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SPECIAL REPORT - SESSION 4

DISTRIBUTED ENERGY RESOURCES AND EFFICIENT UTILISATION OF ELECTRICITY

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Introduction

Session 4 examines the challenges of adapting distribution networks to facilitate the integration of low carbon, renewable and distributed energy resources (DER). These include distributed generation (DG), energy storage, new loads (e.g. electric heating and electric vehicles), active demand, and aggregation of DER (e.g. Virtual Power Plants).

DER integration challenges feature in some way across all CIRED sessions so Session 4 specifically focuses on new concepts, emerging technologies and solutions, results from research, development or demonstration programmes, with results from network and system integration trials being particularly valued. Various DER integration and solution studies also feature.

Session 4 papers highlight the integration of DER within distribution networks through technical, commercial and regulatory solutions. Papers describe developments in network management, active demand side response, energy storage integration, network monitoring, telecommunications and data analytics and the role of DER in wider DSO business operations.

Session 4 Paper Evaluation and Selection

Session 4 received 242 abstracts and this has produced good quality and diverse contributions to the final conference proceedings where 127 full papers have been accepted and will be presented at CIRED 2021. The review process first selected abstracts on the basis of potential, clarity of contribution, quality and early stage content already in the extended abstract. The full papers were reviewed by at least two Session 4 members. Full papers were accepted based on value of contributions to Session 4 scope, well-founded on robust research, experimental and demonstration methods, well referenced, highlighted emerging topics and provided interesting ideas and insight to the CIRED community. The most novel research and innovation stage papers have been invited to present in the Research and Innovation Forum (RIF). The overall best quality papers have been selected for Oral presentation in the Main Sessions

Session 4 Special Report Organisation

This Session 4 Special Report provides summaries of all accepted full papers organized into four blocks as follows:

Block 1: “Modelling, Optimisation and Planning”

Block 2: “Flexibility coordination, markets and solutions”

Block 3: “Case Studies, Industrial applications and Field Tests”

Block 4: “Storage Solutions and Integrations”

The accepted papers are listed in tables in each Block and Poster, RIF and Oral presentation are noted there.

Finally, the Session 4 team would like to thank all the abstract and paper contributors for an excellent array of high-quality contributions that have been a pleasure to review and assimilate. We look forward to an excellent CIRED 2021 and have the chance to discuss these papers with authors and audience members.

The Session 4 Chairman and Special Rapporteurs would also like to thank the Session Advisory Group who played a very active and valuable role in abstract and paper review and who will support the Oral, RIF and Poster sessions at CIRED 2021 in September.

Block 1 – Modelling, Optimisation and Planning

- Sub block 1: Modelling
- Sub block 2: Optimization
- Sub block 3: Planning

Sub block 1: Modelling

Paper 0014 transforms reactive, load-serving, and outage-mitigation focused methods. It includes an integrated approach to develop sensor-rich and learning-ready system models, state estimation, optimal scheduling, and system-level control strategies for dispatchable resources.

Paper 0304 presents a study on how innovative approaches (multi-energy systems) and tools (cellular-based electrical networks with network reduction and the hybrid modelling framework HyFlow) can help overcome the challenges of a sustainable energy future. The results obtained show, that hybrid conversion technologies can be used to stabilize voltages and increase power quality.

Paper 0348 investigates the influence of the spatial distribution of voltage source converters with grid-following and direct voltage control in a medium-voltage benchmark grid is evaluated. The RoCoF and the frequency nadir in the overlaying low-inertia high-voltage grid are investigated in order to verify whether the spatial distribution and different control strategies should be considered when using aggregated models

Paper 0571 provides an update on the work by CIGRE Working Group C6.36: “Distributed Energy Resource Models for Impact Assessment” to identify a set of benchmark DER models for quasi-static time-series load flow (QSTS) simulations, increasingly used to evaluate active distribution system impacts and performance.

In paper 0584, a qualitative analysis of the impact of wind farm feed-ins (Power-to-Gas) into the gas grid is carried out on an illustrative case. A model is implemented for the analysis of transient gas flows in the pipelines.

Paper 0676 proposes a machine learning based e-vehicle (EV) profiling technique to better understand the information behind the random probability and irregularity of EV load. The proposed method considers the time-varying, dynamic character and the complex temporal correlation of EV loads. A series of different EV load profiles is created.

Paper 0696 proposes a heuristic to determine target demand thresholds using a linear programming model based on the site’s energy consumption profile from the previous year. Furthermore, the effectiveness of the obtained values is assessed through a detailed full-year simulation study. Compared to demand charge thresholds obtained from a simpler heuristic, this assessment indicates an additional saving potential of 10% for the microgrid energy bill.

Paper 0807 shows how the use of probabilistic forecasts instead of deterministic forecasts of the wind power production may improve the detection of congestion situations in the grid. Key challenge is to detect the unusual and sudden production changes that can create a constraint on the grid, in order to resolve a congestion problem that may appear.

Paper 0812 explores the dynamics of the daily peak demands of renewable energy communities under aggregation, as multiple countries are introducing capacity-based grid tariffs for residential consumers. Both the aggregation level and yearly consumption of the households comprising it are shown to have a significant impact on the timing of the daily peak demands.

Paper 0910 uses the LINK-based holistic architecture to extend the lumped model of low voltage grids by variable boundary voltage limits (BVL). This ensures internal limit compliance without involving safety margins when calculating and operating medium voltage grid. The BVLs are quantified for different test grids and the effect of the feeder properties on the limit deformation is identified.

Paper 0938 describes the use of quotas to manage predicted congestion and optimise the utilisation of the existing grids. The advantages and disadvantages of formerly used calculation methods and a refined quota calculation method are compared. The refined method will be implemented and validated in another comprehensive field test

In Paper 1081 a new features selection

framework is applied to satellite-derived information in the context of PV production forecasting. The proposed approach permits to select a subset of low-correlated variables, which ensure spatially distributed pixels around the power unit.

Paper 1121 proposes a model of electrical technification to improve the efficiency and sustainability of a shrimp company in Ecuador through the use of photovoltaic panels for shrimp production, which will determine whether or not it is sustainable for this sector

Sub block 2: Optimisation

Paper 0081 introduces a new modified optimization methodology called Modified Moth Flame Optimization Algorithm (MMFO) for determining the optimal Distributed Generation resources mix sizing and siting into the distribution networks. It provides significant outcomes regarding improving the voltage stability, minimizing the power losses and achieve a promising voltage profile enhancement with competent stability margin at all busbars.

Paper 0114 presents, a novel, simple, reliable and cost-effective intelligent power controller to be installed at the consumer side. The paper explores the impact of the proposed controller in peak load shaving and load shifting with consequent improving of energy efficiency and cutting electricity bills. Besides, it investigates its readiness for demand response programs applications and connectivity with the innovative cloud computing platform.

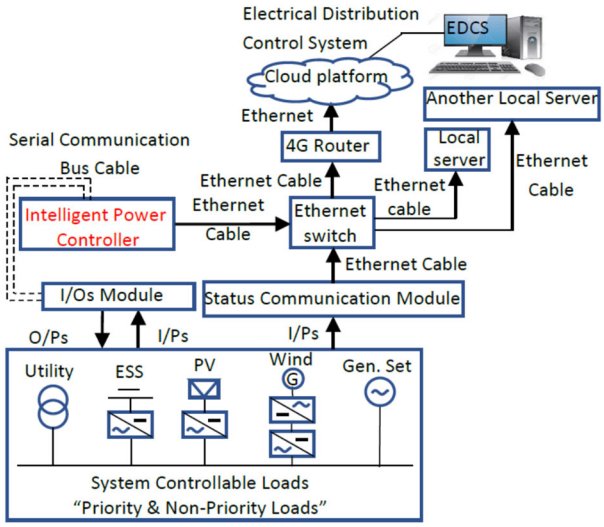

Figure 1: (Paper 0114) Power controller system schematic diagram integrating Microgrid sources

Paper 0231 firstly analyses the demand of 5G network and the difference between its 4G counterpart, then aims at minimizing the station backup energy and hence the operating cost of telecommunication company. This paper proposes the DC power feeding scheme and integrates the concept of virtual energy backup i.e., by connecting the 5G stations and energy storage to the DC network, the centralized energy storage act as an energy backup to the distributed 5G stations. The benefit of the proposed scheme is demonstrated by a full day simulation, and the result shows a very good energy and cost saving. The study has the extensive applicability and practical significance to both the research and construction of 5G dense network.

