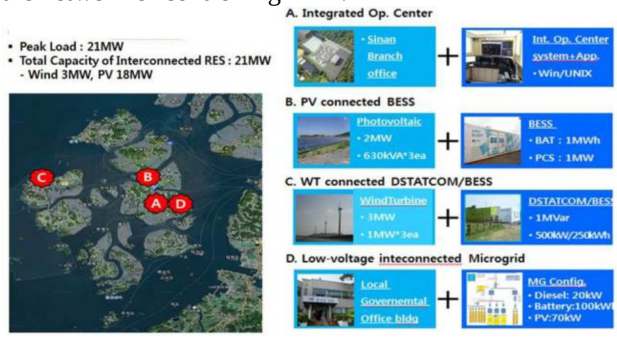


Fig. 4-8: Components of Smart DMS (Paper 0447)

Paper 0722 shares knowledge gained during a large smart grid trial in London. It focuses specifically on how an Active Network Management (ANM) system can improve security of supply as well as increasing the amount of distributed generation connected to distribution networks. The paper presents analysis that illustrates the potential benefit of using ANM in urban networks for this purpose.

Paper 0735 introduces a new active management scheme, where renewable generators are constrained using new technical solutions and commercial arrangements. The paper includes details of interoperability testing using IEC61850 protocols. It also explains the systematic testing necessary in order to prepare such systems for business as usual operation.

Paper 1111 introduces an ICT architecture and control scheme for the Smart Operator concept in Germany. Three sections of LV distribution grid have been equipped as well as a laboratory test bed. The system algorithm has been designed to cater for DER such as energy storage and consumer demand flexibility.

Paper 1246 presents finding from the same project as paper 0735 above. However rather than technical assurance it focuses on learning from operational and commercial trials. It aligns active control actions and implications to the Smart Grid Architecture Model (SGAM) helping to inform the most appropriate configuration for the system. The paper concludes that based on real world operation flexible connection arrangements are suitable for some generators.

Paper 1528 makes the case for a rethinking of the ICT tools and architectures in place for conventional and passive grid operation. It presents results from a project which developed a smart grid reference architecture.

Using middleware interoperability can be assured including access to information for supplier, aggregators, consumers and other market participants.

Sub block 5: Measurement and State Estimation

Paper 0834 investigates a potential solution for dynamic line rating based on a line's impedance. The paper explores three potential ways of estimating line resistance accurately and in real time. The paper concludes that none of the methods are sufficiently accurate for dynamic line rating applications, but does set out why this is the case and recommends further research and development.
Paper 1014 uses real measurements from three long term field trials in Austria to simulate control strategies for voltage regulation. The paper sets out how the simulation based on real measurement information could be used to control grid losses, reactive power flows and number of tap changes required.
Paper 1289 describes how load measurements from three newly built networks were used to study the impact of increased photovoltaic and heat pump penetration. Based on the measurements future constraints can be predicted. The project also created new sets of domestic customer profiles to assist DSOs in future investment planning.

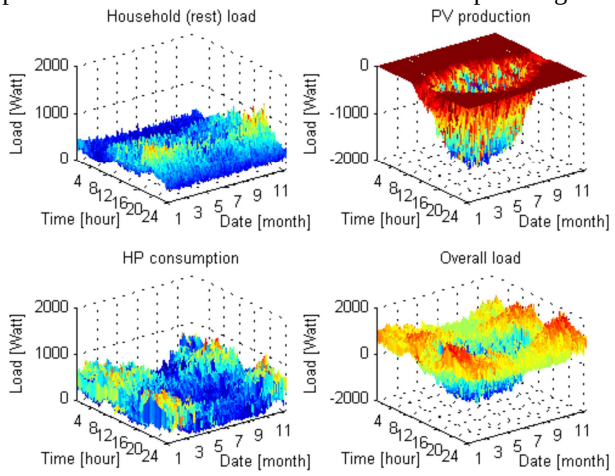


Fig. 4-9: HP, PV, Load and Net Demand Charts (paper 1289)

Paper 1375 presents a process to increase the reliability of weather based real time thermal rating systems (RTTR). Using graceful degradation principles to assess the risk of specific measurement points being unavailable Based on a trial network of two 33kV circuits in the UK the author claims that this methodology could unlock significant network capacity.

