Special Report - Session 5
PLANNING OF POWER DISTRIBUTION SYSTEMS

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Introduction

The S5 papers will be discussed in three events:

- Main Session (Thursday, June 15, 9:00-12:30 and 14:00-17:30),
- Poster Session (Tuesday, June 13, 9:00-12:30 and 14:00-17:30),
- Research & Innovation Forum (Wednesday, June 14, 14:00-15:30).

Round Tables are organized by S5 or jointly organized with other Sessions on transversal topics. In the following the list of RT more relevant to S5:

- RT4: Societal cost/benefit of smart grids (Tuesday, June 13, 14:00-15:30),
- RT5: Reduction of technical and non-technical losses in distribution networks (Wednesday, June 14, 09:00-10:30)
- RT6: Requirements for smart, flexible, future power system architectures (Wednesday, June 14, 09:00-10:30)
- RT8: Innovative grid architectures and control strategies for 2030+ power systems (Wednesday, June 14, 11:00-12:30)
- RT12: Control and Automation Systems for Electricity Distribution Networks of the Future (Thursday, June 15, 9:00-10:30)

The 2017 S5 main session will be divided into four blocks. In each block there will be oral presentations of selected paper (12 minutes in both the Main Session and RIF) and discussion.

The aim of this special report is:

1) to present a synthesis of topics covered by the papers,
2) to call for prepared contributions at the main session,
3) to stimulate the free discussion at the main session.

The session received 132 papers divided into 4 blocks that reflect the traditional topics of S5: Risk Management and Asset Management, Network Development, Distribution Planning, and Methods and Tools. The selection process gave an acceptance rate around 60%.

The S5 papers brilliantly cover planning, development and operation of modern distribution systems. Compared with the previous CIRED, it should be noticed that the attention of researchers has been attracted by the role that demand and production flexibility, eventually with storage systems, might have in distribution systems. As a consequence, there are very good papers that propose models for load and generation forecast and try to exploit the "atomic" knowledge of customers' behaviour achieved with smart meters. Indeed the better is the knowledge of demand and generation, the better the forecasts, the more accurate are the models for including flexibility and demand response in development plans and operational planning. Furthermore, by following the modern trend to including operational actions enabled by smart grid in the panoply of possible development options, some papers analyse how the network development will be impacted by the combination of flexible consumption and stochastic generation. Finally, the inclusion of flexibility in development and planning studies is enforcing the need of probabilistic – risk oriented models and tools for planning, in opposition to traditional deterministic approach, with a greater attention paid to LV systems. Looking at the development of the system, the number of papers dealing with long term and strategic planning is increased. Indeed, it should be recognised that active networks exist, smart grid are not too far from full deployment and now it is time to think systems suited for the carbon-free future. In this sense, visionary and futuristic contributions (e.g., fractal networks, web of cells, multi-microgrids, etc.) are an option together with "classical" meshed and DC systems that are becoming less futuristic thanks to ICT and network automation. Finally, looking at methods and tools, there is a growing renovated interest for energy losses, even in the most developed systems. The reason is that by using modern control techniques to postpone investments, losses increase and penalties can arise from regulation. In this context, the concept of power factor should be abandoned for a more comprehensive voltage regulation. Finally, interesting planning algorithms with electro-mobility are worth to be mentioned.

Block 1: Risk Assessment and Asset Management

Sub block 1: Risk Assessment

In last years, it has become more and more evident that network performance is not only related to its everyday reliability, but also to its capability of facing unlikely, extreme contingencies. Resiliency has already become a keyword in DSOs' vocabulary; but to be resilient, it is crucial to be able to detect clusters of events that can adversely affect the grid in order to investigate how the effects of High Impact-Low Probability events can be mitigated.

Sub blocks 1 includes papers describing methodologies and processes to collect, rank and assess the main clusters of risks related to the operation of distribution business.

Paper 0845 outlines the strategy that SP Energy Networks (SPEN) has developed to identify solutions to mitigate risks, share best practice and address equipment quality issues common across local areas and within the wider industry. This has been achieved by the development of a centralized Asset Management Risk Framework (see Fig. 1), which uses a bottom-up approach based on risks reported at a local and national level. This framework forms part of SPEN's Enterprise Risk Reporting framework, which has been in place for over 15 years and embeds risk management into the heart of the organization's governance process.

Impact Area	Not Applicable	1 Minor	2 Moderate	3 Significant	4 Major	5 Catastrophic	Likelihood	Risk Score
P&L and/or Cash Impact within current budget year		below £1m.	between £1m and £10m.	between £10m and £25m.	between £25m and £50m.	over £50m.	Possible (<50%)	5
P&L and/or Cash Impact beyond the current budget year		below £5m.	between £5m and £25m.	between £25m and £50m.	between £50m and £100m.	over £100m.	Unlikely (<20%)	3
Health & Safety Impact on health and safety over the next 12 months		minor illness/injury treatable by first aid.	illness/injury requiring treatment by medical professional.	moderate illness/injury with full recovery (LTA).	serious illness/injury with permanent function impairment.	fatality.	Remote (<4%)	6
Business Operational Performance Impact on operational activities across the business		poor performance of non-critical activities.	minor disruption to network, support service failures in non critical activities.	disruption to network, some support service failings.	temporary loss of service, failings in some business critical services, business performance harmed.	massive breech of service, serious failings across most business units, long term business performance harmed.	Possible (<50%)	5
Environment		increased use of fuel or increase in waste generated.	leakage of hazardous substances.	leakage of hazardous substances and breech of environmental legislation.	breech of environmental legislation leading to a fine and regulator involvement.	breech of environmental legislation leading to prosecution, a fine and regulator involvement.	Possible (<50%)	5
Stakeholders Reputation and relationships with employees; customers; shareholders, press, government, and/or regulators		short term loss of employee morale, adverse local media report.	minor employee disengagement, adverse prolonged local media reporting, localised stakeholder concern, temporary drop in share price, and a minor reduction in customer base.	isolated employee disengagement within business unit(s), national media interest creating stakeholder concern, negative national stakeholder statements, prolonged decrease in share price, and a moderate reduction in customer base.	employee disengagement across several business units, extensive prolonged adverse reactions from media and/or key stakeholders, significant decrease in share price, and a significant reduction in customer base.	company wide employee disengagement, downgrade in credit rating, extensive widespread negative reporting or public disputes with key stakeholders, loss of investor confidence, extensive reduction in customer base, escalation inevitable and impossible to contain.	Unlikely (<20%)	4
							Risk Score	6.31

Fig. 1: Risk-scoring interface of AMR Framework as exposed in Paper 0845

Sub block 2: Reliability assessment

Distribution networks are planned and developed to be reliable and their performance evaluation always include reliability indexes: absolute values and historical trends of reliability KPIs provide significant inputs to assess the classes of criticalities that are affecting the distribution system, while investigating their discontinuities may provide hints of incoming changes.

Sub block 2 deals with the evaluation of electrical systems and their performances to find general criteria or specific solutions to enhance or maintain reliability of supply.

Paper 0251 updates the outage data in the Netherlands published in 2001 and relevant to previous 25 years. Due to new legislation and the need for more detailed information, the scope of outage registration has changed in time. The Paper reports on trends in the results (CAIDI/SAIDI/SAIFI) over the recent years. Technical background and causes are summarized.

Paper 0140 also deals with the reliability of distribution networks. The main idea is to apply a technique from multi-criteria decision making to identify the most significant reliability indicators and to use this information for prioritizing investments. The DEMATEL technique (Fig. 2) is used in the paper: by the study it can be argued that ASAI and AENS are influenced by other indicators and should not be considered in planning studies.

Fig. 2: General representation of DEMATEL method as applied by Paper 0140

Interactions between power system and ICT system in the planning process are addressed by **Paper 0723**. Smart grid applications (SGA) may represent a cost efficient alternative to conventional network reinforcement for integrating further distributed generation units and optimizing current power systems. However SGA, such as generation side management and remotely controllable switches, are at least partly dependent on an information and communication system (ICT system, see also Fig. 3). For the purpose of assessing power system reliability in smart grids enhanced algorithms have been developed. The selection of configuration options however still represents a challenge due to lack of exact quantitative failure data for the ICT system and various option details. Therefore possible configuration options have been identified and sensitivity analyses have been carried out, which on one hand show the benefits of SGA and on the other hand the influence of those option.

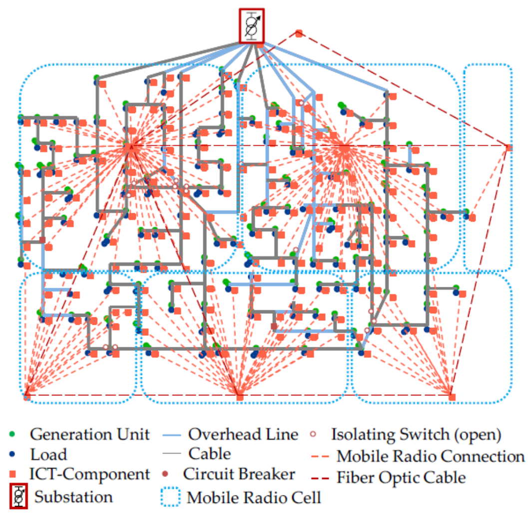

Fig. 3: MV Network equipped with Mobile Radio Communication system as in Paper 0723

The assessment of reliability indexes is attracting the attention of companies and academia. The scientific literature on this field is rich and covers several topics that span from reliability assessment to the optimal position of intelligent devices for fault location isolation and service restoration or the application of post fault actions that minimize interruptions. **Paper 0780** falls in this subject and offers a practical way to assess reliability of MV networks with radial or weakly meshed structure by using a state enumeration method. The worth of the paper is represented by the capability of simulating DSO post fault actions in order to calculate SAIDI and compare different investments. This is a paper and the authors want to produce optimization software to consider the various design options at the same time; probably the opportunities deriving from full automation and smart grid post-fault services should be also added. Anyway, the methodology is interesting and results on existing Swiss distribution network are significant.

Sub block 3: Asset Management and Maintenance Strategies

Sub Block 3 deals with Asset Management in a proper sense, considering it as an analytical problem or dealing with experiences of running such a system. Therefore, this section includes papers either on methodologies to assess the issues of aging equipment and the decisions related to renewal vs. maintenance of existing assets or on systems/processes presently adopted or deployed in utilities to support investment optimization.

Paper 0553 reports on the development of a mobile application used for in-the-field decision support concerning maintenance and renewal in the distribution grid. The tool contributes to a more consistent and time-efficient decision-making process (see Fig. 4), from findings on field inspections, to risk informed decisions implemented as work orders in the DNOs workforce management system. Standardized processing of risk conditions and remedial actions will give:

- Similar decisions among decision makers in the distribution company;
- Awareness and control of risk exposure on company level;
- Productivity improvements due to less time spent in processing maintenance decisions.

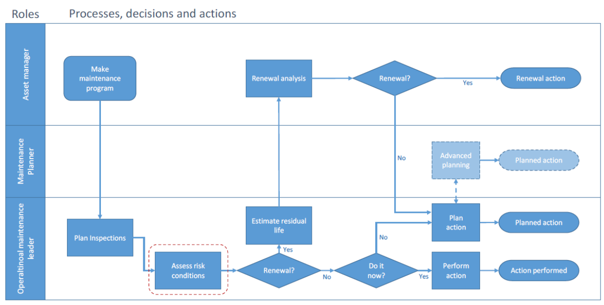

Fig. 4: General process of maintenance management at TrønderEnergi Nett according to Paper 0553

Paper 0406 illustrates an innovative analytics, also known as performance model, to estimate the probability of failure and remaining useful life of Medium Voltage (MV) breakers. The scope of the performance model is to provide the current health condition and estimate the probability of failure within a period of time, residual useful life, risk of failure and a level of accuracy based on the coverage of the failure modes under the condition monitoring. In addition, the performance model calculates the accuracy of the equipment health condition based on data availability and equipment knowledge. This Paper presents the successful application of the proposed performance model on significant circuit breaker (CB) real cases both in industries and in utilities, explaining the benefits of the scalable approach. A first case shows the application of the analytics based on statistical information and environmental condition. Another case describes, instead, how to take advantage of advanced condition monitoring sensors in order to increase the accuracy of the performance model outcomes.

Paper 0828 deals with the Smart Asset Management (SAM, see Fig. 5) project, whose aim is to propose and utilize an effective way of managing data and using them as a basis for smart decision- making. Secondary aim is to prepare the IT environment and introduce tangible tools and systems for SAM, embrace substantial changes to current investment decision-making, data collection and handling. SAM project is focused on LV and MV distribution lines.

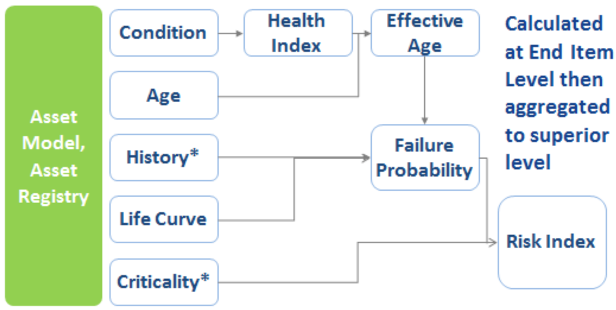

Fig. 5: High-level view of the data aggregation and factoring-in process based on Paper 0828

Network operators are facing a growing need for an improved and more automatic way to facilitate the integration, monitoring and maintenance of smart grid automation devices, including distributed IED (Intelligent Electronic Device), for example those with telecom or cybersecurity features. A reliable database is essential to achieve an efficient maintenance management, whether preventive or corrective. This is one of the fundamental justification for the concept of System Management, developed by EDF and presented in **Paper 823**. To face the challenge of a widespread deployment of heterogeneous IEDs, EDF R&D is building an interoperable and vendor independent system, homogenous with the core 61850 operational functions of the devices, to enable an efficient management of its inventory of equipment.

Paper 1115 deals with a new approach to asset management and to all distribution activities within a company. Indeed, power distribution companies allocate an enormous amount of resources for building and operating the power distribution network. However, a great portion of these resources cannot be converted to tangible value for energy consumers. OPerational EXcellence (OPEX) is a discipline that can be applied for overcoming this issue. In this approach, integrated asset management, resilient and reliable value stream, stable processes, balanced metrics, continuous improvements, and stakeholders' involvement techniques are used in an integrated manner in order to reduce the waste of resources as well as enhance service resilience. The OPEX framework, which has been used in Alborz Electric Power Distribution Company (Iran) for optimal planning and utilization of power grid, is described in Fig. 6. As an application, the authors provided an application to network reconfiguration. Energy losses are waste to be minimized and in addition all actions must allow improving voltage stability. Resiliency is also evaluated to avoid actions that can reduce the achieved value.

Fig. 6: Operational excellence framework (Paper 0115)

Paper 0274 shows how the customer-oriented objectives can be related with the technical condition of cables and optimizes replacement from an Asset Management perspective. The chosen method to study the technical condition of cables is a statistical survival analysis to explore the different probabilities of survival of cables in typical circumstances. A semi-parametric and a non-parametric technique are described. The probabilities of survival are combined with the impact of interruptions to estimate risks. The results give the opportunity to prioritize investments and optimize investment planning.

Paper 0634 shows possible refurbishment strategies of distribution transformer stations (DTSs). The refurbishment of distribution network assets is usually based on long-term strategies that the distribution system operator formulates for particular asset groups. Actually, the strategy of the refurbishment of MV/LV distribution transformer stations can be "simple" (i.e. with replacement of equipment with a functionally identical unit) or, by taking care of the smart grid trend, the refurbishment can include the installation of remote control as well as measuring and signaling devices. On the basis of a reliability simulation it is possible to estimate the impact of individual strategies on the supply continuity indices, and to compare the strategies. The selective DTS refurbishment applied at least for some time significantly reduces mainly SAIDI, in comparison with refurbishment based on age.