Paper 0286 introduces a strategy for optimal reconfiguration of MV distribution networks with photovoltaic systems using signals from smart meters and earth fault indicator to identify the faulty cable. Simulation studies are performed to investigate all possible scenarios for system restoration.

In paper 0465 a novel strategy for charging/discharging electric energy storages (EES) in a community structure which are designed to flatten the aggregate load curve in a smart grid. An evolutionary modified water-filling algorithm is supposed to optimally assign the recharged/discharged power of each EES in the scheduling time horizon.

Paper 0474 aims to minimize losses in distribution networks with a large share of wind

power plants by optimizing the reactive power flow through the distribution networks by controlling reactive power set-points of wind power plants using genetic-algorithm based optimization. The study is conducted on a real Danish distribution network, with a large share of controllable wind power plants, under varying wind and load conditions using actual measurements.

Paper 0594 presents a potential flexible reactive power service using an optimisation algorithm to determine the reactive power dispatch to increase load headroom, reduce network losses and manage network constraints. The analysis was undertaken using the optimisation algorithm for a range of operating conditions across 3 different Bulk Supply Point networks. With optimised reactive power dispatch, the networks provided headroom for the equivalent of 10,000 additional electric vehicles.

Paper 0601 proposes the participation of a local energy community (LEC) in providing flexibility services to electrical network. In this regard, the LEC is proposed to provide active power support for the distribution system operator in order to control voltage and manage the congestion of the local LV feeders. The LEC also simultaneously provides frequency containment reserves for normal operation (FCR-N) to the transmission system operator for system-wide flexibility needs.

Sub block 3: Planning

Paper 0010 introduces a tool to perform power tracing and neural network analysis to evaluate the network options and the impacts of losing multiple generators and the loads.

Paper 0111 investigates how, in the context of renewable energy communities, a collaborative framework can positively impact global electricity costs. A tool to optimally consider initial costs (investments) as well as operational daily costs has been developed. This is then used to compare both collaborative and individual frameworks. It is shown that a collaborative framework can lead to lower investments costs for the community members while ensuring a better impact on the network.

In paper 0212, effects of distributed energy resrouces (DER) integration in the distribution system are studied by the simulation analyses using the distribution feeder model based on the real demonstration project “smart community demonstration project in Miyako island”. It was shown that the voltage rise problem can be supressed by the DER control to reduce the reverse power flow from the PV systems.

Paper 0224 identifies the optimal allocation of Fault Current Limiters correlated with optimal allocation of DGs in radial distribution systems for minimizing power losses using Grey Wolf Optimization (GWO) via two stages procedure.

Paper 0259 presents the development and testing of a simulation framework for the analysis of multi-energy systems, which integrates network calculation software, supply and load scenarios as well as coupling technology models. The functionalities are presented in a case study, in which a co-simulation of a German electricity, gas and heat distribution system is analysed.

In paper 0306, Doubly Fed Induction Generators (DFIGs) are used as distributed wind generators. Optimal DFIG placement and sizing in a power system distribution network are determined by using the Non-Sorting Genetic Algorithm technique. Still, a reactive power dispatch remains a major challenge to improve voltage and reduce active power losses.

Paper 0312 uses a Trader Inspired Algorithm (TIA) for the optimal operating strategy of Distributed Generation units in radial distribution networks. It is used to find the optimal DG’s location, size and power factor to reduce power losses and stability index enhancement by employing a candidate multi-objective function.

Paper 0578 presents a novel approach to manage and implement advanced monitoring solutions in a flexible, scalable and intelligent distributed way using a distributed architecture based on an open cross-platform that can integrate and link smart nodes to the centralized SCADA system without the risk for data overflow. In addition, it presents functionalities that have been developed and integrated in a toolbox, which has been deployed into the open cross-platform

Paper 0695 presents the impact of EV integration in a real LV Portuguese urban network. It analyses the network loading, energy

losses, and voltage imbalances, under different scenarios of EV charging location and phase connection.

Paper 0700 introduces a tool providing a multi-layered interactive heatmap that will highlight the areas where demand for chargers is high and electricity network capacity is available. The tool designed to support a range of stakeholder groups in deploying the right public EV charging infrastructure, in the right place at the right time.

Paper 0710 presents a framework to analyse not only the potential impact of the integration of RES into the network but also to quantify their impact in combination with their respective control strategies which will be implemented when the devices are deployed at MV or LV. A scalability and replicability framework is presented providing a standardized approach enabling it.

Paper 0749 present the results of an extensive study carried out to assess the Power Quality present in grids that are heavily impacted by EV charging, and assess the compliance with the existing regulations, namely EN 50160 standard.

Paper 0874 describes the use cases designed, developed, and experimented aiming at the reduction of outages' frequency due to local overloads. A smart metering infrastructure and analytic services are deployed in a neighbourhood in Burkina Faso.

Paper 0979 presents a planning tool for low voltage photovoltaic connections. It shows a way to digitize LV networks, where the network model is entirely built from smart meters data. The resulting model can be used to precisely estimate the impact of any change in power, including new productions.

Paper 1084 discusses an approach to improve resilience at remote rural communities and a related case study. Aim is to employ microgrids that provide electric service capacity during blackouts. Once the microgrid is designed to meet the minimum reliability target of the critical facility, it can also be used for other secondary applications which increase the economic value that the microgrid offers to the customer.

Paper 1119 presents an open-source software tool called Distributed Energy Resource Value Estimation Tool (DER-VET) that can optimally size DERs for a given location and estimate the net life cycle cost of a microgrid over a given analysis horizon.

Potential scope of discussion.

The block describes techniques for understanding the impact of DER, and maximising its benefit. Discussion around the challenges of implementing a co-ordinated approach, given the number of stakeholders involved, could be encountered.

Table 1: Papers of Block 1 (Modelling, Optimisation and Planning) assigned to the Session

Paper No	Title	MS a.m.	MS p.m.	RIF	PS
10	Network evaluation with power tracing and visualisation tool				X
14	Innovations in sensor enabled modeling of future distribution systems with distributed energy resources	X			
81	Multi distributed generation categories integration into distribution networks via MMFO algorithm based on techno-economic benefits: a real Egyptian case study				X
111	On the optimization of investments in distributed energy resources in a low voltage energy community				X
114	Demand side management using intelligent power controller for large consumers				X
212	Effect of distributed energy resources integration in the distribution system				X
224	Bi level allocation procedure of distributed generators and fault current limiter sites in radial distribution feeders				X
231	An optimal power distribution scheme for the dense network composed of 5G base stations based on virtual energy backup				X
259	Assessment of multi-energy flow in coupled networks with power-to-hydrogen and power-to-heat	X			
286	Optimal reconfiguration strategy for distribution networks with PV connected systems				X
304	Equivalent cellular-based electrical network models for voltage regulation using hybrid conversion technologies at the medium-voltage level				X
306	Optimal reactive power dispatch of doubly fed induction generators to minimize active power losses				X
312	Optimal operation of electrical distribution networks including distributed generation units using trader optimization algorithm				X
348	Influence of the spatial distribution of grid-forming converter-based generation on the frequency support in a medium-voltage benchmark grid	X			
465	An efficient charging/discharging strategy for a community of EESs in a smart grid based on a modified water-filling algorithm				X
474	Minimize distribution network losses using wind power				X
571	Distributed energy resource benchmark models for distribution impact assessment – update of activities by CIGRE working group C6.36				X
578	ADMS toolbox providing advanced solutions to optimise the real-time grid operation				X
584	Application of dynamic simulation methods to the German gas transmission grid				X
594	Optimised reactive power dispatch to increase network's electric vehicle hosting capacity				X
601	Optimized operation of local energy community with				X

	flexible energy resources providing local and system-wide flexibility services for DSO and TSO needs				
676	Unsupervised machine learning-based EV load profile generation for efficient distribution system operation				X
695	Impact of electric vehicles in three-phase distribution grids				X
696	Optimal demand charge threshold tuning for economic microgrid energy management				X
700	Supporting EV infrastructure rollout using interactive network heatmaps				X
710	Functional scalability and replicability analysis framework for distribution grids	X			
749	Power quality impact analysis of different types of LV-connected EV charging stations				X
807	Use of quantile forecasts for better management of ORIs				X
812	Peak demand dynamics of LV consumers under aggregation and its impact on upstream PV injection	X			
874	Modelling and control of the low voltage network with smart-meters to improve the reliability of supply in Burkina Faso, the Africit-e project				X
910	“Boundary voltage limits” – an instrument to increase the utilization of the existing infrastructures				X
938	Avoiding congestion and optimising grid utilisation - an advanced multilevel quota realised in a comprehensive smart grid demonstrator				X
979	New planning tool for low voltage photovoltaic connection – large scale experimentation	X			
1081	Short-term photovoltaic generation forecasting enhanced by satellite-derived irradiance				X
1084	Optimal microgrid design for community resilience improvement and stacked benefit analysis				X
1119	A planning tool to valuate resilient microgrid design				X
1121	Proposal of an electric technical model for the improvement of efficiency and environmental sustainability in shrimp production				X
Total		**6**			**31**