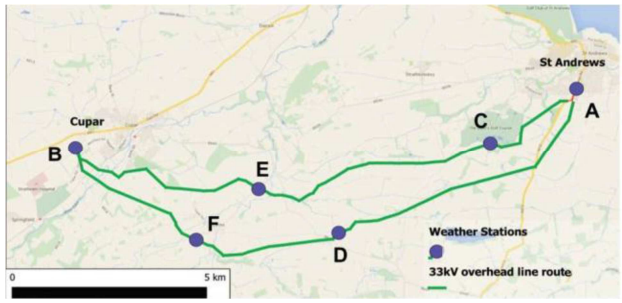


Fig. 4-10: RTTR measurement locations (paper 1375)

Paper 1497uses experimental data analyse ways to improve loss of mains protection systems using IEC61850 protocol. The test bed, a 20kV section of network in central Italy, is fitted with telemetry equipment at control centre, HV/MV substation, distribution substation and at customer premises with active demand. The paper concludes that this approach provides assurance for grid integrity given the rapid increase in low carbon technologies being deployed.

Potential scope of discussion

A significant number of papers in this block deal with energy storage technologies and their valued services. These naturally include distribution services such as peak shaving, increased utilisation of the distribution network, increased capability of DG accommodation, voltage and frequency regulation and power losses reduction. However the papers also recognise that the high cost of electrical energy storage will need other services to be provided including supplier balancing, market aggregator trading and benefits to end users through reduced import/increased export. Although the benefits of storage technologies have been sufficiently demonstrated in the paper 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.

Lower carbon distributed energy resource technologies, including PV, biomass generation and heat pumps constitute the topic of several papers. The topic of making effective use of these technologies for voltage regulation and system control occurs several times. The full enablement of such solutions will likely require new regulatory incentives, changes to standards and adaptation to grid codes. An interesting area of debate is whether the industry is sufficiently prepared for such changes. Is the Smart Grid revolution considered to be purely technical in nature?

It is encouraging to see new papers in this Session that build on those presented at earlier conferences. In particular seeing concepts progress through to the demonstration phase, some at a significant scale (and cost), is welcomed. Several papers also make use of real world results and measurements at the demonstration state as an input to further research and development.

The addition of the Active Demand topic to Session 4 remit has proven to be highly successful based on the number and quality of paper. This includes half a dozen projects at the demonstration or trailing stage, showing the importance of end use flexibility within future electricity networks.

Table 4: Papers of Block 4 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0021: Commissioning and trial operation of photovoltaic power plant Kanfanar (999 kW)				X
0106: OSCP - An open protocol for smart charging of Electric Vehicles				X
0244: EDP Distribuição's Inovgrid first Electrical Energy Storage project				X
0333: Development of a Vanadium Redox Flow Battery for Renewable Generation Constraint Mitigation				X
0447: Development and Field Evaluation of Smart Distribution Management System(Smart DMS) for efficient distribution network operation		X		X
0505: Using communities of summer houses as a winter time demand-response resource.				X
0704: Russky Island Microgrid: active demand emergency control problems				X
0722: Active Network Management facilitating the connection of distributed generation and enhancing security of supply in dense urban distribution networks			X	X
0735: Testing of a Deployed Active Network Management Scheme				X
0738: The VENTEEA 2 MW / 1.3 MWh battery system: an industrial pilot to demonstrate multi-service operation of storage in distribution grids			X	X
0750: Developing a redox flow battery with Spanish technology. Project Redox2015.				X
0806: Monitor BT pilot project: Combined voltage regulation approach for LV grids with PV penetration				X
0824: Scheduling power and energy resources in the Smarter Network Storage project		X		X
0834: Application and analysis of PMU-based online impedance measurement methods				X
1014: DG-Demonet Smart LV Grid - robust control architecture to increase DER hosting capacity		X		X
1111: Smart Operator, the project for the efficient control and monitoring of the low-voltage grid				X
1124: Demand response try out results on a business park in the Netherlands				X
1157: Providing Ancillary Services in Distribution Networks with Vanadium Redox Flow Batteries: AlpStore Project				X
1170: Integration of distributed PV generation: the NICE GRID project		X		X
1246: Operational Experience of using constraint management methods for connecting Distributed Generation				X
1289: Defining the Impact of Distributed Energy Resources based on Measurements				X
1327: Impact of solar PV and heat pump installations on residential distribution networks.				X
1362: E-mobility in the particular context of the French island territories				X
1375: Real-time thermal rating reliability enhancement using a graceful degradation methodology				X
1497: Transfer trip of Loss of Mains protections and logic selectivity by IEC 61850 protocol: an analysis based on experimental data				X
1524: Preventing blackout in Corsican village thanks to local Biomass generator				X
1528: Demonstrating active distribution grids and active demand				X
1613: The Smart Grids Model Region Salzburg - key findings, conclusions and claims of a DSO after several years of project work			X	X
1634: ADDRESS - Main lessons learnt and recommendations for the deployment of Active Demand		X		X