Potential scope of discussion

Machine learning is gaining new life. How can machine learning improve the asset management of complex systems that are getting aged?

How can we take into account rigorously the occurrence of HILP events while assessing the inherent risk of a distribution infrastructure?

Table 1: Papers of Block 1 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0140	Evaluation of the Reliability of the Electricity Distribution Systems by DEMATEL Method				X
0251	Experience and Tendencies after 40 years Outage Data Registration in The Netherlands				X
0274	Where to replace Assets ? Spatial Analysis on Differential Aging of Low Voltage PILC Cables				X
0406	Innovative Analytics to estimate the Probability of Failure and Remain Useful Life of Medium Voltage Breakers				X
0553	A Mobile Application For On-site Risk Based Decision Support				X

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0634	Urban Distribution Network Reliability Simulation and Strategies of Successive Refurbishment of Distribution Transformer Stations				X
0723	Effects of Configuration Options on Reliability in Smart Grids	1			X
0780	A Reliability and Cost Assessment Methodology for Medium Voltage Feeders				X
0823	Improving Asset Knowledge Using System Management Based on IEC-61850	2			X
0828	Utilities and Smart Asset Management - Challenge of the Digital Era				X
0845	Distribution Network Operator Asset Risk Management				X
1115	Operational Excellence in Optimal Planning and Utilization of Power Distribution Network				X

Block 2: Network Development

Sub block 1: Innovative Power Distribution

In the last ten years, DSOs have been by far the most innovative among electricity operators: lower costs and reduced size made previously unavailable functionalities at hand to be deployed in everyday operation. New materials, components and systems are constantly tested and introduced, expanding DSOs' possibilities in network management.

Most of the innovation in distribution is centered on the contribution of new equipment, either owned by the network operator or run by individual network users, to the management of the distribution system. In terms of planning, it implies new reflections on how to take these capabilities into account while designing future grids.

Sub block 1 deals with innovation not linked to specifically "structured" issues either delivering systemic overviews or describing advanced system functionalities.

Paper 1236 introduces the concept of Fractal Grid as a possible paradigm for future distribution networks: the idea beyond the theory is that a reference architecture for the electrical system can rely on self-similarities that can be found in territories as well as in power systems. The Paper shortly describes the Fractal Grid concept, the methodology adopted to approach network design according to this paradigm (see Fig. 7) and the first theoretical results achieved within the framework of the "FRACTAL GRID" funded project.

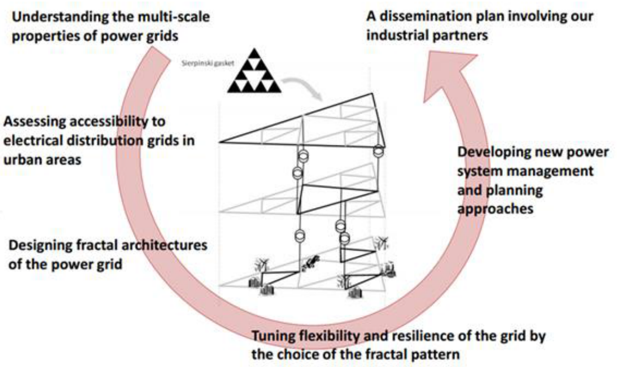

Fig. 7: Research directions of the Fractal Grid approach exposed in Paper 1236

Microgrids represent another approach to the construction of a resilient distribution system, including individual self-sufficient systems eventually linked together in order to achieve higher levels of reliability. **Paper 0861** describes an autonomous microgrid designed in order to supply remote villages in Mazandaran Electricity Distribution Company concession area. The process of selection and sizing of power sources (namely PV and wind turbine) as well as communication, storage and control system is shortly outlined.

A similar kind of installation (Remote Micro-Grid) is described in **Paper 0683**, dealing with a self-sufficient standalone solution developed by KEPCO to supply Korean islands whose connection with the distribution system is not economically viable. The whole system includes PV, wind turbines, diesel generators and storage, as well as a control system; a specific operational strategy has been implemented in order to minimize the Cost of Energy (CoE) for the supplied area.

The whole scenario of evolutionary distribution is enlisted in **Paper 1287**: the authors present the future challenges and the state of the art of research works on new concepts for the power systems of the future. Web-of-Cells concept, multi-microgrids, fractal grid approach and autonomic power systems are all described: for each one of them, the main ongoing projects are exposed as well as the challenges still open.

The transition to a 100% fossil-free electrical system in the Caribbean Island of Montserrat is examined in **Paper 0728** (see Fig. 8). An optimal mix of PV and geothermal generation, as well as an appropriate sizing of a storage system, has been planned in order to reduce the intervention of diesel generators, which currently ensure the supply of electricity in the island, to negligible emergency conditions. An economical assessment shows there is a strong business case, in any reasonable future scenario for both diesel fuel and renewable generation cost, to shift from diesel-generated energy to 100% renewables.

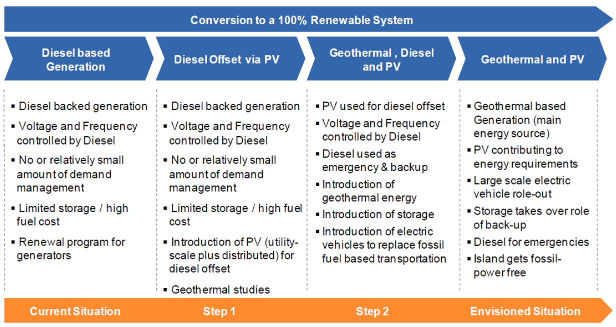

Fig. 8: Aligned roadmap for the energy system transition towards a 100% renewable energy system, as in Paper 0728

A different use for storage in shown in **Paper 1006**: by installing appropriate batteries in the LV busbar of secondary substations, it is possible to reduce the impact of MV outages on LV customers. Battery Energy Storage (BES) as an alternative to MV network reinforcement in order to reduce the economic value of Customers Interruption Costs (as defined by the Regulator) is investigated: results show that there can definitely be a business case for BES introduction, provided the installation site is selected among those which experience the highest number of outages.

Paper 1030 describes a measurement system developed by Swiss DSO BKW (Canton of Berna) to be installed in LV network to achieve all information needed to properly plan at the low voltage level. The system includes a power quality analyzer at substation level, measurements points for each LV feeder and a selected subset of smart meters at customers' premises. The paper focuses on the design of the system (equipment needed, installation problems, optimal data aggregation for planning purposes, etc.) as well as on its possible utilization areas (active/reactive management, power quality, continuity of supply, load profiles, losses, etc.).

Paper 0750 exposes the main characteristics of a MV automation system tested in a pilot project within E.ON. Czech. The authors describe the reference architecture for the pilot, including three reclosers equipping two feeders supplied by the same MV busbar and operated in close loop (switching as in Fig. 9). It must be noted that the maximum number of reclosers that can be installed is limited due to the type of selectivity adopted, but continuity of supply can also benefit from the installation of fault sensors and remotely controlled switches in order to reduce the delays in network reconfiguration. Optimal placement of equipment and expected performances coming from innovative operation are then analyzed.

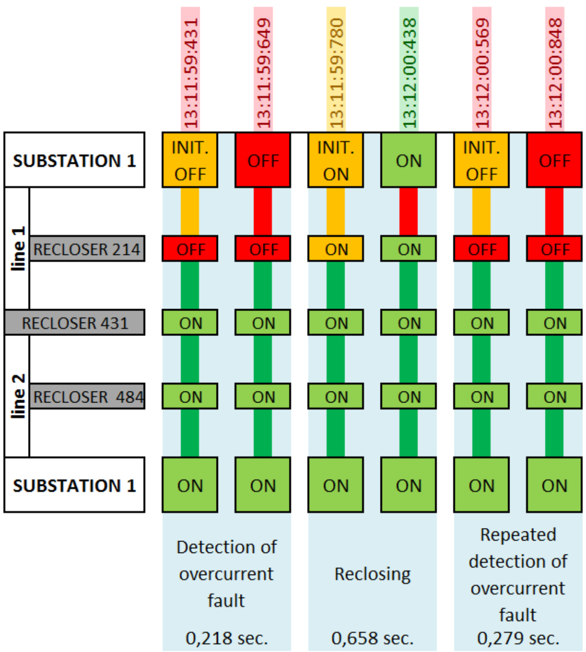

Fig. 9: Graphical interpretation of switching as in Paper 0750

While Paper 0750 describes the possibility of "meshing" radial MV lines, **Paper 0986** investigates the possibility of reducing the existing level of interconnection of MV network in SP Manweb. While performing very well at the technical level and ensuring an effective asset utilization, the reference network architecture adopted within this UK DSO faces complexity challenges when it comes to network extension, operation and management. A transition strategy in order to reduce the need for further interconnections while maintaining the existing levels of reliability and asset utilization, has therefore been defined: it implies the adoption, in specific areas, of less reliable network configurations ("Y" Type instead of "X" Type, see Fig. 10) combined with an increased degree of automation.

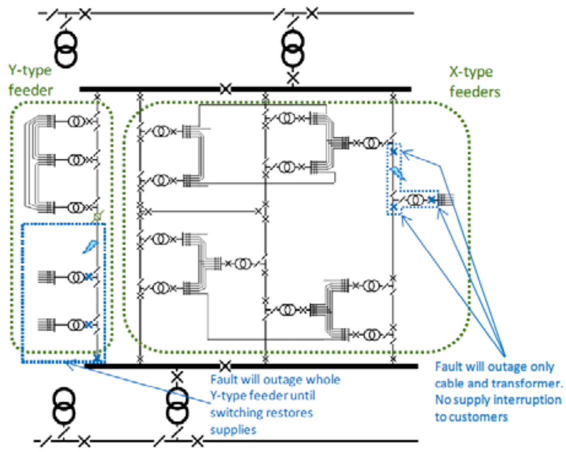

Fig. 10: Typical SP Manweb 'X' and 'Y' Type HV feeders, as described in Paper 0986

A comprehensive distribution management system, which is presently being deployed in CEZ Romania, is described in **Paper 0607**. It includes: a Smart Metering System to manage both the operation and the data of Smart Meters, a Geographic Information System containing all spatial information related to the distribution network, a Workforce Management System to optimize network development workflows as well as everyday operation and maintenance. Through the completion of this project that aims at defining an operational model for several years to come, substantial efficiencies are expected within CEZ.

Innovation in distribution not only includes newly-designed equipment or original ways of combining existing one: **Paper 0305** delivers the first results of a pilot project related to the establishment of enhanced safety corridors in order to significantly reduce the risk associated to Extreme Weather Events. Following a 2015 CIRED paper based on the methodology adopted, authors describe the process of establishing the corridors, sizing them appropriately according to the residual risk detected outside the existing ones, negotiating new conditions with landowners and deploying alternative solutions in case of lack of agreement. Observation of benefits related to new corridor configuration is presently ongoing.

Reactive power management is undoubtedly one of the hottest topics in TSO as well as DSO agenda. **Paper 0347** described a Reactive Power Management system jointly developed by five DSOs in Germany to coordinate the contribution of HV-connected generation to compensate reactive needs from lower voltage levels as well as to help balancing the transmission system. Different regulating functionalities, such as Q(P) and Q(V), are used in order to ensure participation of Distributed Generation units to system regulation while compensating local voltage variations also due to its own infeed. The first stage of the project implies the reactive set points manual definition by the DSO control center (resulting in a reactive power provision as plotted in Fig 11); further implementations foresee automatic optimization of set points according to field measurements.

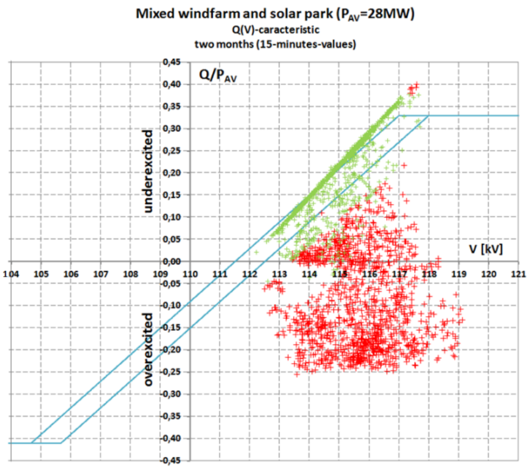

Fig. 11: Reactive power provision from 110 kV connected DG unit with partly compliant Q=f(V) functionality, as in Paper 0347

Paper 0975 exposes ongoing activities performed by CIRED/CIGRE C6.25/B5 Joint Working Group (WG), focusing on the planning and optimization of active distribution systems. A detailed description of functionalities, made available for both TSO and DSO by the introduction of enhanced control levels in distribution, is provided. Authors show that flexibility options, such as increased system awareness, adjustment capabilities and automatic reconfiguration options can all contribute not only to better operation by also to short-term planning.

Sub block 2: Smart Grid Systems and Applications
Sub block 2 includes papers explicitly dealing with Smart Grid topics, ranging from strategic development plans to infrastructures and architectural novelties, to specific functionalities' delivery. It must be noted that Smart Grid applications also include LV networks.

Paper 0318 outlines the future development of the electrical system in Indonesia: following an assessment of the expected evolution of demand and generation in the Country, and according to the opportunities Smart Grid may offer, a comprehensive roadmap has been elaborated. A structured approach is adopted in order to specialize Smart Grid features and performances to match the different needs of most relevant subsystems in the Indonesian area: continuity of supply, system stability, access to electricity.

Paper 1272 describes the preliminary results coming from the project "FlexNett" developed by Finnish DSO BKK. The project aims at investigating advanced flexibility options such as storage and a fault location system. An accurate description of specific functionalities and expected benefits is provided: in detail, the positive effects of storage installation in the distribution network range from the increase of continuity of supply and power quality to the mitigation of voltage variations, while advanced fault location and restoration ensure improvements in outage management, reduction of operational costs and possible deferral of reinforcement investments.

Paper 1321 also deals with advanced functionalities made available by a network architecture in which individual components, such as Distributed Energy Resources and Microgrids, are integrated with a Distribution Management System (DMS, see Fig. 12). Firstly, typical DMS functionalities such as voltage regulation and fault restoration are examined; then, specific focus is given to communication and information exchange between DMS and Microgrid Controllers to ensure the delivery of system support services such as active and reactive power dispatch.

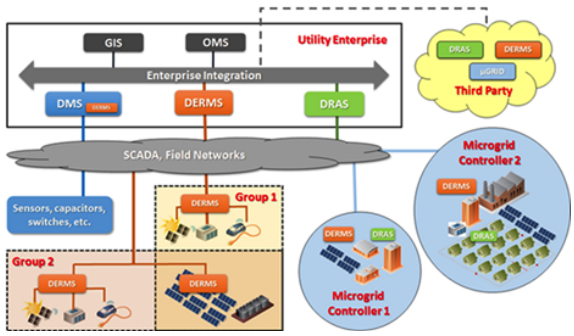

Fig. 12: Reference model of an Integrated Electrical Distribution System, as reported in Paper 1321

Communication is a key enabler in Smart Grid development: **Paper 0374** summarizes the most significant characteristics of a communication system supporting main Smart Grid functionalities in order to verify the possible adequacy of 5G option. Communication performances needed to ensure appropriate operation of tele-protection systems, to deploy advanced automation and control, to allow enhanced monitoring and diagnostics are therefore analyzed. Results show that 5G wireless system has the potential to be an alternative to cabled communication due to its wide area coverage, low latency, reliability and scalability: however, its success will be greatly dependent on how this will be achieved ensuring, at the same time, affordable costs.