Block 2: "Flexibility coordination, markets and solutions"

Paper 0044 describes the potential usage of electric vehicles (EV) in providing ancillary services based on V2G technologies, with a focus on the estimated ancillary services demand for 2030 (automatic frequency restoration reserve – AFRR and manual frequency restoration reserve – MFRR). It also analyses how local grid constraints might impose limitations on the provision of those ancillary services.

Paper 0164 presents a methodology that enables to decrease the complexity of modelling grid constraints, through a clustering algorithm prior to grid modelling, when assessing the usage of dispersed flexibility, tested with DSOs from the German state of Baden-Württenmberg, with reproducibility and scalability issues considered. The results also demonstrate that grid topologies can have a decisive influence on the redispatch potential of flexibility at the PCC between DSO and TSO.

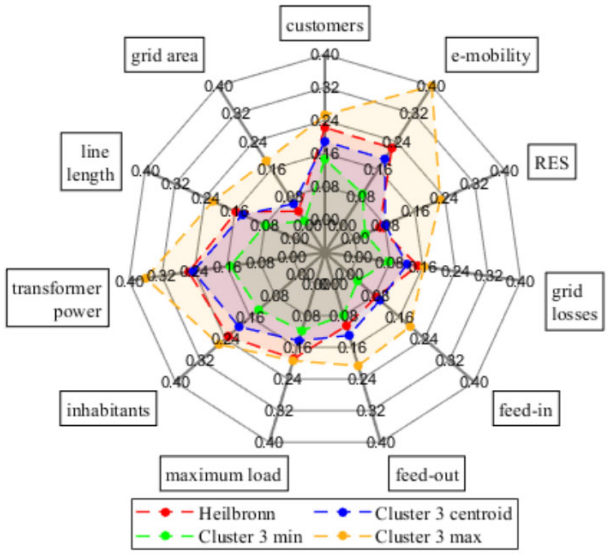

Figure 2: (Paper 0164) Spider web used to plot the characteristics of each DSO (shown for one typical DSO and for cluster 3)

Paper 0267 introduces a smart energy management of multiple BESS types, for aggregators, considering contracts established with the DSO and battery degradation, in systems with PV production. The methodology developed sets an optimum operation set of the BESS, considering the trade-off between profit and lifetime of the BESS.

Paper 0310 discusses the detailed, dynamic modelling of distribution networks with large amounts of DER, through equivalent grey-box models which retain the characteristics of lower voltage levels. The paper presents three different approaches for the required modelling depth of those systems.

Paper 0341 presents TABEDE, a solution for demand response for buildings developed under a 2020 Horizon R&D program. It controls and optimizes building loads in response to grid signals, also being able to forecast and optimize energy consumption, incorporating DER requests.

Paper 0373 describes 2020 Horizon R&D project DOMINOES, aiming at the development of an integrated operation and management of local markets in the energy market environment, enabling the usage of flexibility and energy potential, which could not be fully exploited under isolated local markets.

Paper 0385 introduces a case-study in Austria associated with flexibility scheduling of distribution systems, associated with a 2020 Horizon R&D project. Flexibility is used based on BESS, EV and residential building energy management systems to maintain voltage level on each bus within ±2% of the nominal value, through a scheduling system that incorporates uncertainty and demonstrated on a distribution network.

Paper 0409 describes a flexible load management pilot project developed in Portugal associated with the management of residential electric hot water systems. These heaters were used for peak shaving, with the goal of assessing the potential for DSO investment deferral. The pilot demonstrated a positive business case associated with the installation of devices guaranteeing the usage of the flexibility potential associated with water heaters, which also can reduce residential peak loads.

Paper 0441 discusses the opportunity for households with DER of providing bottom-up services through aggregators – and how the simultaneous provision of energy supplied by DER might violate the design limits of distribution networks. The paper proposes the usage of operating envelops (individualised time-varying limits to the energy exported) to

guarantee network integrity. These envelops are broadcasted to DER aggregators, which used them to manage the portfolio. Results were simulated on a MV-LV network.

Paper 0488 provides a Hardware in the Loop (HIL) simulation example of a microgrid, allowing an extensive testing in laboratory conditions performed by Schneider, before actual deployment in India. The simulations done through HIL allow to test complex architectures, validating the microgrid controller before on-site implementation.

Figure 3. (Paper 0488) Overview of genset human-machine interface

Paper 0492 develops a solution for the integration of microgrids and their observability and control by the DSO, able to interface with the PV inverters associated with residential rooftop systems. The approach will empower LV dispatch centres, fostering the usage of flexibility in the grid. The presented project contemplated two pilots in Portugal, with promising results.

Paper 0516 presents a technical demonstrator of the usage of EV charging stations with BESS to provide flexibility services in Frequency Containment Reserve for Disturbances and Frequency Containment Reserve for Normal operation in Finland, presenting the potential revenue associated with service provision and an estimation of activation time frames.

Paper 0519 describes results from the Italian demonstrator of the H2020 R&D project SysFlex, in which smart grid devices are integrated with SCADA to provide flexibility both to the TSO and the DSO on the ancillary services market, considering constraints. The demonstrator used PV generators, BESS, on-load tap changers and STATCOMs (static synchronous compensators).

Paper 0546 presents the results from H2020 R&D project BD4NRG, making a case for federated learning – a decentralized machine learning technique –, of flexibility prediction in smart grids, addressing the intermittency challenge. The paper concludes that federated learning is a promising approach for building privacy-preserving energy portfolios of aggregated demand data.

Paper 0586 describes a study of flexibility service mechanisms in active distribution grids, considering the operational (P, Q) capabilities of DER inverters in Germany. It assesses the cost-optimized and (N-1) feasible operating points, visualizing flexibility resources in a real-time situation, considering also restrictions on the calculation time associated with the flexibility service mechanisms used.

Paper 0591 discusses the grid integration of DER, addressing the connection of wind and solar power plants according to the European Network Code requirements, adapted to the Portuguese electrical system, through simulation studies evaluating the plant performance, prior to the connection with the grid of those plants. The developed methodologies are based on dynamic digital simulation and a case-study of the application is also presented.

Paper 0598 introduces the R&D project NYSERDA, associated with the New York distribution system, developing the concept of flexible interconnection capacity solutions, with active management of DER output to avoid network violations. Assesses the trade-off between lost PV production and interconnection cost savings enabled by the DER management system. Also presents simulation results for various scenarios and sensitivities, identifying when the concept is more valuable.

Paper 0610 discusses how to reduce the risk of penalty costs faced by aggregators, associated with imbalances when pooling several RES in regions with frequent grid congestion, through flexible DER systems, whose flexibility constraints are communicated day-ahead.

Paper 0678 presents a comparative analysis of the curtailment rules for flexible DER. LIFO and pro-rata schemes are compared from several perspectives, including capacity factors and

network utilization, including considerations on the role of sensitivity factors.

Paper 0682 describes an offline simulation platform developed under H2020 R&D project SysFlex, to test in realistic conditions the energy management system software for operating an VPP, with an industry-scale demonstration. The demonstration aims at optimally operating a VPP to provide multiple services to the system, simulating 1-second behaviour of the system, from one day to several months.

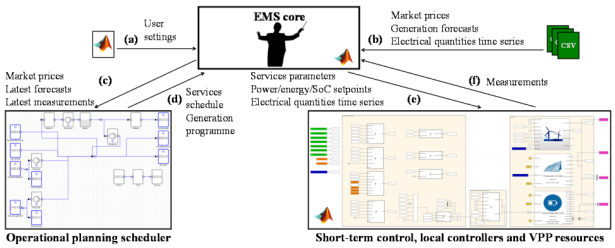

Figure 4: (Paper 0682) The proposed offline simulation platform to test the Energy Management System

Paper 0688 proposes common services attributes, for DER-provided distribution grid services, which can be used by distribution planners to characterize the location, timing and magnitude aspects of a distribution service opportunity. It also discusses performance verification, on an EPRI-led working group supported by the U.S. Department of Energy.

Paper 0726 presents three coordinated EV charging algorithm, preventing the appearance of overloads on LV grids. The algorithms differ in the number of control signals they specify: the usage of one global control signal, on control signal per feeder, or one per charging station. The performance of each algorithm is then compared. The more individual control signals are specified, the lower the average charging time.

Paper 0756 introduces a DER integration solution in the aggregator platform for the optimal participation in the wholesale and local electricity markets, through an optimization model. The model enables the consideration of dispatchable and non-dispatchable DER, as well as BESS, also enabling the participation of the resources in the wholesale market through a bi-level programming approach.

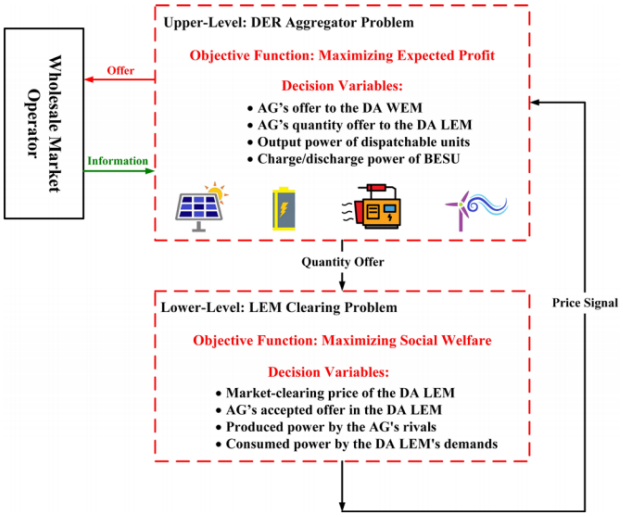

Figure 5. (Paper 0756) Bi-level decision-making framework

Paper 0790 describes a flexible grid-connected microgrid which participates in energy and ancillary services markets, considering different variables (uncertainty of energy prices, wind speed, solar irradiation and call for ancillary services provision).

Paper 0868 discusses the secure communication with decentralized prosumer applications through home area networks and wide area networks, considering the aspects of responsibility and definition of boundaries of the ICT network.

Paper 0899 presents a study, based on Finland data, on the behaviour of domestic electrical heating systems with spot-based price signals. Concludes that electric heating or cooling consumption may not change, considerably, peak loads in the distribution grid level.

Paper 0906 describes sector-coupled energy (multi-commodity) systems, using flexibility of smart DSM, developed through a German-Finish R&D project, FUSE. It uses AI-based DSM methods to increase the resiliency of distribution grids, considering multi-energy applications and local network conditions, evaluated in laboratory.

Paper 0948 introduces the H2020 R&D project Coordinet, analysing power flexibility at different voltage levels, with the aim of demonstrating how TSOs and DSOs can act in a coordinated manner, purchasing and activating system services, enabling the integration of DER in the market. The paper describes the Greek

demonstrator, which developed a local market enabling the reliable operation of distribution grid and the active participation of DER in flexibility markets.

Paper 0970 considers the impact of ageing assets on distribution network locational marginal costs, focusing on the quantification of ageing as a short-run network variable cost, influencing optimal DER scheduling.

Paper 0986 discusses the optimization of load demand response in support of the national grid, through a methodology developed and implemented in the North West distribution networks (UK), through the fast reserve market. The paper describes the branch-and-bound based optimal strategy to improve load demand response, whose results are compared with the rule-base method, concluding that the optimised method improves load demand reductions, helping the TSO to mitigate frequency drop due to low generation production.

Paper 0988 presents the H2020 R&D project IElectrix, dedicated to demand response and customer engagement, with a demonstrator set up in Delhi to explore innovative solutions allowing the implementation of local energy communities with PV and BESS. Analysis behavioural response of residential consumers to peak pricing.

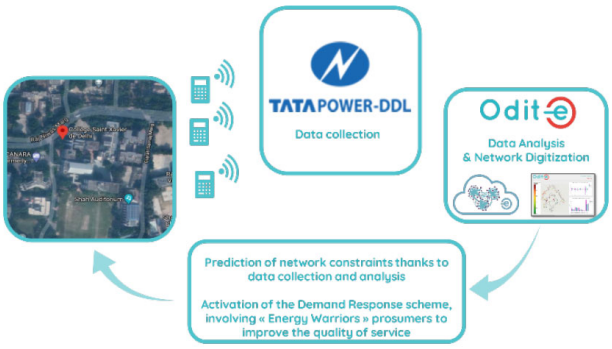

Figure 6. (Paper 0988) Global architecture of Odit-e & TATA Power Delhi Distribution cooperation

Paper 0998 describes an assessment of the impact of reliability on the provision of operating reserve from smart grids. Examines the conditions for the provision of operating reserve, considering the reliability of the grid and congestion management measures. Concludes that current grid usage and generation technologies have an impact on reliability and operating reserve potential.

Paper 1064 compares a local versus centralized control of flexible loads in a power grid. Three different strategies for controlling EV charging, based on grid frequency, are compared: 1 utilizing DSO's existing metering infrastructure; 2: using centralized measurement with dedicated flexibility server; 3: using local measurement and control. Concludes that dedicated systems built for EV charging power control offers faster response, better reliability and control.

Paper 1112 presents a risk-based framework that automates management of the demand side response between consumers and DSO, based on a fuzzy-logic controller optimizing the usage of consumers' assets. A case-study is presented, involving an unexpected increase in EV penetration causing grid overload. The risk-based methodology successfully mitigated the stress in the grid, meeting consumers expectations regarding EV charging. The project was supported by the U.S Department of Energy.

Potential scope of discussion

Flexibility topics are still novel, involving several concepts and simulations optimizing the potential usage both from a consumer and from the system perspective. Flexibility is a crucial tool to support energy transition technologies and will mature, in order to be used as a network planning tool, used as an alternative to network reinforcements, while also guaranteeing systems stability through ancillary service provision to the system.

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0044: Evaluating the potential of future e-mobility use cases for providing grid ancillary services	X			

0164: Influence of clustered distribution grid characteristics on redispatch potential of dispersed flexibility	X			
0267: Smart energy management of multiple battery types for aggregators use considering negotiated contracts with the distribution system operator and battery degradation				X
0310: Impact of the modelling depth of distribution grids on the accuracy of aggregated distribution networks				X
0341: TABEDE: A new solution to advance demand response, clean energy and cost savings				X
0373: DOMINOES – a roadmap to integrated local energy market operation and management				X
0385: Flexibility scheduling for distribution systems: A case study in Austria				X
0409: Flexible load management: How DSOs can benefit from energy efficiency plugs for water heating management				X
0441: Bottom-up services & network integrity: the need for operating envelopes				X
0488: Hardware in the loop for microgrid control validation in IELECTRIX project				X
0492: Centralized observation and control of rooftop photovoltaics				X
0516: Demonstration of reserve market operation and local flexibility in a smart office environment			X	
0519: Set-up of a new coordinated process for ancillary services provision from DSO to the TSO: an innovative approach to the exploitation of flexibilities connected to the distribution grid				X
0546: Flexibility prediction in smart grids, making a case for federated learning	X			
0586: Development of a flexibility service mechanism for the determination and exploitation of flexibility in active distribution network through parallelized optimal power flow calculations	X			
0591: Grid integration of renewable energy power plants according to the Portuguese regulation				X
0598: Techno-economic value of DERMS for flexible interconnection of solar photovoltaics				X
0610: Provision and value of flexibility for reducing financial risks caused by prognosis uncertainties				X
0678: Rules of curtailment for flexible DER connection: A comparative analysis				X
0682: An advanced offline simulation platform to test in realistic conditions the energy management system software for operating a virtual power plant	X			
0688: Distribution grid services: Requirements, procurement, and performance assessment				X
0726: Coordinated electric vehicle charging – performance analysis of developed algorithms				X
0756: Integration of DERs in the aggregator platform for the optimal participation in wholesale and local electricity markets			X	
0790: Optimal microgrid participation in coupled energy and ancillary services markets considering uncertainties using CvaR approach				X
0868: Considerations on communicating with decentralized prosumer applications through home area network and wide area network				X
0899: Will the SPOT-price-based demand response overload the distribution network?				X
0906: Sector-coupled energy systems using the flexibility of smart DSM				X