Making best use of capacity management to avoid unnecessary network expansion in LV networks is the topic around which **Paper 0210** is centered. Authors describe a specific application of the Universal Standard Energy Framework deployed in the Lombok neighborhood of the city of Utrecht: Lombok pilot project aims at ensuring the charge of EV through excess PV generation as well as relying in V2G functionalities to avoid shortages of supply and network congestions. Evidences gained through the operation of the control infrastructure show the capacity management is currently working as expected; future extensions are expected to include reactive management as well.

Sub block 3: DC Distribution Systems
The topic of DC distribution in LV networks has already been underway for some years, starting from the fact that virtually all new significant loads are represented by DC equipment, which would easily suit a DC grid; theoretical models and reference architectures have already been investigated as well as network operation. Therefore main research activities in Sub-block 3 mostly relate to specific issues such as replacement strategies, cost-effective options and often include demonstrators or real operational cases.

Paper 0542 describes the process of designing, constructing and testing of a real LVDC distribution line in a mountainous area within the perimeter of KEPCO, the Korean DSO. The LVDC installation (Fig. 13) has been carried on in order to reduce the impact of vegetation on the distribution system; due to the low load supplied, an existing 22,9 kV AC system was replaced with a 220 V DC one. Specific focus is given to the conversion units, to the insulation-monitoring device and to the monitoring system. Future research will include improvements in conversion system efficiency and reliability and the development of LVDC operation standards.

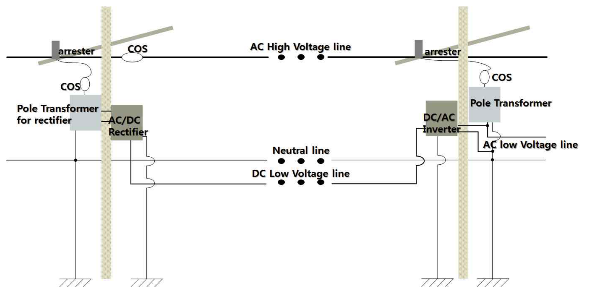

Fig. 13: Actual LVDC Distribution Line Configuration, as reported in 0542

Paper 0732 presents a detailed demonstration plan for the development of a LVDC system to supply the isolated system of Geochado Island in South Korea.

The process includes the definition of optimal RER capacity to be installed in order to grant power balancing in the network, for which a specific control system - including load management features – has been designed. Expected results from the project include the definition of operational strategies to optimize LVDC management.

The problem of converting an existing 33 kV AC line into a 27 kV DC one is exposed in **Paper 0974**, describing the main findings of ANGLE-DC project, developed under the 2015 Network Innovation Competition organized by Ofgem. Authors describe the actions needed to convert two existing AC circuits, from the island of Anglesey to the Welsh mainland, to operate as DC circuits (see Fig. 14): this will lead to an increase in the capacity of the connection without over-stressing existing infrastructure. A significant contribution to the development of MVDC technology is expected due to the findings of the project.

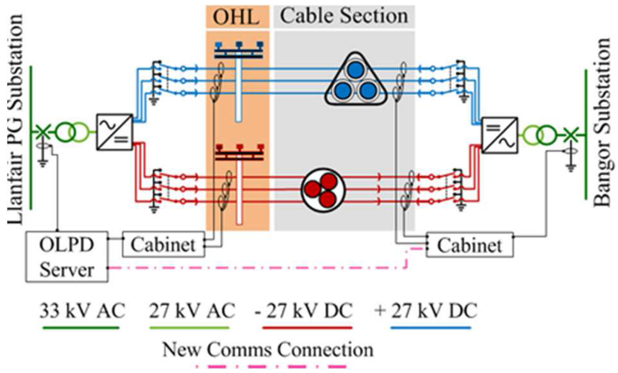

Fig. 14: DC circuit with an Online Partial Discharge monitoring system and new communications connection (Paper 0974)

Paper 1003 compares two alternative options to develop a DC infrastructure starting from an existing AC one. Full DC and Link-type solutions are analyzed with reference to a refurbishment intervention in a rural Finnish area to identify the most suitable investment decision. Results show that there is no one-size-fits-all solution for the refurbishment problem: investment costs are by far the most relevant ones in the economical evaluation of alternatives, FDC resulting more competitive against LTDC the lesser the number of customers to be connected.

Potential scope of discussion
Distribution systems have dramatically evolved but some concepts are not evolving at the same speed. One example is represented by the use of power factor as a metric to assess the good behavior of customers in the power system. Is there any reason to keep using average power factor values? Is this reasonable in the era of second-generation Smart Meters that can allow real time operation? Would be better abandon the concept of power factor and talk about Volt/VAR regulation?

Which are the reasons for enabling DSO to own and operate storage systems?

Table 2: Papers of Block 2 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0210	Capacity Management of Low Voltage Grids using Universal Smart Energy Framework				X
0305	Innovative Solution of Safety Corridor Design for Overhead Lines: Increasing Resilience to Extreme Weather Events while Providing Environmental Benefits - Results	3			X
0318	Pioneering Smart Grids for Indonesia - the Case of a Smart Grid Roadmap Development				X
0347	Reactive Power Management by Distribution System Operators – Concept and Experience	6			X
0374	Challenges and Opportunities of 5G in Power Grids				X
0542	Construction of Actual LVDC Distribution Line				X
0607	Recognize the Need for Innovation and Smart Solutions for Distribution				X
0683	Demonstration of Remote MicroGrid System in Korean Island				X
0728	Planning 100% Renewable Energy Islands - The Case of the Caribbean Island of Montserrat				X
0732	Demonstration of LVDC Distribution System in Island				X
0750	MV Grids Development And Automation				X
0861	Planning of Autonomous Smart Micro Grid for Electrification of Remote Villages in MEDC				X
0974	Initial Designs for ANGLE-DC Project: Challenges Converting Existing AC Cable and Overhead Line to DC Operation				X
0975	Control and Automation Functions at the TSO and DSO Interface – Impact on Network Planning				X
0986	Strategic Interconnected Network Transitioning	4			X
1003	Comparison of LVDC Distribution Network Alternatives: Full-DC vs. Link-Type Solutions	7			X
1006	Cost-benefit Analysis for Using Batteries in Low-voltage Network for Decreasing the Outage Time Experienced by Customers				X
1030	Measurement Concept for Efficient Planning of Distribution Grids	5			X
1236	Fractal Grid - Towards The Future Smart Grid				X
1272	Flexible Network Operation				X
1287	Challenges, Innovative Architectures and Control Strategies for Future Networks				X
1321	DMS Advanced Functions for Accommodating High Penetration of DER and Microgrids				X

Block 3: Distribution Planning

Sub block 1: Advanced Planning

Papers in this sub block deal with new approaches to distribution planning. Different time scales are examined (e.g. long term planning and short term) as well as different voltage levels (e.g. HV, MV, LV). All papers give a significant contribution to the state of the art with particular reference to the adaptations that are required by the need to incorporate renewable energy sources and to exploit the benefit of demand flexibility. Novelties are represented by the abandon of deterministic approach, the inclusion of operation actions in planning and the application of decentralized/distributed techniques.

Paper 0947 report the comprehensive and detailed results from a UK project that aims at designing the 2030 distribution system and at identifying the best options for solving the expected issues (e.g. voltage regulation issues as reported in Fig. 15). The project and paper have a plenty of significant results and the density of information is hard to be synthetized in few sentences. Anyway, from the planning practices point of view (S5 main topic) it is worth to observe that in order to fully utilize the existing network capacity and ensure acceptable network operation under a range of network conditions substation load profiles and load factors together with minimum demand and generation export, as well as maximum demand studies should be considered, and that network planning should be able to assign full value to the flexibility that smart solutions can provide to manage uncertainty but conversely that the risk associated with the loss of flexibility that the existing system margins provide is accounted for.

Voltage	Issue	Base Network			
		Urban	Rural	SPM	Central London
132kV	Undervoltage	✓	✓	× limited undervoltage issues	✓
	Overvoltage	✓	✓	✓	✓
33kV	Undervoltage	× limited undervoltage issues	× undervoltages at HV side of transformers on transformer feeder circuits	✓	-
	Overvoltage	✓	× overvoltages at HV side of transformers on transformer feeder circuits	✓	-
11kV	Undervoltage	× extensive undervoltage issues	✓	× undervoltage issues on rural radial network	× limited undervoltage issues
	Overvoltage	✓	× extensive overvoltages	✓	✓
LV	Undervoltage	× undervoltage issues with connections in excess of Scenarios 1 & 2	× undervoltage issues with connections in excess of Scenarios 1 & 2 when fed by upstream primary with set point of 1pu	× limited undervoltage issues	✓
	Overvoltage	× overvoltage issues with connections in excess of Scenarios 1 & 2	× extensive issues when supplied by primary with set point of 1.03pu. Overvoltage issues with connections in excess of Scenarios 1 & 2 when fed by upstream primary with set point of 1pu	× Limited overvoltage issues	✓

✓ - indicates no issues
× - indicates issues as elaborated

Fig. 15: Expected voltage regulation issue in the UK distribution system (2030) according to Paper 0947

Paper 0857 deals with Network and Investment Planning (N&IP) that is a challenge in terms of financial and technical sustainability. N&IP is even more complex in global context that means different planning rules, regulatory frameworks and level of development. ENEL proposes a general framework that allows finding the optimal CAPEX allocation within the company by considering the needs of national DSOs. A decision tool for the qualitative comparison of view of the companies has been built. It allows simulating the way of distributing variations in the maintenance CapEx. The accuracy depends on available KPIs that have a high correlation with the need for maintenance CapEx. Due to scale effects on the infrastructure of the companies being analyzed, it would be convenient to subdivide large companies into sub-companies with more homogeneous scales, in order to make an analysis under more homogeneous conditions.

Paper 0061 deals with long term-strategic planning with a holistic approach that includes the benefits of smart grid in the list of possible design options with particular attention to the exploitation of demand/generation flexibility. The main strength of the approach is that different voltage levels are taken into consideration with a very interesting application of multi-agent time-series simulation integrated within software for network expansion optimization. The developed approach enables network planners to improve their network planning process with multiple voltage level analysis in one step, consideration of different scenarios over multiple years, automatic optimization of the critical situations, estimated costs of the different actions depending on the scenario and its occurrence which allows a financial evaluation (Fig. 16).

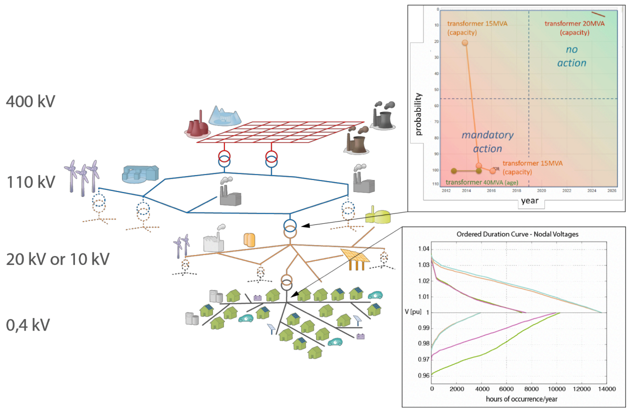

Fig. 16: Scope of integrated planning as described in Paper 0061

Paper 0954 is devoted to long term planning applied to development of distribution systems in Zurich. The authors proposed a tool for strategic planning that is capable to manage the combination of conventional and innovative measures. The planning periods for new technologies are shorter than for conventional grid expansion. New technologies do not necessarily need to be used as permanent solutions; they can also be cost-effective intermediate solutions until conventional grid expansion becomes necessary at the end of a component's lifetime. These considerations leads to the conclusion that short-time intervals for planning should be used in order to allow including the impact of the uncertainties that affect distribution planning. Fig. 17 shows the architecture of the proposed planning process that has been applied to the case of the electro-mobility under four different scenarios of development. The results confirmed that agile planning is necessary with shorter planning intervals result in reduction of investment risks but at the same time increase the complexity of the planning.

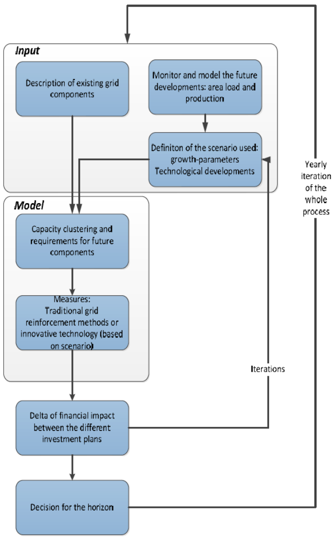

Fig. 17: The strategic planning process proposed by Paper 0954

Also **Paper 1237** analyses the UK power system with the aim at identifying and evaluating options for a future network security standard to potentially fulfill Engineering Recommendation P2/6. The authors identify drawbacks and weaknesses of existing security standards that are still based on deterministic criteria, binary approach to risk, with a level of redundancy not linked to the VoLL for customers and that do not consider the opportunities from no-network solutions and active operation. As a result, the present security standards tend to be conservative and they would be cost effective only for "extreme" cases with high failure rates, long restore/repair times and low upgrade costs. In most cases however, particularly at the HV level, the existing networks could accommodate demand growth in the short term, relaxing the N-1 requirement up to the point where the reinforcement becomes economically justified. In some cases the peak load can nearly be doubled without the need for network reinforcement; networks with low reliability performance, low upgrade cost, and high outage costs (high VoLL) tend to require a higher degree of redundancy. Finally, the requirements for network upgrade due to demand growth are also lower when operational measures are used. The analysis demonstrated that it is still beneficial to defer the investment if possible, as. It is worth mentioning that the VoLL for some HV UG network with high reliability and high upgrade cost, may need to be more than £3,500,000/MWh, to maintain N-1 degree of security.

Paper 0117 deals with integrated planning and it represents a good combination of theoretical studies applied to a real case (the work plan activities of CELESC, a Brazilian DSO). The main idea is to improve the MV planning process by improving the quality of knowledge in the company for a better input to decision-making, and by using multi-criteria evolutionary programs for optimal decision-making related to the choice of investments. Software has been developed to optimize the choice of work plans. It is worth to notice that with this software under the same budget constraint (US$ 2.74 million), CELESC proposed 38 works whereas OMAP, using the prioritization algorithm a priori, proposed 43 works.

Paper 0708 deals with the possible benefits from changing to radial operation to meshed operation. Even though the topic is not new, the authors give a comprehensive contribution that confirms the benefit of meshed operation of distribution systems with reference to German system also (similar results had already been published with reference to Italian and French systems). The most effective way for meshing, a closed loop with two feeders supplied by the same primary substation, is capable to fix voltage regulation issues and power congestion in more than 70% of cases with small CAPEX (cost of novel protection schemes is not considered in the study). It is worth noticing that, as shown in Fig. 18, benefits are not limited to distribution systems only. The relief of HV lines is shown for different combination of generation and load in the MV side after meshing.