0948: Coordinet project: Unlocking power flexibility at different voltage levels				X
0970: Impact of transformer and cable aging on distribution locational marginal costs in active distribution networks				X
0986: Optimisation of load demand reduction response to support national grid				X
0988: Ielectrix project – demand response and customer engagement in Shakti demonstration	X			
0998: Assessment of the impact of reliability on the provision of operating reserve from smart grids				X
1064: Local versus centralised control of flexible loads in power grid				X
1112: Risk-based residential demand side response				X
Total	**6**		**2**	**26**

Block 3: "Case Studies, Industrial Applications and field tests"

Paper 0045 presents a comparison of deterministic, stochastic and time-series methods to assess the PV hosting capacity networks. Differences between the scientific and industrial application of the hosting capacity methods are discussed. The paper concludes it is not possible to point at a method as the most suitable one for quantifying the hosting capacity. To point at such a method would require an exhaustive application of the methods to a large number of the low-voltage distribution grid and a qualitative comparison of the results.

Paper 54 describes a project in Innsbruck that trialled a hybrid grid with a focus on shifting the needs for heat production and heat consumption. The main goal of the project was the development and implementation of an energy management system to fully automate and optimize cross-sectoral energy flows. Based on generation- and consumption forecasts, an algorithm creates optimized schedules for the individual units and storage facilities, saving 310 tons of carbon dioxide emissions annually compared to the previously installed natural gas fired heating system.

Paper 59 presents the results of studies into the impact of an energy return system for efficient management of regeneration in modern metro railway networks. This system will be capable of returning the regenerated train braking energy from the metro network to the 20kV distribution grid that is otherwise wasted in on-board braking resistors in the form of power losses (heat). It determines yearly cost savings of the order of € 1 m / year for the case of a 12.9 km line with 15 stations, proving a viable energy return system for implementation.

Paper 068 presents the application of dynamic rating to increase the available transfer capacity and to enable increased EV charging capacity. Through stochastic calculation the hourly available capacity is estimated and then used to calculate the hosting capacity. In this sense, the probability of overloading considering different EV types is calculated. The results show that the probabilistic hosting capacity would be a better indication to estimate the minimum and maximum EV load demand in the coming hours.

Paper 116 examines utilisation of EV Charging flexibility to reduce grid constraints. Most of the time charging flexibility is not required for grid support, so it can be used for a spot market optimized energy procurement. By calculating the load flow based on the cost-optimized charging schedule, the impacts on the extent and number of critical grid states of two low voltage distribution grids for the year 2050 are presented. The implemented charging management system is able to solve all critical grid states. Based on that the effects on the energy procurement savings for a charging point aggregator manifest themselves in a decrease of 5 % on average in comparison to the optimization without taking into account the grid constraints.

Paper 118 describes how to face the challenge of interoperability between microgrid components based on the coming IEC 61850-7-420 object model standard, especially for meeting IEEE 1547 and EN 50549 grid code requirements. A specific focus explains how to benefit from the IEC 61850 based data models in non-IEC 61850 based systems and highlights the potential benefits.

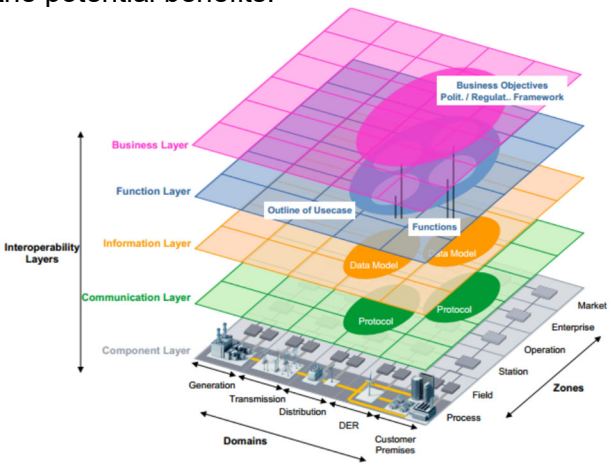

Figure 7. (Paper 118) Smart Grid Architecture Model

Paper 148 also discusses the challenges and opportunities associated with the entry of CPOs into the flexibility trading domain. A CPO situated in Norway - a country with a particularly high electric vehicles (EVs) uptake rate - is used as a reference case for the investigations carried out, thus ensuring the high relevance and real-life applicability of the discussed topic, strengthening the future role of CPOs as flexibility aggregators and help adapt the market

environment to ease the participation of CPOs as flexibility providers.

Paper 158 presents a case study conducted by EPRI to determine the best control settings for a large group of PV systems connected to a distribution circuit. In this study, different weather conditions are evaluated combined with a set of control settings for the smart inverters deployed in the distribution system. This study identifies the impact of smart inverters when added to the PV installation. The distribution system benefits when these devices are well coordinated with the existing system voltage control technologies is showcased

Paper 225 illustrates the necessity of defining the optimal technology mix of Hybrid Renewable Energy Sources for certain system conditions from the perspective of both economy and system dynamic behaviour. In this study, the focus is on transient system stability. The methodology for developing dynamic equivalent of the whole HRES plant for transient stability studies in the form of a low-order transfer function model is presented. Illustrative results are obtained using an HRES plant consisting of several non-dispatchable renewable generation technologies.

Paper 245 presents a replicability and portability methodology of a virtual synchronous generator (VSG) to facilitate its development in an industrial context. This solution is designed to improve the electrical grid stability when facing a high penetration rate of renewable energies. In order to validate both the methodology and the portability of the proposed model, the VSG-based inverter is tested at different scales of inverters. The solutions are integrated in an experimental grid for validation.

Paper 271 presents a methodology for increasing the hosting capacity of the grid for distributed energy generation, using an autonomous grid voltage control for PV-installations and wind turbines. The control is a combination of reactive power absorption by a fixed cos(φ) of 0.9, and a P(U)-control. This choice is based on the results of various case studies combined with load-flow simulations. The main criteria used for the selection of the control are MV-grid voltage, amount of curtailment, and robustness for implementation. The prediction of the curtailment caused by this control is based on a simulation model in which accuracy is increased by using metering data at the point of common coupling (PCC). As the voltage violations occur in the MV-grid, the setpoints of the control have to be corrected to be able to use the local voltage at the DER installations as input for the voltage control. To verify that the voltage control in the customer installation remains operational and meets the agreements of the DSO, a daily monitoring method for the grid connection is developed. The developed solution can solve ca. 30% of the voltage related transport restrictions in the grid with an average expected curtailment of ca. 8%.

Paper 340 describes the real-time, virtual-physical simulation environment developed to validate a cloud-based Distributed Energy Resource Management System (DERMS). This work forms part of the ‘ScotCLUE’ project which resides within the wider ERA-NET Smart Energy Systems CLUE consortium. CLUE aims to develop and validate a tool kit, across five European demonstration sites, which supports the implementation of sustainable local energy while considering future ICT architectures and the interaction with surrounding electricity systems. The benefit of this hybrid virtual-physical demonstration approach will allow real-world distributed energy assets to be used in parallel with software models. This allows de-risking of future investment in energy assets by verifying their operation/performance prior to installation.

Paper 374 introduces a tool for the automatic detection of such “hidden” behind-the-meter solar generation. It is designed to discriminate the nodes with and without PV generation and is aimed at a high accuracy. The tool consists of a neural network coupled with an analytical classification algorithm, which considers an exogenous information (i.e. node consumption and temperature data). Open-access data about consumption and solar radiation were used to simulate the electrical grid and validate the proposed approach. The implemented solution was tested across all the nodes of the grid and its sensitivity has been analysed with regard to the level of PV penetration and period of observation. The tool is able to recognize the nodes with a new PV installation with an accuracy of up to 100%, depending on the exogenous conditions.

Paper 0380 studies the combined impact of PV, EV, and HP on the stability of LV grids, through the analysis of a typical LB Belgic rural grid. The effect of a smart charging strategy was evaluated. The main impact on the grid comes from HP integration, with a potential to overload the transformer. To effectively reduce grid constraints from PV and HP integration, EV should actively act to reduce grid instability. Also, flexibility should be considered both for EV and HP.

Paper 0390 presents a methodology for the evaluation of MV voltage levels, recurring to LV measurements. This state estimation methodology is presented theoretically and compared with results obtained in a real French grid, proving that with a lower cost state estimation methodology (due to the lower cost of LV sensors), it is possible to obtain results with a 1% precision.

Paper 399 describes how an efficient use of solar energy can be achieved by operating Photovoltaic (PV) panels at the maximum power point (MPP) for powering an induction motor. This paper discusses multiple techniques for computational demonstrating of Maximum Power Point Tracking like Perturb & Observe (P&O) and Incremental Conductance (Inc.) with Field Oriented Control Drive. The control techniques are implemented by using Matlab/Simulink. The simulation results clarify the effectiveness of the controllers based on Incremental Conductance techniques with Field Oriented Control for each performance index as it provides lower overshoot value and lower rising time and high dynamic response.

Paper 0403 describes de set-up for energy-efficient residential buildings for Nigeria and Sub-Saharan Africa, considering insulation to improve energy efficiency. It then proposes the combination of PV and BESS, allowing to achieve energy self-sufficiency.

Paper 418 proposes an efficient algorithm to recognize the digital currency mining consumption using the smart meter data. Current consumption, power factor and power consumption are considered as the main parameters. Accurate analyses are performed for the miner's behaviour and some principal criterion are proposed to identify miner's consumptions. Moreover, the proposed algorithm is implemented to recognize miner's consumptions in Mashhad Electric Energy Distribution Company (MEEDC). The final results show the applicability and proper performance of the proposed solution in energy management and providing a new source of earning money for the utilities.

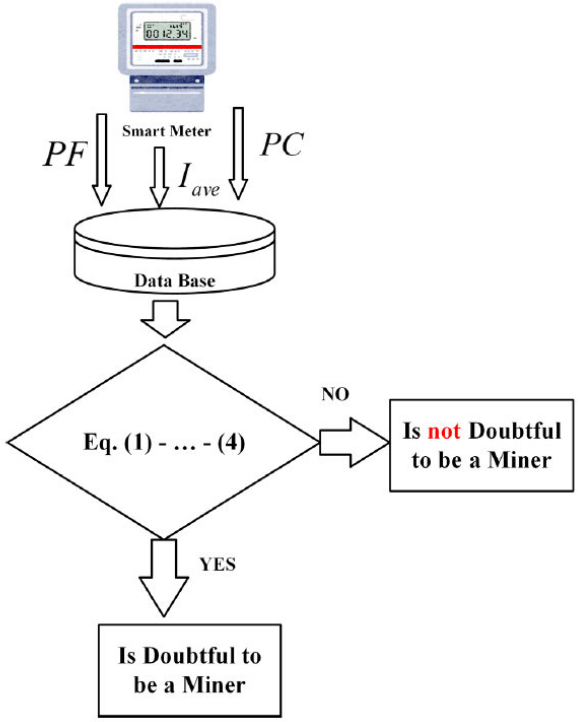

Figure 8. (Paper 418) Proposed algorithm flowchart

Paper 574 describes how Smart Meter data was gathered, structured and analysed, allowing the proactive identification of distributed generation and electric vehicle's charging stations that can potentially cause voltage non-conformities in the LV-grid. The authors present the approach, main conclusions and benefits that were found by developing a platform in which Smart Meter data is used to identify and preventively act eliminating abnormal voltage conditions in the LV-grid.

Paper 640 aims at developing an islanding solution based on already installed photovoltaic (PV) plants and that would require a minimum amount of changes in the existing distribution grids. More specifically, this paper proposes a control structure for a PV-based grid-forming system that can be used as a building block for the pursued islanding solution. A set of simulation results demonstrates that the proposed system is capable of withstanding

severe perturbations while functioning in stand-alone mode.

Paper 0643 describes multi-energy systems in green airports through mathematical modelling, which would include multi-energy systems for the operation of the airport and meeting electric aircraft charging loads and fuelling stations producing hydrogen through electrolysis from wind and solar energy. It uses Kansai airport (Japan) as a case-study.

Paper 647 presents an integrated tool that facilitates the estimation of the installed capacity of rooftop solar PV systems connected to low voltage networks, thus increasing the visibility of these networks. The integral tool proposes the joint analysis of three methods to take advantage of their individual strengths and to compensate for their respective weaknesses: 1) aerial image analysis, 2) reverse power flow analysis and 3) a novel technique referred to as mean power generation analysis. The results show that a more accurate estimate of the installed capacity of the PV systems connected to each feeder phase was obtained when using the integral tool, despite the strong load-masking effect observed in some feeders.

Paper 651 explains how applications are needed to analyse the effects of multiple Distributed Energy Resources (DER) on transmission and distribution networks. These must estimate the behaviour of many types of DER autonomous control functions. DER controllers are expected to receive setpoints, curves and schedules sent from higher level management systems. DERs are often managed in groups which makes the control systems even more complicated. This paper describes a modelling approach for describing these autonomous control systems for integration with network analysis. This uses a design pattern with function blocks similar to the approach of PLC programming languages and simulation applications.

Paper 714 illustrate a practical design-to-cost approach to iteratively find the optimal techno-economic solution which fulfils the customer constraints. To support this approach, EDF R&D has developed PREMO, a microgrid techno-economic predesigning tool presenting a low technical complexity level paired with reliable technical and financial results. The paper describes the main functionalities, the modelling aspects and the gap PREMO intends to address. Performance is then demonstrated on a real EDF project, in South America.

Paper 721 describes a standardized set of power flow models for typical Dutch LV distribution networks is developed using real networks and operational data provided by a Dutch DSO. These network models are used to assess if typical Dutch LV distribution networks are ready to operate with large penetration of low-carbon energy technologies (e.g. PV systems, electric heat pumps, EVs). According to the obtained results, simulations of all the modelled networks showed the same behaviour for the power flow at the head of the distribution system and the voltage magnitude level. The changes in voltage magnitude however is dependent on the size of the network, resulting in larger changes in the larger networks. While the voltage magnitude level of the smaller networks stays within the ± 10% range, the larger networks encounter voltage magnitude violations. Thus, it can be concluded that the larger networks are not ready (under the current conditions) for large penetrations of low-carbon energy technologies, while the smaller networks appear to be ready.

Paper 803 shows how inverter-based microgrid operating at constant frequency performs under various transient and dynamic events, including islanding, fault inside the microgrid, loss of its primary grid-forming unit and rapid load changes. The microgrid comprehends one grid-forming unit, one grid-supporting/grid-forming unit, one grid-feeding unit and variable loads. Firstly, transient response of the microgrid during islanding to stand-alone operational mode is analysed. Results show how the main grid-forming unit can restore the voltage and balance active and reactive power fluctuations in stand-alone mode. Secondly, a fault inside the microgrid is applied when the microgrid operates in steady state and stand-alone mode. During the fault, the main grid-forming unit disconnects, and the grid-supporting unit changes its mode to grid-forming and restores the voltage and stabilizes the microgrid.

Paper 854 presents the domOS solution, which brings three mains contributions to the digitalization of buildings:

- it specifies an IoT ecosystem enabling the decoupling of the infrastructure layer (in-building sensors and actuators, smart appliances, gateways) and the service layer;
- it develops a set of compliant services for energy efficiency, energy flexibility and demand-side management; and
- it tests services and infrastructure on significant scale demonstrators.

The paper focuses on the implemented methodology and preliminary results of the solution's implementation in a Swiss site. A Living Lab approach which uses methods to co-design services with users is also applied. The expected outcome of the methodological approach is new user centred business models for smart energy services.

Paper 0875 describes a model developed to assess the stability of microgrids, through the interaction of synchronous machines and virtual inertia emulators associated with inverters connected with distributed resources (generation or storage).