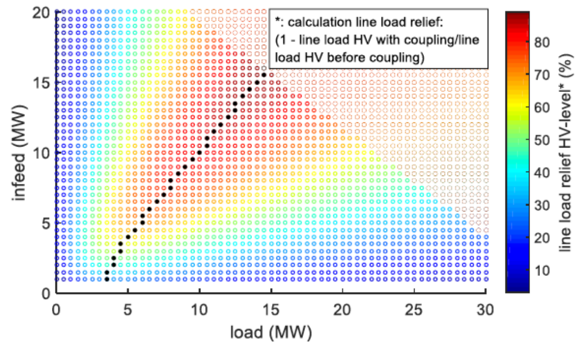

Fig. 18: Positive impact of MV meshing on the HV infrastructure according to Paper 0708

Paper 0727 offers a good contribution to the optimal distribution planning solved with analytical models. The problem is formalized as MINLP and original contribution are given. The authors proposed the application of Bender's decomposition and convex outer decomposition. Despite the high reduction of complexity, improvements have been achieved for both quality of results and computational times. The paper looks very theoretical but the new frontiers of planning, which oblige to include multiple energy services and a multitude of actors in development planning, for sure will profit from such kind of theoretical studies that look from the very early beginning to practical applications.

Paper 1218 offers a significant contribution to the definition of Network Planning Case (NPC) suitable to networks with high shares of DG. Indeed, despite the terrific change faced by DSO, planning is still based on NPC that aims that do not consider the real coincidence factor between the consumption and/or generation and that are obtained by applying general rules. The authors propose a new methodology for the determination of relevant NPC based on synthetic time series. This concept tackles the problems of non-existent customer data and bypasses the tremendous effort for time series calculation by reducing them to relevant cases (Fig. 19). For Synthetic NPC generation, synthetic time series are created with the analysis of measured time series. Stochastic interdependencies (linear and non-linear) are derived and used to model realistic time series for all customers connected to the distribution system. In order to reduce the computational effort, dimensioning NPC and representative are sorted out. From the example presented, it emerges that two or three NPC for the dimensioning of the grid and roughly 30 NPC for the calculation of annual values, such as losses or feed-in-management, are necessary.

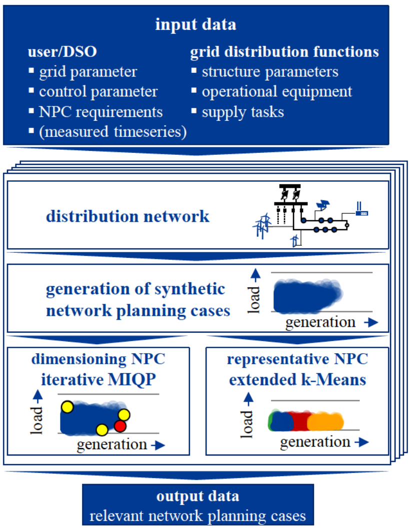

Fig. 19: The methodology proposed by Paper 1218 to find relevant NPC

Paper 1031 is a preliminary and visionary work that deals with a possible application of machine learning techniques to distribution planning that authors consider being and art and a science. Particularly, the authors wanted to explore the application of Artificial Neural Network to optimal distribution planning (optimal design and routing) since this activity is at the top of Bloom's hierarchy of human learning steps (i.e. the capability to create). The authors proposed Hopfield's network for this kind of application that is assimilated to the salesman travel problem (minimum length path). The main drawbacks of the proposed methodology are the computational inefficiency, the level of development (research) and the absence of commercial tools.

Paper 1025 deals with a very practical methodology that exploits the information from AMR in order to have profiles for load flow calculations. The authors have tested the methodology with 10 kV distribution network from a given primary substation in Denmark. It is worth to notice that according to the data collected the Velander's formula used to estimate maximum load (used for design calculations is still valid) but it can difficulty be used in feeders with significant levels of distributed generation where the combination of generation and demands makes it problematic a proper identification of minimum load. Data collected from smart meters can be used profitably in network calculations for operation and planning analysis to enhance the quality of studies and go beyond Velander's models. Voltage maps can easily be obtained (Fig. 20) and important information on the role of DG on network losses, not always positive, can be obtained by DSOs.

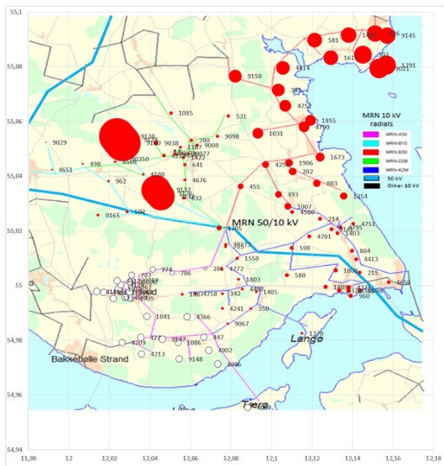

Fig. 20: Voltage rise in a portion of Denmark distribution network calculated from real data gathered from AMR (Paper 1025)

LV distribution networks are still the weakest ring in distribution planning since squeezed between the opposite needs of giving rapid answers to customers and the need to include in formal studies networks that are close to the end customers whose behaviour can difficulty be represented with average models. Anyway, the role of LV is going to change and efforts are necessary for propel modelling and planning. Since customers are going to be deeply involved in network operation, it is a good for any planning study to start with an updated knowledge of people in term of expectations and possible investments. **Paper 1034** does an interesting contribution for better know customers represented by homeowners and renters in the Netherlands. People value the reliability of the grid 88-232 € depending on the duration.

The willingness-to-pay (and to spend) would increase self-sufficiency level. It is interesting to notice that there is a large group of people that looks at self-sufficiency and sustainability and it is not driven by costs (larger than group with highest education). This people will go off-grid first and is naturally eligible to co-operate with DSO for exploring innovative services. Finally, PV will continue to be installed and electric vehicles will increase their penetration. A general conclusion is that the electric sector will change faster then the heat/thermal and DSO should review their policies in order to anticipate the change.

Paper 0383 demonstrates the importance of LV customers behavior and load forecast in LV planning applied to a significant Dutch case where there is the goal of reaching energy neutrality by 2050, particularly in the residential sector. Electric Heat Pump (HP) and PV installation are re-shaping the way energy is consumed and transformed at residential level and giving the end costumer the power of choosing. The authors first propose a method to forecast how the customers will behave. The model starts from a very detailed representation of the area of interest (address level) and assumes that each customer in the area will decide for the best energy mix according to price and environmental signals. The forecast model has been applied to define 4 scenarios of development: local-sustainable with subsidised local generation; central-sustainable with centralised renewable generation; local-not sustainable with low access to renewables and demand response; central-not sustainable, i.e. the traditional situation where natural gas and centrally generated electricity from fossil fuels are supplied to customers. The paper shows the impact of scenarios in specific distribution networks and network bottlenecks are identified (Fig. 21).

Fig. 21: Example of the LV grid and bottlenecks due to scenarios of development (Paper 0383)

Related to the topic of LV networks is the impact of demand flexibility on network development. **Paper 0868** represents an accurate analysis of the impact of DSM on voltage stability in distribution networks. The study is based on a network with sub transmission (132 kV, 33 kV) and distribution circuits (11 kV). This comprehensive study goes deeply on the effect of DSM on voltage stability that is strictly correlated to the distribution of load types (constant impedance, constant power, and constant current load) moved with DSM at a certain time of the day. The main conclusion is that network voltage stability changes with the DSM action. The type of customers involved and the time of application influence the impact on voltage stability. Interesting sensitivity charts are proposed to identify the most critical areas.

Paper 0258 deals with the problem of non-loads and harmonic pollution referred to the optimal sizing of distribution transformers. The authors propose a method based on IEC60354 and IEEEC57.110 standards. The methodology has been tested with reference to the complexes of Golestan and Khedri in Iran where a significant THD has been measured caused by lighting and computers. The examples proved that in highly polluted complex – the Golestan one, the distribution transformer should be changed and that the existing 400 kVA transformer ageing ratio increases by 2.6 due to presence of harmonic currents and voltages.

Paper 0677 proposes an interesting planning procedure that is oriented to develop network that follow the Japanese topology of multi-divided/multi-connected networks (Fig. 22). This network topology allowed Japanese networks to obtain higher levels of reliability compared with industrialized countries. The results of the study confirmed that the multi-divided scheme offers better performances and is also economically convenient, particularly if high rates of demand growth are expected.

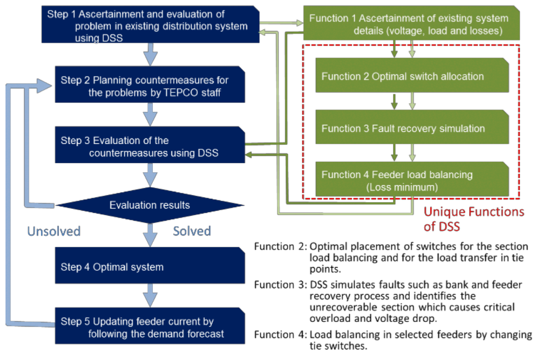

Fig. 22: Planning process for multi-divided/multi connected networks (Paper 0677)

Micro Grids (MG) are an opportunity for the development of distribution systems. Many authors have demonstrated that with MG costumers can achieve financial benefits and better quality whereas DSO can postpone investments without jeopardizing reliability and even increasing resiliency. **Paper 0394** deals with the conditions that make MG attractive for industrial customers, interested to reduce their energy bill. The problem is formulated as long term/short term planning with multiple stakeholders (DSO, industrial prosumers, industrial estate operator) that act as autonomous agents according to the Game Theory. The optimization program developed by the authors finds the Nash Equilibrium that is not the optimal solution for each stakeholder but rather a solution through which each stakeholder is satisfied. MG operation favors exchanges between prosumers and consumers inside the MG.

MGs are particularly attractive in rural or remote areas with weak or no network connectivity available. In this case MG must run autonomously and their design and planning is not straightforward since generation and distribution cannot be kept separate. This topic is brilliantly dealt with by **Paper 0841** that propose an optimization algorithm for the optimal planning of autonomous MG. Joint planning of generation and distribution can be cast as mixed-integer non-linear integer program (MINLP). The planning problem should provide an investment plan for the considered system over a given time horizon, which can be translated into the three following questions: Which assets should be placed? Where to place them? When to place them? The objective is to minimize the total cost of the system. The authors propose four convex algorithms for the joint optimization of MG with different relaxation techniques; the algorithms have been applied successfully to a small sample and represent a good starting point but they should be tested on bigger examples with more nodes.

Managing the transition from an isolated-neutral MV system to a different grounding system requires a planning effort in order to collect all the benefits related to the final conditions while avoiding its potential disadvantages and minimizing the negative impact of the transition itself. **Paper 0393** goes deep in comparative analysis of neutral earthing alternatives in the MV network of Xining: authors not only describe the reasons for examining all possible options (see Fig. 23), but also define the future process to be put in place in order to choose the optimal solution.

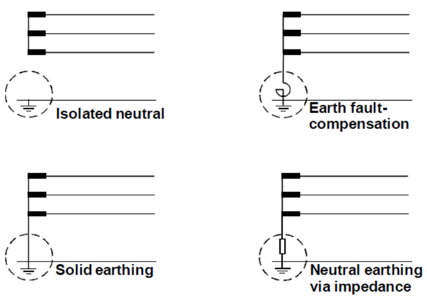

Fig. 23: MV neutral earthing alternatives as in Paper 0393

Sub block 2: Planning of Active Networks and Smart grids

Nowadays all distribution networks are in fact active to some extent and include smart functionalities; it is simply obvious that the large majority of papers dealing with planning are in some way related to the opportunities as well as the threats linked to the presence of distributed generation, as well as other distributed resources, and to their advanced capabilities. Sub block 2 includes papers who make, more or less, an explicit reference to "active networks" or "smart grids", introducing methodologies and algorithms to include in the planning process the already available or foreseen capabilities and/or roles. The expected results include a more efficient use of the infrastructures, an increase of the expected level of performance and/or an enhanced interaction between the different sets of users.

One of the most interesting trends in future networks is related to the possibility to make use of available flexibility in order to fulfill through operational measures the same contractual obligations that nowadays require investments in the infrastructure. To do that, robust methodologies ensuring operational measures can be put reliably into account in the planning phase are needed. **Paper 0204** presents a simulation tool, developed under the sponsorship of the German Federal Ministry of Education and Research (Project ARRIVEE), allowing an accurate representation of the contribution of different flexibility options (both in source and demand) to the adjustment of network condition to contractual standards. A case study is presented, showing flexibility may help avoiding critical grid conditions, eventually allowing deferral of grid enhancement.

A comprehensive model for planning purposes, taking into account not only flexibility options but also uncertainties of network usage, is introduced in **Paper 0360**. A multi-step algorithm is chosen to solve the network expansion optimization problem (Fig. 24). The authors firstly outline the problem setting activities; an accurate description of the algorithm follows; finally, some exemplary results are shown, related to a 10 kV MV network to which the connection of a wind farm is expected.

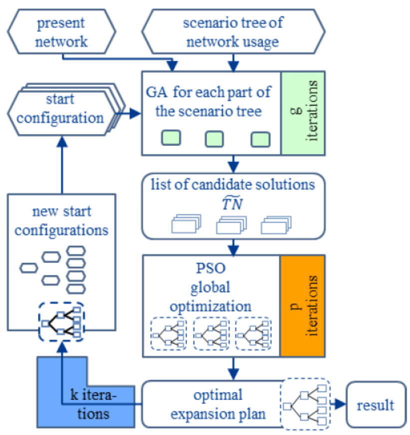

Fig. 24: Overall optimization algorithm as in Paper 360

Paper 0831 introduces the so-called "Intelligent Grid Platform" (IGP), a planning tool through which the full panel of conventional and non-conventional grid solutions is taken into account while deploying a comprehensive plan. Alternatives include (conventional) grid expansion, installation of storage systems, DER curtailment management, flexible loads use. A global optimal solution, including investment as well as operational and flexibility costs can therefore be chosen. Some case studies are then presented.

In **Paper 0571,** a power system flexibility evaluation index (FEI) is proposed for planning purposes. FEI of a power distribution system is defined as the probability that flexibility resources satisfy the flexibility requirements. FEI of a given system and for defined time scale can be determined through a Monte Carlo simulation. By calculating FEIs of different systems including RES and flexibility resources, it is possible to evaluate by comparison the future performance of alternative solutions.

Paper 0771 describes a methodology that can be used for planning purposes in active distribution networks: it aims at determining the optimal network reinforcement and expansion plan also considering as flexibility option the ancillary services that can be provided by DG. A hybrid genetic algorithm (GA) – non-linear programming (NLP) approach is chosen: more specifically, the proposed method minimizes the network investment and operational costs. An application is shown on a 21-bus distribution system to validate the method's performance.

Paper 1357 also challenges traditional "fit and forget" planning arrangements by introducing an enhanced expansion planning control mechanism, which integrates a multistage analysis process with an adaptive network control algorithm (Fig. 25). The proposed tool, that allows taking into account flexibility options in planning, is tested on a modified 12-bus rural distribution network. The simulations executed show that by incorporating active network management techniques within the planning strategy, an investment deferral can be achieved.

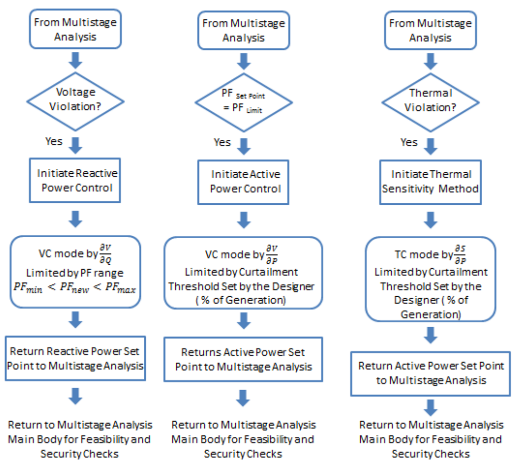

Fig. 25: Functional charts for reactive power, active power curtailment for both voltage and thermal control as in Paper 1357

Paper 1042 introduces an integrated tool for active network expansion planning, taking into account flexibility of generation and load in addition to the traditional infrastructure and operating costs. The case study of a 10 kV network with 11 nodes, 6 aggregated residential loads having 4 heat pumps and 10 PVs and 5 industrial loads directly connected to the network is then described and analyzed. A six years expansion planning horizon with one representative day per year having a high positive-load is chosen for the study.