Paper 887 discusses a tool for simulating various charging scenarios of large centralized electric vehicle parking solutions and compares the outcome with respect to the simultaneity factor to current planning rules and real-world experiences. Additionally, the involvement of charging algorithms is simulated and the impact on needed power capacity for local transformers is analysed. Besides verifying that the observable simultaneity of charging is mostly in line with other studies, this work provides a more detailed investigation of different use cases such as home, work and shop charging. Furthermore, it is proven that simple peak shaving can drastically reduce the maximum power of EV parks without interfering with the usage patterns of the vast majority of EV owners.

Paper 898 explores different strategies (renewable capacity augmentation, battery augmentation, optimized energy management algorithms…) and simulates their impact using an in-house microgrid model for Saint-Nicolas Island, (Brittany, France). The simulation results suggest that the innovative solution of coupling a small Li-ion battery to a larger pre-existing lead-acid battery - combined with a limited increase of the installed photovoltaic capacity – would make the 100% renewable electricity mix possible. Following this study outcomes, Enedis engaged several actions to further increase the renewable share in the electricity consumption.

Paper 927 outlines an intelligent active network management (ANM) platform which will be designed and implemented by SPEN to solve the challenges for new distributed generation connection.
The roll-out of the ANM platform across SPEN network can bring significant benefits including:

- addressing network constraint problems,
- establish an industry leading, wide scale ANM solution,
- facilitating connection of more renewable generation with carbon benefits, and
- reduce customer connection costs.

In addition, the ANM platform will be the enabler for the future DSO function (e.g. dispatch flexibility service). The DER coordination between ESO and DNO through ANM platform is also explored.

Paper 0933 presents a DC microgrid concept aimed at maximising energy efficiency in transportation systems. Integrates energy supply to DC urban trains with PV, BESS and bus charging stations, allowing to use train braking energy in the network, using it to charge buses' batteries.

Paper 0954 describes a novel digital communication interface, based on an interface to be installed on the DER site and enabling the communication up to the DSO management centre. It has interoperability based on IEC 61850 and cybersecurity-enabled functions.

Paper 972 presents a power flow analysis of the LVDC backbone in order to determine the appropriate cable size. Based on this analysis the energy losses are computed for a LVDC backbone architecture. Subsequently, the benefit in terms of energy savings, self-consumption and self-sufficiency is investigated compared to a traditional grid architecture.

Paper 1006 describes several pathways analysed with the goal of transiting the energy production system of the island of Miquelon (France) towards a 100% renewable electrical energy mix.

Paper 1030 highlights the advantages of using sensors using a case study of introducing/upgrading a renewable energy grid. This is required to ensure system reliably, as live data on power flow direction, distortion and other parameters is essential. The paper includes specific applications such as cable pooling of multiple sources on a single grid connection and power factor improvement providing the possibility to actively request reactive power from renewables.

Paper 1039 provides the description of a model to control a microgrid with several different resources associates (PV, wind, fuel-cell, battery), ensuring an adequate dynamic response of the system during transient peak power demand changes.

Paper 1077 describes the usage of a lab testbed for active distribution networks and the results of several experiments, including a physical validation of a control algorithm of DER according with the voltage levels observed by each, observing the interactions between OLTC and reactive power of multiple DER; a trade permission system aimed at mitigation insufficient coordination between DSO and other actors of the system, avoiding the emergence of congestion issues on DSO grid originated by flexible services procured by TSO; and on direct load frequency control.

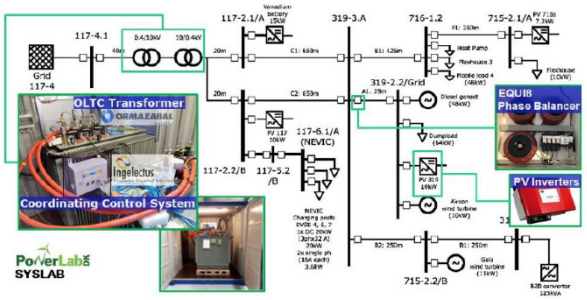

Figure 9. (Paper 1077) Physical setup for the HOLISTICA experiment, testing the performance of OLTC and multiple DER.

Paper 1113 presents the development and application of a method to estimate the technical and nontechnical loss in real distribution systems. The proposed methodology realises the energy balance with real-time measurement given by the Supervisory Control and Data Acquisition (SCADA) system and the energy billed in the consumers units by the Energy Metering and Billing System (EMBS). For simulation and results, two real Brazilian distribution system are analysed in order to demonstrate the benefit and efficiency of proposed methodology. The calculus of energy balance in real-time environment and the power flow results showed precise and reliability, enables the utility to define a proper control action.

Potential scope of discussion

The Block provides insight into simulations and real world trials of solutions for managing renewable energy sources. Discussion topics include the challenges for utilities and users in making use of the solutions at the scale required, and the need to adapt codes and policy to reflect the changing landscape.

Table 3: Papers of Block 3 (Case Studies, Industrial applications and field tests) assigned to the Session

Paper No	Title	MS a.m.	MS p.m.	RIF	PS
45	Solar PV hosting capacity methods and industrial application gaps				X
54	Innsbruck´s prototype for a cross-linked energy system				X
59	Energy Benefits from Bidirectional Electrical Substations in Metro Railway Systems				X
68	Increasing the grid capacity for electric vehicle charging using dynamic rating			X	
116	Impacts of spot market optimized energy procurement for private electric vehicle charging points on the distribution grid		X		
118	Facilitating the operation and integration of DER and microgrids using the IEC 61850-7-420 standard data models, especially for meeting IEEE 1547 and EN 50549 grid code requirements		X		
148	The entry of charging point operators into the flexibility trading domain – challenges and opportunities				X
158	Grid voltage control incorporating hybrid control devices exposed to variable weather conditions				X
225	Limitations of the applicability of the concept of hybrid renewable energy source plant in practical implementation			X	
245	Replicability and portability of an advanced grid-forming VSG control for electrical grid with high rate of renewable energies				X
271	Increasing hosting capacity for distributed generation by using local autonomous voltage controls, from case study to DSO-product				X
340	Initial validation of a real-time cloud-based 'web-of-cells' energy management system			X	
374	Automatic detection of distributed solar generation based on exogenous information				X
380	Impact of distributed energy resources and electric vehicle smart charging on low voltage grid stability		X		
390	Use of LV measurements in order to feed a state estimator aiming at evaluating the MV voltage with a 1% precision				X
399	Advanced control of industrial solar variable speed drive for three phase induction motor				X
403	Designing energy-efficient residential buildings for Nigeria and sub-Saharan Africa considering aerogel thermal insulation material and photovoltaic power generation				X
418	Identification of unauthorized mining farms using smart metering data		X		
574	Improving power quality through the analysis of smart meter data				X
640	Photovoltaic-based storage-less system to support islanding in distribution grids				X
643	Multi-energy systems in green airports				X
647	Increasing the visibility of low-voltage networks through data analytics				X
651	Extending the IEC common information model with functions for planning and optimization of distributed energy resources				X
714	A design to cost approach applied to isolated microgrids				X
721	Assessing the operation of typical Dutch distribution systems with large penetration of low-carbon energy technologies		X		
803	Islanding of a microgrid operating at constant frequency with two grid-forming inverters				X

854	Developing new smart services in buildings for demand side management in the municipality of Sion, Switzerland				X
875	Impact of the interaction of synchronous machines and virtual inertia provisions on the small-signal stability of microgrids				X
887	Electric vehicle car park charging simultaneity and grid connection power requirement analysis				X
898	The island of Saint-Nicolas on its path towards a 100% renewable energy territory		X		
927	Design and implement intelligent active network management (ANM) platform for network constraints				X
933	Electric bus charging station supplied by urban electrical DC railway network				X
954	A new cyber secured and interoperable communication interface to enable the management of remote distributed energy resources by DSOs				X
972	RE/SOURCED pilot project: Design and power flow analysis of a LVDC-backbone with hybrid energy system				X
1006	The road towards a 100% renewable electricity mix in the French island of Miquelon				X
1030	Sensor technology in a changing electrical grid				X
1039	Fractional order PID controller design via Tabu search algorithm in a hybrid renewable energy system				X
1077	Testbeds for active distribution networks: case experience from SYSLAB			X	
1113	Technical and nontechnical power loss estimation using real-time access to distribution system				X
Total		**0**	**6**	**4**	**29**

Block 4: "Storage Solutions and integration"

Paper 0052 contributes to the research on the determination of residential flexibility, achieved through loads with storage capability through Thermal Energy Storage loads (TES), monitored in laboratory to provide a model to evaluate demand response option. The model can thus be used to evaluate energy efficiency and demand response (DR) policies. The potential benefits accrued by this DR might achieve a 17% peak shaving, while saving money for end-users.

Paper 0096 studies the optimal demand charge threshold tunning for a microgrid, minimizing the energy bill while considering the management of a genset, a battery and a PV system combined with the site load.

Paper 0201 analyses LV networks with high penetration of residential batteries (BESS), PV and EV, for different operational strategies, which are simulated for a residential feeder in Northern Ireland. The results demonstrate that BESS can support the network, mitigating the negative impacts of PV and EV. Nevertheless, their unsupervised large-scale operation can have negative impacts on the network operation.

Paper 0211 illustrates the sizing of BESS that would be necessary on a LV transformer to delay asset upgrades, preventing voltage constraints and optimizing renewable energy generation, suggesting the usage of 2nd life BESS with varying state of health.

Paper 0384 examines the role of centralized and distributed short-term storage technologies in Austria, at the transmission grid level, to maximise renewable energy generation. The developed model results show that the potential of centralized is, in general, sufficient for balancing short-term power fluctuations when renewables dominate the overall generation portfolio.

Paper 0502 presents a case-study developed in Australia, demonstrating the usage of BESS with microgrid control to maximise renewable hosting capacity, realize tariff benefits, enhancing reliability and running 100% green processes – including the production of green hydrogen.

Figure 11. (Paper 0502) 260 kVA controllable hydrogen electrolyser (front left) and 30-bar high-pressure hydrogen storage vessel (centre)

Paper 0666 analyses the usage of residential batteries to provide primary frequency response (PFR) through droop settings. The proposed methodology is tested on a realistic Australian MV-LV grid, yielding results showing that by calculating droop settings with individual time-varying export limits, it is possible to achieve larger PFR contributions while ensuring grid integrity.

Paper 0713 provides an analysis of the usage of residential home batteries for balancing the Swedish power grid, considering the expected PV production and residential batteries deployment in 2040 and the need for these batteries to contribute to both primary frequency reserves (normal and disturbed), including an economic assessment of the PV system payback when the provision of those ancillary systems is considered.

Paper 0796 introduces a novel concept to increase battery supply time during network outages by deploying residential demand response, which would normally be used for primary frequency regulation markets, but which during an outage could be rented for the DSO to maximise the battery supply time for its customers.

Paper 0836 presents a pilot project carried on in Finland to verify a distribution network and electricity markets integrated BESS concept, based on shared ownership of the equipment, dual use of the system resources and a new service market model. The overall technical

structure of the BESS, learnings from the pilot, key results from the commission tests and experiences gained are described in the paper.

Paper 0909 evaluates the impacts of a storage system on a typical secondary distribution network, with different consumers and with the presence of distributed solar generation. The network is simulated for normal conditions, with generation, with generation and storage and with centralized dispatch.

Paper 0919 presents a concept and market model for the utilisation of BESS in distribution networks, describing the long-term utilisation potential of the concept. The purpose was to investigate potential locations for BESS in Elenia's (Finland) network, showing that service charge and savings on regulatory outage costs have the greater influence on the number and location of BESS.

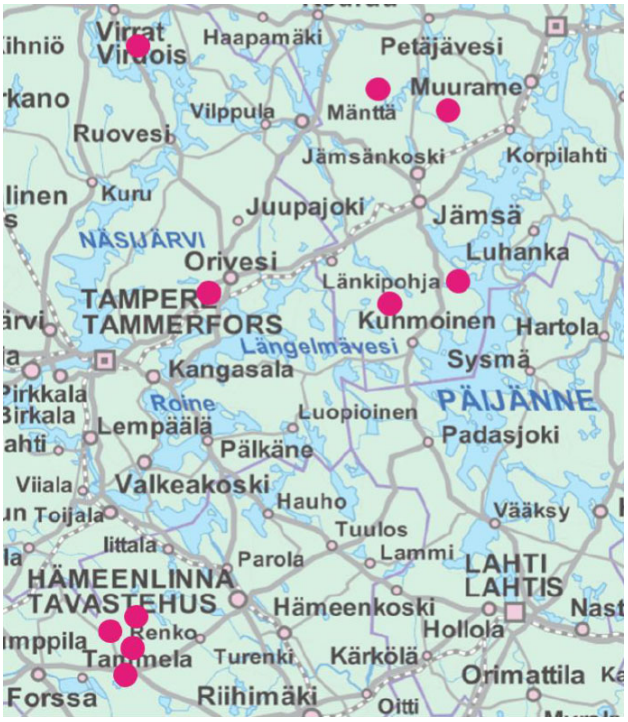

Figure 12. (Paper 0919) 10 most profitable locations for placing batteries in Elenia's network

Paper 1002 introduces a reinforcement learning method for developing an operational strategy for an Energy Storage System (ESS) to achieve energy arbitrage in a power system, maximising profit for different scenarios, while comparing the performance of the proposed model with that of optimization-based methods.

Paper 1032 describes a prediction model for the deterioration of a Li-Ion BESS associated with a hybrid PV system installed in Corsica Island. Different estimation models were developed to predict the thermal behaviour and state of charge of 5 hybrid RES power plants with a Li-Ion BESS associated. These approaches improve the understanding of the evolution and degradation of the systems, providing insights used for optimized management system of each power plant.

Paper 1055 presents a pilot-project developed in Brazil that includes the installation of a BESS in a LV network with large PV penetration, describing a testing procedure developed to allow the commissioning of the equipment. The paper describes the key challenges and experience acquired through the installation of the system.

Paper 1062 describes a deep learning-based methodology for PV power quality control in systems with associated BESS. A machine learning model (neural network) allows to capture the dynamics of the PV, delivering accurate predictions, stabilizing the state of charge of the BESS notwithstanding the variations of PV production.

Paper 1100 presents a methodology for sizing BESS systems on MV grids connected with PV. The storage systems can help to smooth the production diagram associated with PV generators, while controlling the volt-var characteristics of the network.

Paper 1138 introduces a methodology for frequency regulation stabilization, through the association of a BESS and a supercapacitor with a system fed through a wind power generator. The capacity of the BESS and of the supercapacitor are optimized through nonlinear programming.

Potential scope of discussion

Integration of RES with BESS systems, enabling flexibility and RES hosting capacity maximization. More efficient solutions from and end-user and DSO, also considering power quality and ancillary service provision.

Efficient sizing and location of BESS on DSO networks.

Challenges associated with the operation of isolated systems with 100% RES generation

Table 4: Papers of Block Storage Solutions and integration assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0052: Description of a residential thermal energy storage demonstrator: modelling, identification, validation, aggregation and validation of DR performance				X
0096: Improving energy efficiency in DC microgrids with integrated energy storage				X
0201: Understanding the impact of high penetration residential batteries with low carbon technologies on the low voltage networks		X		
0211: Balancing second life batteries with different SOH for use in stationary storage systems				X
0384: Compensation of short-term power fluctuations at the transmission grid level by centralized and distributed short-term storage technologies on the example of Austria				X
0502: Grid forming energy storage with microgrid controls provides green hydrogen, enhanced reliability, reduced site costs and lower emissions. ATCO Clean Energy Innovation Hub (A Case Study)		X		
0666: Using residential batteries for primary frequency response: Time-varying export limits and active droop calculations		X		
0713: The potential for balancing the Swedish power grid with residential home batteries		X		
0796: Extending grid battery supply time by controlling residential heating loads				X
0836: Experiences from implementation and operation of a distribution network and electricity markets integrated battery energy storage system		X		
0909: Centralized distributed storage dispatch				X
0919: The utilisation potential of battery energy storage systems in rural distribution network		X		
1002: Developing Optimal Energy Arbitrage Strategy for Energy Storage System Using Reinforcement Learning				X
1032: State of charge and thermal-related deterioration prediction for li-ion storage systems in hybrid photovoltaic systems in the island of Corsica				X
1055: Challenges and experiences in installing a battery energy storage system connected to a low voltage network				X
1062: Deep learning based intelligent methodology for photovoltaic power quality control with energy storage				X
1100: Methodology for sizing battery energy storage systems to support the 13.8 kV distribution grid				X
1138: An optimal hybrid battery energy storage system and a supercapacitor framework for frequency regulation in presence of wind power				X
Total		6		12