Paper 0569 deals, again, with active networks including flexibility. Authors describe an "operational planning" tool coordinating the flexibility activation planning by introducing an activation probability for every flexibility option. The objective function of the algorithm developed is minimum cost of the activated flexibilities, guaranteeing the acceptable operation of the network. An IEEE distribution network with distributed generation sources is used as base scenario for evaluation. A correlation between the probability of activation for flexibilities and the global result provided by the operation planning tool was observed, since at low levels of probability results provided by the algorithm significantly differ from reality: further work is needed to make the model more robust under uncertainty conditions.

A comparison of traditional as well as flexibility options available in an active network with reference to energy losses is the focus of **Paper 0855**. A reference network, based on IEEE 33-bus standard, is analyzed in relationship to its possible evolution according to a fully conventional, fully non-conventional and hybrid approach to match with DG growth. Results show that traditional reinforcement has the highest potential in energy savings, while smart grid solution ensures lower costs; the hybrid approach ranks between the two both in costs and in losses.

Two case studies for use of flexibility potential in distribution networks are exposed in **Paper 1027**. In the first one, the installation of a third HV/MV transformer in an existing substation equipped with two of the same size is compared with the activation of flexibility options in a 30-year period, the installation being initially planned for the fifth year. In the second one, the installation of a second HV/MV transformer in an existing substation equipped with one of the same size is compared with the activation of flexibility options in a 30-year period, the installation being initially planned for the fourth year. Results show (see. Fig. 26) that practical results are strongly dependent on specific characteristics of available flexibility, such as its location on the network, and that present modeling levels are far from being ready to be used in a generalized manner.

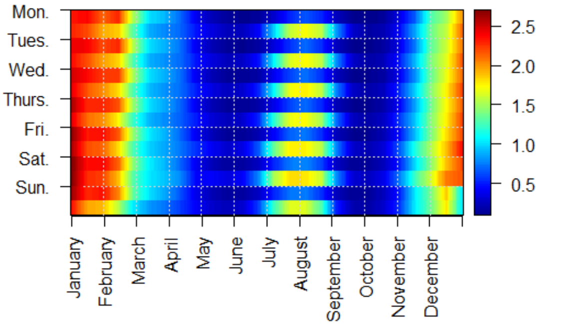

Fig. 26: Statistical need for flexibilities over the year (average for 245 climatic scenarios / mean=1) - Case study of Paper 1027

Paper 0048 deals with the use of a specific type of flexibility, the DG curtailment, in HV planning. In particular, the paper focuses on the different needs for grid expansion of a 110 kV HV network in case dynamic (i.e. based on grid conditions at the moment of curtailment) vs. static (i.e. based on fixed parameter related to the connection point only) curtailment practices are adopted in network operation. The curtailment methods are tested using a probabilistic expansion planning method based on the calculation of probabilistic load flow. Results show that the adoption of dynamic curtailment, which obviously implies communication, may lead to significant reduction on network expansion needs at the price of a limited curtailed energy.

An analytical method to assess the impact of distributed generation and energy storage on reliability of supply is described in **Paper 1106**, based on the findings of RESmart funded project. Capacities of DG and ESS operated in islanded mode are supposed to be used to restore the interrupted supply: the analytical model takes into account the hourly time dependent patterns of load and renewable generation during the fault in order to assess the potential of DG and simulate the charge and discharge of ESS. Results show: both conventional and wind DG technologies can improve reliability in a significant way, unlike PV whose contribution was limited; by integrating energy storage, the restoration capability of PV and wind can be increased more than with an increase of mere generation; storage rated power has a greater impact on reliability than storage capacity.

As voltage constraints prove generally to be the most common limiting factor for hosting capacity of distribution networks in the presence of DG, two voltage control strategy options (centralized vs. decentralized) are compared in **Paper 0991** (see Fig. 27). Both strategies result being adequate in solving a LV grid voltage problem as presented in the two case studies; however, the optimal choice strongly depends on the actual extent of curtailment vs. admissible one which, in turn, is related to the penetration of DG itself.

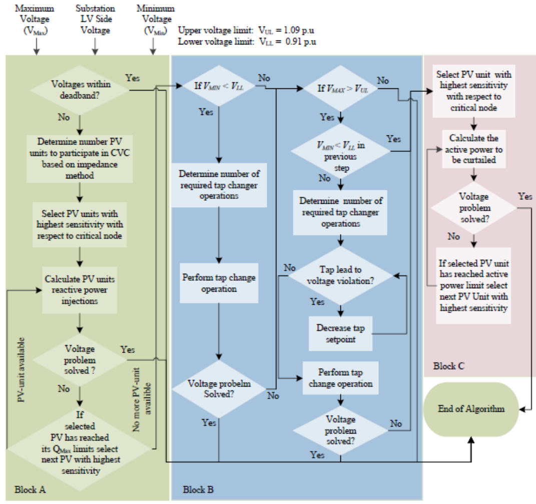

Fig. 27 Centralized voltage control algorithm as exposed in Paper 0991

Voltage regulation in LV networks is also analyzed in **Paper 1093**. Alternative solutions, namely network reinforcement, active and reactive control, OLTC transformers, are considered in order to validate, through field measurements in the real network of Epplas, worst case scenarios (both conventional and newly-proposed) to be adopted in network planning.

Paper 1118 deals with the problem of finding optimal locations for renewable energy installation, based on the predictions from National Grid and grid constraint. Three different classes of methodologies are introduced, namely MinCost, GridConstraint and EnergyConstraint (see Fig. 28); a spatial RES expansion forecast is performed, and new generation is determined based also on grid connection issues; finally, the impact of new RES on the wholesale electricity prices in analyzed and future prices are calculated. The price simulation reveals that optimal locations can lead to lower prices only to a limited extent.

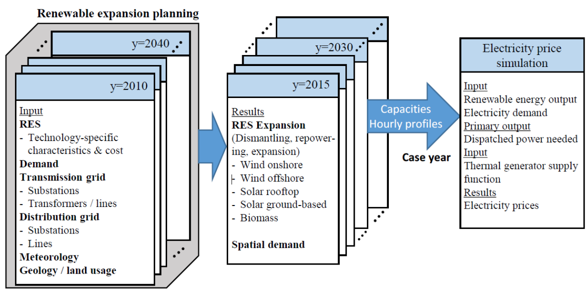

Fig. 28: Schematic overview of modelling approach of Paper 1118

The problem of optimal network planning under uncertain conditions and nontechnical obligations is exposed in **Paper 1210**. The case of Croatian DSOs, which are by force of regulation obliged to preserve network resources to ensure connection to unlikely DG initiatives of never-ending validity, is described. Then a planning model, designed to cope with the existing complexity, is detailed. Results show that the exposed criteria ensure reasonably accurate planning with negligible violations; however, a fairer distribution of risks among different operators could ensure a far better evolution of the system.

One of the impacts of distributed generation on a previously passive network is its effect on the reduction of peak load by self-consumption: **Paper 1248** analyzes this specific issue, focusing on the relationship between PV penetration and reduction of network sizing for conventional customers at the same quality of supply. The simulation run proved reasonably accurate (> 90% when using more than 300 scenarios) and shows that RES allow lowering the sizing power by a 4 % to connect new customers to a same MV feeder without reinforcement needs.

The possibility of increasing the cost-effectiveness of DG (namely PV) connection assessment in investigated in **Paper 1367**. The paper describes DPG.sim, a simulation platform developed for ETH Zurich, in which a typical European low voltage distribution grid is modeled. Starting from this benchmark LV grid, the assessment of the connection request is made, based on voltage rise calculation and hosting capacity verifications. Time series simulations are performed in order to determine an appropriate evaluation of the request. Results are provided, showing time-series based grid simulations are able to provide valuable insights for distribution grid operation and planning, as a larger DG hosting capacity can be made available avoiding otherwise costly conventional grid upgrades.

Paper 0400 describes an approach to group “smart inverter PV” deployed within a LV system to enable the correct monitoring and control of these smart inverters. Through the clustering process, a better coordination, enhancing distribution operation, can be achieved. Results show that through the proposed approach an increased effectiveness can be obtained, as well as that the process of clustering is not intuitive, as the composition of cluster may differ from case to case.

Paper 1004 focuses on the problem of Cost-Benefit Analysis (CBA) for investment decisions in Energy Storage Systems (ESS) connected to the distribution grid (a case study is represented in Fig. 29). As ESS are versatile component and their contribution to the performance of the network may be delivered according to different – eventually cooperating, otherwise conflicting – strategies, a comprehensive approach to CBA is needed. The paper, developed through a research project funded by Italian Regulator AEEGSI, proposes a hybrid methodology, based on the combination of a Multi-Objective optimization and a Cost-Benefit Analysis, in order to build a simple look-up table that easily allows identifying those project proposals that can be considered convenient a priori.

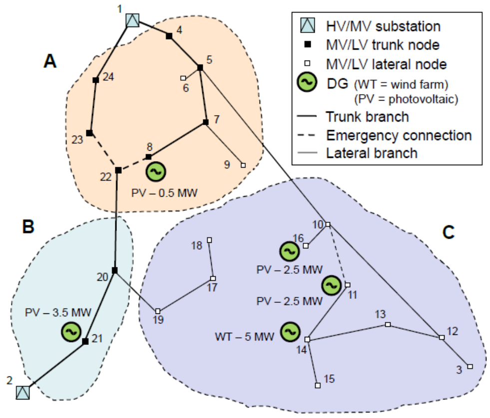

Fig. 29: Case study analyzed in Paper 1004

Paper 0848 exposes three methods for the utilization of solar roof potential analysis for the calculations of PV hosting capacity at medium voltage feeder level: forward PV increase, backward PV increase and even increase are considered to determine maximal and minimal hosting capacity. To do that, installed DG is gradually increased according to the chosen approach until violations appear. Results show MV/LV transformers overload is the most common violation appearing in even and forward increase conditions, while voltage violations represent the limiting factor in backward increase one. Furthermore, the method with an even installation of PV systems along the feeder results in higher hosting capacity of PV for the analyzed grids.

Sub block 3: Optimal Placement of Power and Control discrete Components

Innovation in the field of distribution has made largely available advanced functionalities embedded in physical component that must be installed in the grid; at the same time, changes in network conditions may suggest innovative uses for conventional components. Following that, a placement optimization process must inevitably start, according to methodologies somehow irrespective of the kind of component and the scope of installation.

Sub block 3 mostly deals with specific planning problems essentially related to optimal placement and sizing of discrete components such as actuators, fault passage indicators, capacitors’ banks, storages, and so on. In some cases, the problem is put at a higher level, implying decisions on optimal load and generation installations or connection.

Advanced network automation is one of the most popular Smart Grid functionality to improve continuity of supply and, more in general, service quality. **Paper 0154** deals with the typical planning problem of optimal placement of reclosers in a MV system to deploy self-healing functionalities. The proposed methodology takes into account the presence of RES and its influence on network constraints. The case study results show that the optimal deployment of reclosers, properly coordinated (see Fig. 30) and allowing advanced self-healing schemes, improves reliability, by mitigating the impact of permanent and temporary faults, and enhances security of supply.

Centralized	Semi-Decentralized	Decentralized
Dispatch Centre	**SSC**	**IED**
DMS/OMS	**micro-DMS**	**peer-to-peer GOOSE**
Any type of RTU	Any type of RTU	Specific RTU
High wide area scalability	Medium wide area scalability	Local area scalability
Slower response time	Average response time	Faster response time
High complexity	Medium complexity	Low complexity
Any type of remote control	Any type of remote control	Distributed intelligence

Fig. 30: Comparative analysis of Self-Healing schemes as in Paper 0154

The same optimization problem is dealt with in **Paper 1242**, in which a methodology of optimal allocation of reclosers to improve continuity of supply is presented. Normally Opened devices (NOs) used for distress between feeders, as well as Normally Closed devices (NCs), used in the sectioning of feeders and in the isolation of faults, are treated by the proposed approach. The algorithm adopted was implemented through a software allowing analyses of interconnected MV systems including more than one feeder at a time. Expected benefits, in terms of SAIDI, SAIFI and ENS, have been calculated and successfully validated in a real case study of the EDP Bandeirante distribution network.

Paper 0030 summarizes the present challenge of automation planners in distribution: the proposed algorithm takes into account the presence of DG, uncertainties in load and generation themselves, different types of automation devices (included - eventually - already installed ones), a risk evaluation related to probability and impact of faults and related outages in the system. The proposed procedure, based on fuzzy set concept, mixed integer linear model and risk management analyses, allows the generation of automation coherent development plans that can be examined and evaluated according to their capability of coping with risk.

Loads and generators could by hardly regarded as “Power and Control discrete components”: however, as their placement in the network impacts on system performance and its optimization may be operated following similar criteria than control equipment, **Paper 0026** fits well in Sub block 3. To mitigate the well-known issues of localized voltage violations while minimizing investment needs, authors focus on operational practices such as balancing of single-phase connections of both passive and active customers. The paper shows that by means of an accurate selection of connection phases, overvoltage in LV networks due to unbalance can be effectively reduced (see Fig. 31).

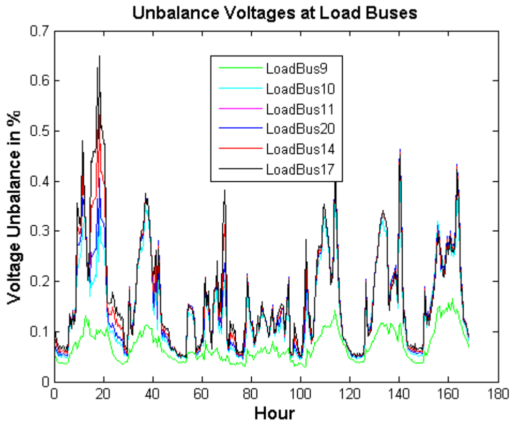

Fig. 31: Voltage unbalance as resulting from the balancing as of Paper 0026

Optimal placement of shunt capacitors in MV systems is discussed in **Paper 0020**. To maximize the benefits of installing such components by accurately selecting their installation sites, a Crow Search Algorithm (CSA) has been used. The proposed procedure has been applied on East Delta Network as a real distribution network in the Unified Egyptian Network, ensuring a fester convergence than more established algorithms and proving reasonably accurate.

Paper 1346 deals with optimal placement of reserve capacity in sub-transmission substations. Load transferring capability with tie switches is studied. To do so, a mathematical model has been developed in which optimal reserve capacity of substations and optimal placement of tie switches are determined simultaneously. The resulted optimization model is formulated as a mixed-integer non-linear problem (MINLP), and the genetic algorithm (GA) is used to solve the problem. The impact of installation of reserve capacity is determined through the Customer Interruption Cost (CIC) derived from outage management in primary distribution networks. The effectiveness of the proposed model is evaluated in a test distribution network. Results show that the benefits of reserve capacity are strictly related to the presence of tie switches to make it available, and that small, appropriate investments in the latter may significantly improve the contribution of the former.

Sub block 4: EV Accommodation Planning

Papers in Sub Block 4 deal with the planning of distribution infrastructure facing the increasing presence of electric vehicles for private mobility, the load growth and RES and DG penetration. Due to the topic becoming more and more established, submitted papers tend to be few in number and not centered anymore to macro-models or roadmaps but more focused on specific integration problems, such as fast charge infrastructure impact or recharge strategies selection.

Paper 1281 evaluates the expected impact on a selected subset of Hellenic Distribution Network of a large deployment of electric vehicles. Authors take into account the main technical issues, such as voltage limits, branches congestion levels and losses evaluation. For assessing the impact of EV, vehicles are considered as loads that charge from the grid. The analysis takes into account driving profiles of EV owners, type of vehicle (battery capacity, energy consumption), travelling distance, road conditions etc. and approximates the hourly allocation of the energy requirements under various EV charging strategies. A steady state analysis toolbox is used to estimate the critical number of EVs that can be integrated in a distribution line (see Fig. 32).

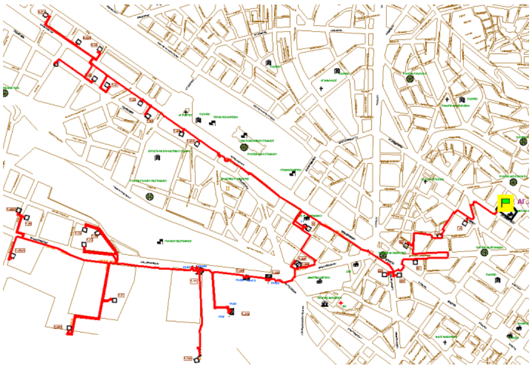

Fig. 32: Urban distribution grid under study in Paper 1281

Optimal allocation of EV charging stations to support the expected evolution of electric private mobility while optimizing the integration with the existing distribution grid is analyzed in **Paper 0551**. The mathematical models proposed for EV charging network planning are meant to maximize the charging service capacity and to minimize power losses in distribution systems. More in detail, a multi-objective decision-making model, with two optimization objectives of different dimensions and conflict with each other, is described: membership functions are introduced to transform the original planning model to a single objective optimization problem. The proposed model is solved by genetic algorithm. A 25-node traffic network and an IEEE 33-node distribution system are used to verify the models and the solving techniques presented in the paper.

Paper 0859 deals with the optimization of an Electric Parking Lot (EPL). The proposed approach is developed in two phases: firstly, an optimization of the EPL itself is achieved by selecting the best charge/discharge strategies to fulfill electric vehicles' needs; then an optimal placement for the EPL within the existing distribution network is operated, taking into account both EPL needs and its potential contribution to network operation, resulting in improved voltage profiles, increased system stability and network losses reduction. The proposed method is implemented on the IEEE 33-bus distribution system: the simulation shows that if an appropriate charge/discharge strategy is selected, all objectives can be achieved.

The specific problem of optimal placement of fast charging station for public transportation is assessed in **Paper 0802**. Authors report the main findings of project "ElectriCity", currently underway in Gothenburg, Sweden, where a public transportation line is operated using electric and plug-in hybrid electric buses. Firstly, the grid impact is assessed by simulations in an optimal power flow based model using General Algebraic Modeling System (GAMS), in which optimal schedule of customers' flexible loads is also contemplated. Then mitigation actions, such as installation of storage, are defined and optimized to minimize the impact of charging infrastructure on network performance and losses.

Potential scope of discussion

The trend towards a wider application of probabilistic methods has been confirmed and reinforced also in CIRED 2017. Indeed, to deal with the uncertainties of production and demand flexibility probabilistic models and time series analysis are necessary. Are these models ready for industrial application? Can we manage the complexity of new probabilistic approaches when applied to real size applications? Can we assess the proper worth of innovative techniques without probabilistic approaches?

Micro grids are an option for system development that can in principle offer service improvements with fewer investments. But, MGs are rarely included in distribution planning. Why? How can micro grids be compared with traditional investments? Can the micro grid worth be captured with deterministic approaches? Is there a business model reasonably good for all stakeholders?

Can futuristic distribution systems be implemented with the current regulatory framework?

MVDC and LVDC have many merits and many papers (see Block 2) demonstrated both the feasibility and convenience of them. Why DC is still not a real option considered by planners? Is everything about the breakers?

Table 3: Papers of Block 3 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0020	Optimal Allocation of Capacitor Devices on MV Distribution Networks using Crow Search Algorithm				X
0026	Increase the Hosting Capacity of 4-wire Low Voltage Supply Network for Embedded Solar Generators by Optimising Generator and Load Placement on the Three Supply Phases				X
0030	Risk Based Procedure for Network Automation Planning in Radial Distribution Networks with Distributed Generation				X
0048	Comparison between Static and Dynamic Curtailment of RES in Probabilistic High Voltage Distribution Grid Planning				X
0061	A Holistic Network Planning Approach: Enhancement of the Grid Expansion Using the Flexibility of Network Participants				X
0117	OMAP (Organizational Memory Aided Planning): An Integrated Planning Tool Using Concepts of Knowledge Management and Multi-Objective Optimization				X
0154	Optimal Recloser Deployment to Leverage Self-Healing: A Techno-Economic Robustness Assessment				X
0204	Flexibility Options for Medium Voltage Grid Planning				X
0258	Optimal Sizing of Distribution Network Transformers Considering Power Quality Problems of Nonlinear Loads				X
0360	Multi-temporal Robust Expansion Planning of Distribution Grids considering Uncertainties and Curtailment of RES				X
0383	Local Forecasting Could Identify Future LV Bottlenecks				X
0393	Suitable Methods for Neutral Grounding of Xining's Distribution Networks				X
0394	On the Use of the Game Theory to Study the Planning and Profitability of Industrial Microgrids Connected to the Distribution Network			2	X
0400	Utilizing Observability Analysis to Cluster Smart Inverters on Secondary Circuit for Residential Deployment	12			X
0551	Optimal Planning of EV Charging Network Based on Fuzzy Multi-objective Optimisation				X
0569	Behaviour Analysis of an Operational Planning Tool facing Activation Probabilities, for Near Optimal Operation of Smart Grids	13			X
0571	Planning of Flexible Power Source in Power Distribution Systems with High Penetration of Dispersed Generation				X
0677	Case Study of the Distribution System Planning for a Multi-divided and Multi-connected System				X
0708	Impact Of Meshed Grid Topologies On Distribution Grid Planning And Operation	8			X
0727	A New Approach to Large Distribution Network Optimization using Modern Implementation of Benders Decomposition				X
0771	Active Distribution Network Planning based on a hybrid Genetic Algorithm-Nonlinear Programming Method			5	X
0802	Impacts of Fast Charging of Electric Buses on Electrical Distribution Systems				X
0831	Automated Smart Grid Planning considering Flexibility Options and Voltage Regulating Assets		14		X
0841	A Comparison of Convex Formulations for the Joint Planning of Microgrids			4	X
0848	Evaluation of PV Hosting Capacities of Distribution Grids with Utilization of Solar-Roof-Potential-Analyses				X
0855	Effects of Network Reinforcement Options on Energy Losses				X
0857	Methodology to Support the CapEx Allocation in a Global Scenario with Multiple Companies, ENEL Case Study				X
0859	Optimal Placement and Charge/Discharge Scheduling of an Electric Parking Lot considering Reactive Power Capability				X

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0868	Assessment of the Impact of Demand Side Management on Distribution Network Voltage Stability				X
0947	Key Findings of DS2030 - a Study in to Future GB Distribution Network Operations				X
0954	A Method for Flexible Long-term Planning with Agile Adaption to Changing Requirements	9			X
0991	Distribution Grid Planning Considering Smart Grid Technologies				X
1004	Cost/Benefit Analysis for Energy Storage Exploitation in Distribution Systems		15		X
1025	Grid Planning by Integrate Customer Meters				X
1027	Flexibilities in Grid Planning: Case Studies on the French Distribution System		16		X
1031	Artificial Intelligence Potential in Power Distribution Planning			6	X
1034	Grid Defection and Value: a Demand Perspective	10			X
1042	Smart Planning: An Innovative Tool for the Investment Planning of Smart Distribution Networks				X
1093	Technical Comparison of Measures for Voltage Regulation in Low-Voltage Grids				X
1106	An Analytical Method to Assess the Impact of Distributed Generation and Energy Storage on Reliability of Supply				X
1118	Analyzing the Effect of Increasing Renewable Capacities in Great Britain on the Regional Allocation and Wholesale Prices				X
1210	Risks of Determining the Optimal Technical Solution of Power Plant Connection to Distribution Network				X
1218	Determination of Relevant Network Planning Cases	11			X
1237	Economically Efficient Distribution Network Design				X
1242	A Methodology to Allocate Automatic Recloser in Large Power Distribution Networks				X
1248	Evolution of Electrical Distribution Grid Sizing Considering Self-Consumption of Local Renewable Production				X
1281	Evaluation of the Impact of Plug-In Electric Vehicles in Greek Distribution Network				X
1346	Simultaneous optimization of tie switches placement and reserve capacity margin of Sub-Transmission Substations considering the Conflict between Short-term and Long-term Planning				X
1357	Demonstration of an Actively Managed Planning Approach for Connection of Renewable Generation				X
1367	Towards More Cost-effective PV Connection Request Assessments via Time-series Based Grid Simulation and Analysis				X

Block 4: Methods and Tools

Sub block 1: Load/Generation Modelling and Forecasting

Availability of elementary data on individual loads from Smart Meters makes it possible to develop a more accurate representation of aggregates of "atomic" consumption that is more and more essential in planning as the "smart" functionalities embedded in most components may lead to rules of combination of individual loads that may significantly differ from purely statistical ones. At the same time, new models for distribution operation require a deeper insight in the "generalized" behaviors of network users.

Sub block 1 deals with methodologies to make use of technical information, field data and measurements, new logics of elementary load management to build models of individual and collective behaviors that may accurately represent the complexity of "smart" loads.

Load forecasting is becoming an important part of new development planning, especially as energy usage continues to grow and utility companies work to meet these demands. **Paper 842** compares flat versus calculated VA/m^2 methods for determining the Ultimate Demand of a development (see Fig. 33). By dividing the development into subsections and taking a detailed look at the different building sub-types a more accurate VA/m^2 can be calculated. This detailed approach gives a more accurate representation of the load requirements for the development.

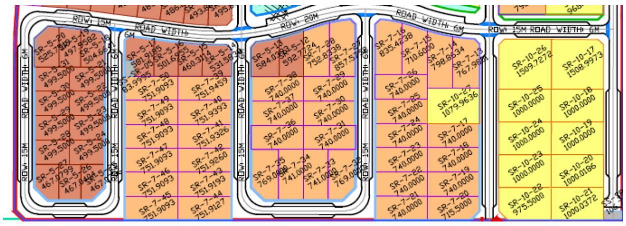

Fig. 33: Subdivision of Land for Small Area Forecast as in Paper 0842

Paper 0182 proposes a methodology for the long-term forecasting of reactive power in distribution networks using scenario assumptions and distribution-based monitoring and network data. Following this approach, future Q demand at substations up to T-D interfaces is assessed taking into account trends in underlying demand and generation, as well as the corresponding interactions with network assets. To demonstrate the benefits from the use of time-series network modelling as part of the proposed methodology, future Q exports at individual and aggregated T-D interfaces and the proportion of time for these exports are quantified. This considered the whole 132 to 33kV network belonging to a UK DNO. This methodology can be used by distribution network planners to identify future trends in Q demand at the T-D interfaces and substations down to primaries. The associated scenario results should not only be used to analyze the associated impacts (e.g., effects on voltages) in distribution networks, but also to investigate potential solutions to limit Q exchanges at T-D interfaces.

Paper 0370 aims at studying large databases through use of two Data Analysis tools: Business Intelligence and Data Mining. The first is frequently described as a set of tools that transform raw data in meaningful and useful information. With the Data Mining tools that information was explored so that consistent patterns could be identified. As a result, a strong and well-founded methodology has been set up, making it possible to identify seven groups that characterize the behavior of the MV network. For each group, the average load profiles by season and day type have been computed. The analysis of the results showed a good adherence to the reality, taking into account the geographic location and the downstream loads of the Primary Substation that make up each group. This work represents a starting point in the analysis of this kind of information (see Fig. 34), providing EDP Distribuição with a real knowledge of the network, essential for several business areas of the company, particularly in network planning, management and optimization.

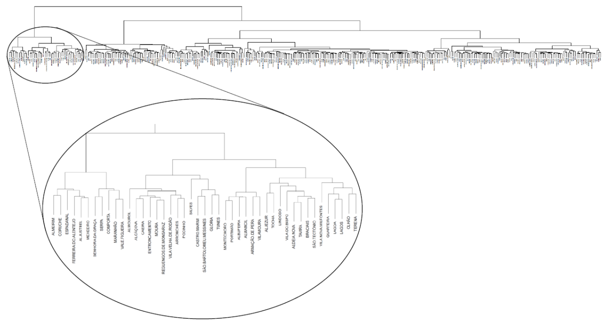

Fig. 34: Hierarchical tree representing the universe of PS studied in Paper 0370

In **Paper 0584** a Refined (with Logistic Function) Smooth Transition Auto-Regressive (RLSTAR) model is proposed for wind power forecasting. Multiple regimes switching of wind power time series is investigated. Furthermore, fat tail effect is applied to the proposed model for wind power forecasting. RLSTAR models can effectively depict the multiple regimes switching effect and resolve the discontinuity point issue theoretically, such that the forecasting results can be much closer to actual conditions. A case study clearly illustrates that standard version of RLSTAR provide the most promising forecasting results. Asymmetric parameters and incremental asymmetric parameters in the RLSTAR models show distinctive practical meanings. From the analysis on these parameters, it is indicated that volatility in wind power time series have significant double asymmetric effect.

Paper 0600 refers to application of a data driven scenario based approach to predict the adoption and expected local penetration levels of PV installations in an actual distribution network area in the Netherlands. Local PV adoption probabilities are scaled according to a trained statistical model. Integration of this model in the scenarios is shown to provide a significant improvement in prediction accuracy. Additionally a probabilistic forecast is simulated highlighting the local impact on the electricity network for several future scenarios.

Forecasting electricity demand at the local level of a building up to a feeder is increasingly necessary in several applications in the smart-grids context. Actors like aggregators and retailers, and tools like home energy management systems, require such forecasts as input. In **Paper 0625**, a probabilistic day-ahead forecasting model is proposed to predict hourly electrical demand from individual households. This stochastic model uses smart-meter data and temperature predictions to make quantile forecasts. Performance is evaluated using data from a real-life smart grid demonstration site developed in Évora, Portugal as part of the European project SENSIBLE. The proposed model consistently outperforms a persistence model and provides reliable probabilistic forecasts (see Fig. 35).

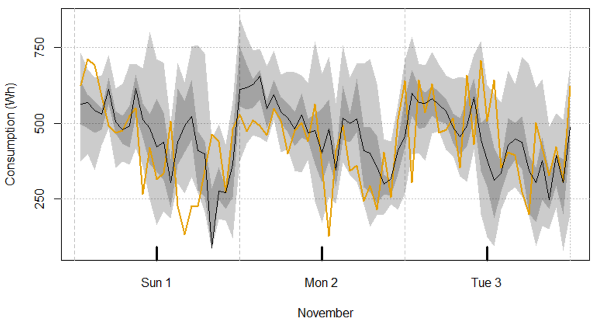

Fig. 35: Example of day-ahead forecasts for one household according to paper 0625

By 2020, Smart Meters will potentially provide the UK's. Distribution Network Operators (DNOs) with more detailed information about the real time status of the Low Voltage (LV) network. However, the Smart Meter data that the DNOs will receive has a number of limitations including the unavailability of some real time smart meter data, aggregation of smart meter readings to preserve customer privacy, half-hourly averaging of customer demand/generation readings, and the inability of smart meters to identify the connection phases. **Paper 0654** investigates how these limitations of the Smart Meter data can affect the estimation accuracy of technical losses and voltage levels in the LV network and the ways in which 1-minute losses and correct phasing patterns can be determined despite the limitations in smart meter data.

Paper 0743 is about a new innovative bottom-up load forecast and grid development method at local level developed by Enedis and Mines Paris, called MOSAIC, that aims at assessing the impact of long term local development projects on the electrical grid. The first results obtained and the success observed by growing expectations from local authorities incentivize Enedis to further develop and finalize MOSAIC. Thanks to MOSAIC, Enedis will be able to integrate in its planning methods local specificities such as economical or urban planning decisions. Furthermore, MOSAIC makes possible to run successively different scenarios. Therefore, for important projects, the local government will have feedbacks on the potential impact of its development project early in the project life cycle. This knowledge can help to make the best decision for the energy transition. MOSAIC will not replace Enedis' traditional planning methods. However, it can improve them, especially when radical changes in future area makes it impossible to rely on past consumption trend.

The characterization of the load behavior and of the dependency on voltage is gaining more and more importance in network studies for modelling the expected benefits of innovative operational strategies. The Conservative Voltage Reduction (CVR) is a classical example based on the assumption that loads behave as constant impedance/constant current loads that must be confirmed with experimental and field studies. The authors of **Paper 0836** try to contribute on this field by looking at a particular load – the street lighting – that is experiencing a dramatic change due to the deployment of LED lamps in lieu of more traditional lamps (fluorescent, high pressure discharge, etc.). With an experimental analysis, different street lighting technologies have been examined in order to find the polynomial coefficients of the ZIP model. LED lamps can be represented with a constant power model for active power and with a constant current model for reactive power; the LED lamp power factor is much better than other technologies and decreases as voltage increases; finally THD is much higher in LED lamps. It is interesting to see that when connected to a feeder, the global behavior is different as shown in Fig. 36.

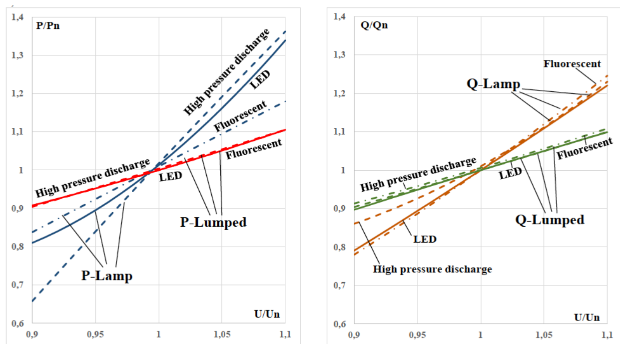

Fig. 36: Behaviour of a single lamp (left) compared with street lighting when the same technology is used (right) from Paper 0836

Paper 0827 describes the new load/generation estimation method (advanced hour- method) developed by Chubu Electric Power Company (CEPCO) making use of 30-minute power consumption data measured by smart meters. By using advanced hour-method, detailed load/generation and multiple standard limits are calculated. Revision of standard limit, estimation method for new contract, and system architecture are also investigated.

Paper 0856 describes the first major steps to quantify and deal with the stochastic effects of customer behavior on bottom up load estimations. The methods were developed and tested with real measurement data. It has been shown that the load of a single customer cannot be modeled as an independent stochastic variable because of the correlations with other customers. A quantification of the uncertainty has been defined as the probability that the load exceeds the expected load at least by a constant factor. The error of this uncertainty can also be calculated. An improved method for estimating the maximum load is proposed for bottom up models (see Fig. 37). It is shown that this method gives much better results than the original one. For less than 10 residential customers, the original method is at least a factor two too small, the proposed method is accurate within 10 percent.

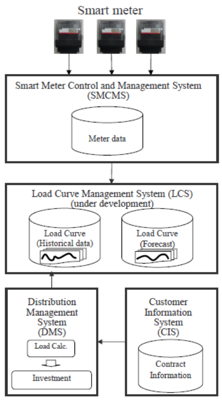

Fig. 37: Architecture of the system described in Paper 0856

Paper 1020 presents a new analytics application based on big data from smart meters. Using unsupervised machine learning methods of grouping (clustering), the daily load profiles can be determined from a large amount of input data. By examining the load probability distribution in each cluster, consumers' stochastic models are created. The original daily load profiles are reproduced by using the Monte Carlo method, which allows very accurate analysis of LV and MV networks. The results obtained are used for spatial load forecasting. One of the major problems faced by distribution companies in the network planning is to assess the load and location of new consumers. Detailed analyses of existing consumers help solving this problem. The forecasting process was upgraded with newly-acquired GIS (geographic information system) data on land plots intended for construction. This gives a detailed view of the area saturation and allows better load forecasting at micro locations. The Paper briefly presents how it all fits together to evaluate the future load development for the entire considered area.

Power load forecasting is an essential step in the network development planning process, being the base for the prediction of potential network saturation criticalities. The goal of **Paper 1064** is to show a new methodology (see also Fig. 38), developed by Enel Global Infrastructure and Networks, in order to identify future saturation criticalities on HV/MV Substations, in all Enel's distribution companies located worldwide taking care of standard and (n-1) condition. The output of this methodology (detection of future criticalities) represents one of the most important inputs in the global CapEx allocation process.

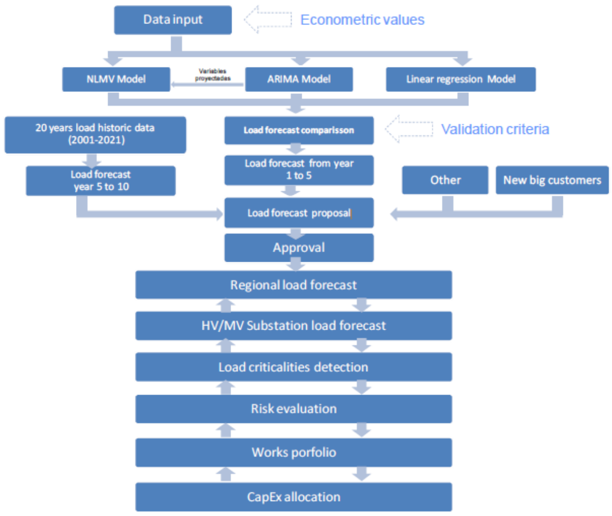

Fig. 38: Multi-country criticalities detection methodology according to Paper 1064

Paper 1247 presents the forecast of electricity consumption based on mathematical models by using the available historical consumption, with daily resolution, including up-scaling, applying a hybrid model that incorporates multiple linear regression with artificial neural networks. Therefore, the hybrid model exploits both the unique features of the regression model and of the artificial neural network to determine different patterns. Thus, it is advantageous to model linear and nonlinear patterns separately by using different models and combining the forecasts to improve overall performance modelling and forecasting. The applied methodology is very reliable given that the forecast errors are close to zero, and the observed differences are justified essentially by temperature effect.

Paper 1222 aim is to demonstrate the superiority of the cross-correlation based (CCB) distance over a selection of the best time series clustering approaches for grouping electrical load profiles. This provides the best trade-off between accuracy (in terms of internal clustering evaluation indexes and CPU times. A next step would be to include the CCB distance in more robust partitioning algorithms such as spectral, kernel and density-based methods. The work consists in a first study: the comparison of clustering techniques on the same dataset should be extended to other techniques far being exhaustive, and the satisfaction of other types of distance invariances, such as occlusion and complexity more particularly, should be investigated. The work intends to provide a comprehensive introduction to the vast field of clustering, with an emphasis on the issues to consider when it comes to load data. The CPU time argument is even more relevant if one consider the data tsunami that is expected from the electricity distribution networks. In that Big Data context, fast distances in combination with multi-step parallelizable clustering approaches should be favored.

Alliander, a Distribution Network Operator (DNO) in the Netherlands, faces potential challenges due to changing behaviour of its customers. New equipment such as electrical vehicles, solar PV and heat pumps can have a huge impact on the loads in the grid. **Paper 1071** evaluates ANDES, a load forecast model developed by Alliander that can make forecasts of future grid load for 40 years ahead, for multiple scenarios and from LV-feeders up to HV/MV-substations. In contrast with traditional load forecasting methods, the results of ANDES give insight into future peak loads and new load profiles due to an increased amount of EV, PV and HP in the grid. These results (see Fig. 39) can be used to identify future bottlenecks in the grid and design the appropriate measures.

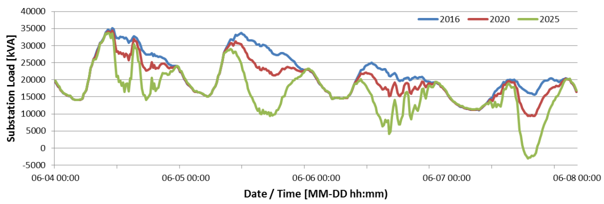

Fig. 39: Example of generated load profile for HV/MV-substation in Paper 1071

Sub block 2: Network Modeling and Representation
Innovative components installed in the grid imply innovative behaviors to be modeled and represented: furthermore, innovative system solution need a systemic description to be adopted in network calculations.

Sub block 2 deals with the development of newly-designed - or the refinement of established - network equivalents, either consisting in analytical description of individual elements such as Fault Current Limiters or in synthetic representations of full systems or relevant network subsystems to be adopted in specific network calculations.

Paper 0222 is about a strategy to integrate its operational and enterprise IT landscape based on CIM standard carried out by Elektro Gorenjska, a Slovenian distribution utility. The utility's vision was to set up and follow a multi-year roadmap for full integration of their crucial OT and IT systems. The integration will be performed by utilizing CIM-based integration platform, including enterprise service bus, CIM repository and implementation process support environment.

In **Paper 0932**, a methodology for including Fault Current Limiter (FCL) devices in standard short-circuit studies is proposed. The impedance of FCLs obtained from the manufacturers is presented and used to develop computer models for two Resistive Superconducting and Pre-Saturated Core FCLs. The proposed methodology (see Fig. 40) and FCL data provided can be used by planning engineers to incorporate in their primary power system analysis software and standard static short-circuit analysis.

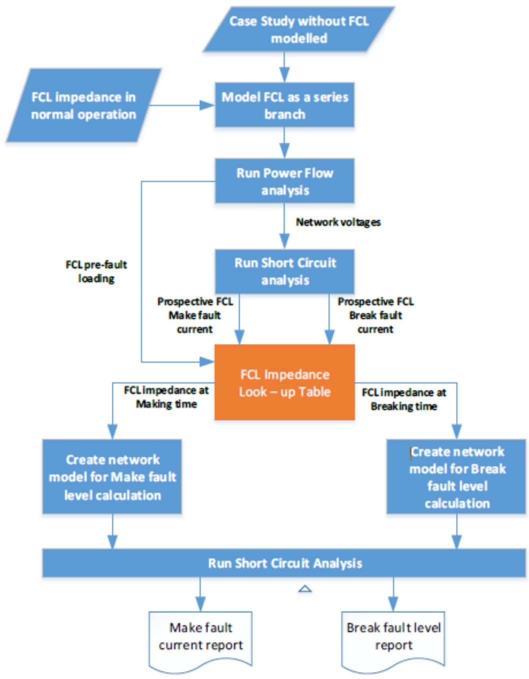

Fig. 40: FCL Static Modelling Methodology for Short-circuit Calculation according to Paper 0932

Paper 0315 deals with the effects of unsymmetrical behavior of PV and battery systems. The goal is to investigate whether the prevailing unbalance limit of 4,6 kVA in Germany is still acceptable or if it has to be (and to which amount) adapted. The voltage values as well as line and neutral conductor currents are evaluated for different unbalance limits per phase. Furthermore, this scheme has been applied to a variety of PV distributions within the grid in order to produce generalized conclusions.

Paper 0314 describes a model that allows simulating medium voltage active networks, whilst having an aggregated overview of the low voltage ends. This model does not employ load flow calculations of the LV networks, but only uses the results of a load flow on a medium voltage network. It allows taking into account the topology of these networks and the distribution of loads and generators in a simplified way. Despite the approximations, this model allows evaluating maximum voltage drops and rises with accuracy suitable to planning studies in large real size distribution networks. The application for the study of off-load taps of MV/LV transformers and for testing the efficacy of Volt/VAR regulation in the low voltage generators is proposed.

Paper 0380 describes a multi-agent system (see Fig. 41) for distribution network planning. The system provides active and reactive power time series based on weather data and individual parameters of loads and generators. Using this simulation technique a forecast-based network reconfiguration algorithm is tested in the scope of a one-year-simulation.

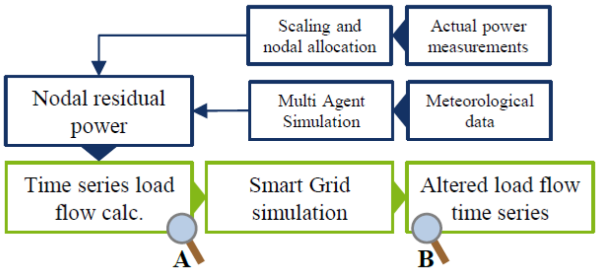

Fig. 41: Paper 0380 – Overall concept

Paper 1175 introduces and compares several techniques for integrating external control system models into power systems models for time domain simulations. In particular, a new technique is reported for PowerFactory-MATLAB/Simulink co-simulation interfaces, which offers a significant advantage over alternative methods in terms of the reduction in simulation runtimes and flexibility for the end user.

In the literature, statistical approaches are usually proposed to predict electrical quantities (e.g. renewables production). In **Paper 1229**, a novel method based on matrix factorization is presented. The approach is inspired by the literature on data mining and knowledge discovery and the methodologies involved in recommender systems. The idea is to transpose the problem of predicting ratings in a recommender system to a problem of forecasting electrical quantities in a power system. Preliminary results on a real wind speed dataset tend to show that the matrix factorization model provides similar results than ARIMA models in terms of accuracy (MAE and RMSE). The proposed approach is seen as highly scalable and suitable with noisy data (e.g. missing data).

Sub block 3: Load Flow and Short Circuit Calculations

Sub block 3 includes paper representing the state of the art of the most typical electrical calculations used in network planning and in components' sizing. Some of the papers pave new ground by focusing on recently-arisen problems or benefitting from previously unavailable information; some aim at specializing already established approaches in order to assess individual problems in more detail; other propose simplification of existing models in order to cope with large volumes of data.

Paper 0238 describes the advancement in state grasping method for MV distribution networks state estimation. This is aimed to improve accuracy in grasping voltages and line currents of a Japanese MV distribution network with high penetration of renewable energy sources (RES), mainly photovoltaic generators (PV). Controlling on-load tap changers (OLTC) according to the exactly estimated voltages contributes for maintaining voltages into the restricted ranges with less number of OLTCs. Investments for distribution network can be optimized by making components fit in with the exactly estimated line currents. Proposed method will be realized by utilizing measured data from sensor-equipped automated switchgears and smart meters. The method (See Fig. 42) has been verified in computational simulation, and the estimation accuracy was high enough for applying to short-term and mid-term planning.

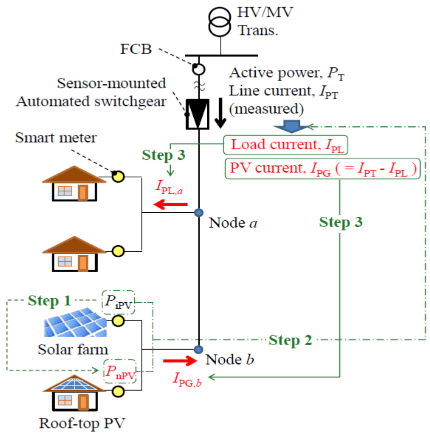

Fig. 42: Schematic diagram of the methodology proposed in Paper 0238

In **Paper 0031** the performances of a new load modelling strategy relying on Smart Meter (SM) data have been evaluated in the framework of a Pseudo-Sequential Monte Carlo techno-economic analysis conducted on a LV feeder. Those performances have been compared not only to the ones obtained with traditional Synthetic Load Profiles (SLP) models but also to the ones reached with the new modelling methodology when SM devices are not installed within each domestic customer. By doing this analysis, the new load modelling strategy proved to be more accurate than the SLP approach by being able to better approximate the local behavior of LV clients. Moreover, thanks to a pre-processing clustering step that allows categorizing LV clients, this new modelling method also demonstrated its robustness in front of SM missing information and, therefore, its suitability for LV networks not (yet) fully equipped with SM devices.

The target of **Paper 0179** is to provide a clear and comprehensive analysis of probabilistic load flow using

Point Estimation Method, and its accuracy in the evaluation of the quantiles of the state variables of real electrical distribution networks. Three Points Estimation Method (TPEM) has been implemented to evaluate the first four moments of output variables (voltages, currents and active power flows), and several methods to reconstruct the probability density function from moments and calculate the quantiles have been compared, including Generalized Lambda Distribution and Gram-Charlier Development. Monte-Carlo PLF has been taken as reference to evaluate the accuracy of aforementioned TPEM results and the scope of application of the method in a real electrical distribution system. This study has shown that TPEM is a good alternative to the Monte-Carlo method to perform probabilistic load-flows for networks with a high number of nodes and loads. Such a tool enables to calculate the quantiles of networks' state variables, and thus quantify the risk of occurrence of a constraint.

Paper 0247 presents novel hybrid heuristic-genetic algorithm for optimal distribution network reconfiguration. The algorithm can be used to find optimal network topology which either minimizes network active power losses (Fig. 43) or network loading index while fulfilling radial and connectivity constraints and other system constraints. Comparing to other similar approaches, described algorithm brings significant improvements in crossover and mutation process as well as initial population generation. These results with fast convergence rate make this approach suitable for much bigger, real-size networks. The algorithm was tested on real case network for city of Dubrovnik, for which optimal topologies were determined under active power loss minimization and network loading index minimization framework. The test results shows that algorithm maintains radial connected network structure in all steps, and assures fulfillment of system constraints in terms of bus voltages and element capacity constraints.

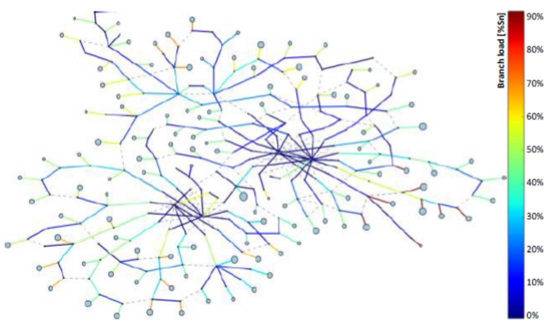

Fig. 43: Optimal network topology in case of network active power loss minimization as in Paper 0247

Paper 0976 describes the development and application of a technique to determine the fault level infeed for 11 kV networks with discrete load profiles. Normally fault levels are modeled using a standard contribution of a load factor (MVA) per fault level infeed (MVA) value. The MVA per MVA fault level infeed for 11 kV networks is, as determined by the UK Energy Network Association recommendation G74, 1 MVA of fault level contribution per 1 MVA of load. This is based on the assumption that load on the 11 kV network is being derived from the LV network. With the influx of low carbon loads and distributed generation this assumption is no longer valid for all networks. Within the Tier-2 project, FlexDGrid, 10 fault level monitors (FLM) have been installed (see Fig. 44) on the 11 kV network in Birmingham, England. These FLMs are able to create a 5ms phase to phase high resistance short circuit which doesn't affect the customers but allow to calculate both the Make and Break fault levels for the 11 kV network to which it is connected. Through the possibility to control this artificial disturbance on the network, for the first time real-time fault level values can be generated. So an updated MVA per MVA fault level infeed value for all 10 substations, has been made available increasing the accuracy of fault level calculations, assisting system planners in refining network models and determining the available fault level headroom in existing system assets for new customer connections.

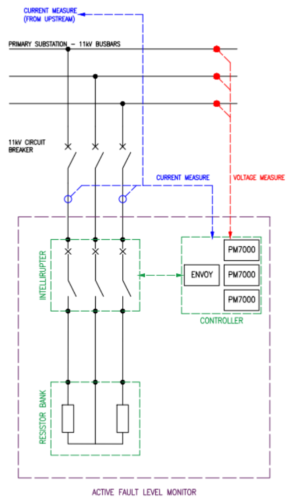

Fig. 44: Fault Level monitoring system as described in Paper 0976

Paper 0367 investigates the impacts on the low voltage (LV) distribution network of a reduction in 11 kV voltage control settings. Through use of statistical modelling, the effects of a real-life reduction in voltage settings were measured and quantified. This highlighted statistically significant reductions in average real power demand, maximum real power demand and average reactive power demand. A reduction in demand of the magnitude observed would provide big savings for impacted customers if all substations in South Wales applied the proposed settings.

Paper 0381 proposes and demonstrates a probabilistic approach to simulating LV networks, which can incorporate flexibility in (future) household load. This method provides insight in probabilities of power flows and voltage magnitudes occurring, and can therefore predict chances of overloading cables and violating voltage limits. Compared to the current planning method (worst case approach) for LV networks, this allows for a more accurate estimation of risk levels when designing the network. Activation of user flexibility can influence the probability of power flows or voltage magnitudes violations.

Paper 0738 describes the impact of short-circuit level on Medium Voltage (MV) networks resulting from the increase in Low Carbon Technology (LCT) equipment connected to the UK Transmission and Distribution Networks. Fault Level (FL) is an important network measure that can instigate network investment and is expected to change as a result of LCT connections such as renewable resources, Combined Heat and Power (CHP) plants, storage units and electric vehicles (EVs) connecting to the network. FLs will decrease in transmission networks and increase in Low Voltage (LV) and MV distribution networks. The results of the studies have shown that the connection of MV LCTs has the biggest impact on MV fault levels. However, the level of impact largely depends on the Point of Connection (PoC) of the LCT. To ensure that the impact of the MV LCTs is fully captured it is recommended that fault level assessments are carried out using a detailed model of network impedance from the PoC to the upstream primary substation.

Paper 0805 analyses the performance of a distribution network, in terms of voltage profile, total harmonic distortion of voltage and current, power factor (pf) and real/reactive power flow at substation, with multiple single-phase PV systems (block diagram in Fig. 45). The main contribution of the Paper is the quantification of the percentage of PV penetration at which the presence of PV may adversely affect the performance of the distribution network and the usage of a more probable worst-case scenario than a theoretical worst-case scenario, as generally used. The use of PV as a means for reactive power compensation to improve the power factor at the substation is also studied. Though voltage profile is generally discussed as the parameter worst affected by presence of PV, the analysis indicates that it is the last parameter to be adversely affected by the presence of PV.

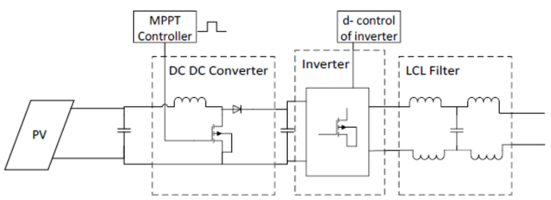

Fig. 45: Block diagram of a two-stage PV inverter with LCL filter (Paper 0805)

Paper 0910 deals with an automated process to generate MV and LV network models developed by Alliander, a Dutch DSO. As a result, both near real time insights as well as a uniform validation model for safety, quality and capacity analysis are made available and operationally used within the company. The generated network models are available for all departments in the company. As a result, a drastic time reduction for generating actual network models is achieved.

Paper 0577 intends to compare two different approaches for the stochastic analyses of low voltage distribution networks. A quasi-sequential approach using a distribution based method and a sequential approach using Seasonal Auto Regressive Mobile Average (ARMA) time series for individual consumption and generation are benchmarked on a low voltage network. A qualitative and quantitative analysis of two scenarios (without and with storage, the former shown in Fig. 46) shows the advantages and limitations of both approaches. Additionally, it highlights the great potential of modeling sequentially as new load management techniques will be made available.

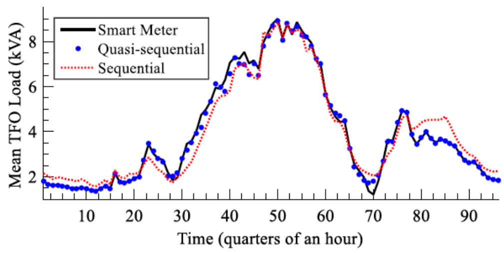

Fig. 46: Mean daily apparent power load of the MV/LV transformer as in Paper 0577

European Grid codes define new network management rules. More specifically, the Demand Connection and Operational Planning and Scheduling Codes impose constraints at the transmission and distribution grids interfaces and require generating operational planning tools for distribution networks. Hence, the new voltage and reactive power management algorithms should embed an estimation of voltages, power flow and reactive power reserves. A load flow tools is necessary to comply with these requirements. In order to answer these decrees, it is important to estimate accurately the voltages and powers inside distribution networks. The intermittent nature of renewable sources leads to consider stochastic variables in power flow algorithms. A review of power flow methods and their ability to comply with these requirements is performed in **Paper 0806**, which shows that computationally demanding nonlinear methods have to be discarded when dealing with stochastic data and considering limited calculation time. A combination of linear methods is proposed, for which average errors in power and voltage are quite low, when applied to a real-life distribution network. The validity domain of the method is also presented.

Paper 0294 proposes a model to assess the dynamic behavior of PV inverters when frequency goes up to 50.2

Hz. The reason of the study is related to the fact that with hundreds of thousand small inverters connected to the distribution system the behavior of such generators cannot be disregarded. Recently countries like German and Italy have imposed the retrofit to existing generators. The main conclusion of the work is that even after the retrofit the disconnection of PV at 50.2 Hz is not certain and the variance of the frequency measurement done at every PV inverters plays a key role and allows a gradual disconnection, leading to a controlled variation of the frequency.

Sub block 4: Energy Losses

The maximization of profits creates the tendency to postpone investments in the network infrastructure, with negative effects on losses. In order to oppose this tendency, several countries adopt regulation directives that reward the distributors if losses are reduced and penalize them if losses increase.

Sub block 4 therefore deals with algorithms and methodologies aimed at evaluating electrical losses, developing innovative models or analyzing specific cases supporting planning or investment allocation.

Paper 0963 describes the initiatives taken by SP Energy Networks to manage network losses according to the regulatory approach set by UK Electricity Regulator, Ofgem (see Fig. 47). Actually a stakeholder and holistic approach is required when analysing and managing losses to achieve the maximum benefit. They have been identified to:

- improve losses knowledge over its entire network, geographically and with regard to voltage;
- build upon work carried out within the UK and capture international experience from its parent company and others;
- develop tools to use Smart Meter Data and network information ahead of the widespread roll out of the Smart Meter equipment, dealing with partial data availability;
- ensure the interests of stakeholders are recognised in designing the way forward;
- share the learning widely and encourage collaborative working;
- develop enablers for the DSO role of Active Network Management as a way of reducing losses and facilitating capacity;
- develop holistic working within the industry and its stakeholders.

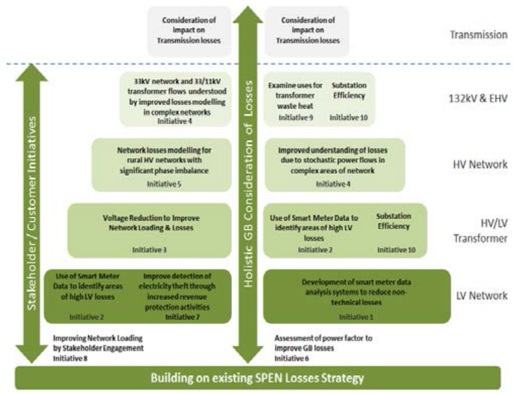

Fig. 47: SPEN approach to losses as in Paper 0963

Paper 0306 deals with a method used to build a set of LV typical grids, which are able to capture the variability of assets and operating conditions in order to assess the non-linear impact of distributed generation on losses. Based on simulations carried out over such typical networks, the impact of PV distributed generation on LV grid losses is evaluated for different PV penetration levels, up to 100% of secondary substation peak load as well as for different PV geographic penetration scenarios, from urban to rural. Results have shown that the impact of PV distributed generation on the value of losses is expected to be significant and tends to reduce the absolute value of losses. However, such impact can be interpreted very differently if losses are measured as a relative value. When referred to the energy supplied to the secondary substation, results have shown that relative losses tend to increase. Conversely, when referred to the energy consumed, relative losses tend to decrease.

Paper 1076 draws the attention on losses of MV and LV feeders calculated with the power difference methods that are highly sensitive to tolerances in the current and voltage sensors. These errors are largely avoided by using an I^2R method, although this is subject to tolerances and errors in the network data. The network topology can be validated by combining additional current and voltage data with the power-flow analysis (see comparison in Fig. 48). This can detect unmetered demand, errors in the phase allocation records, and errors with the monitoring installation. Correlation methods have been successfully used to identify phase allocation errors of single-phase loads or to locate unmetered demand on the MV feeder.

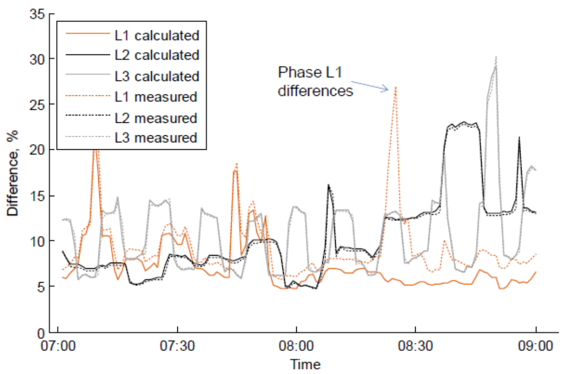

Fig. 48: Difference between LV substation currents from power-flow analysis and from measurement as in Paper 1076

Paper 0489 deals with modelling of distribution network elements and their implementation in backward/forward sweep (BFS) power flow method. An improvement of BFS method is developed by using the breadth-first search method for network renumbering and creation of modified incidence matrix. The improved method minimizes the read elements of each iteration and results in a significant reduction of total calculation time without accuracy loss. This improvement makes this method more suitable for using in real time calculations. The proposed method is used for calculation of power losses in unbalanced and symmetrical network, which are compared. The purpose of this test is to show the advantage of a three-phase power flow analysis compared to a symmetrical model.

Distribution engineers are not used, as the authors of **Paper 0785** said, to consider the energy efficiency as the only goal of investments. However, this is required by EU and National Regulators as in Croatia and makes it necessary paradigm change in planning. The paper offers a comprehensive analysis of Croatian distribution system and with a complex study that uses the forecasting for demand and network investments to find the roadmap for EE in Croatia. The most valuable actions are the increasing of voltage from 10 kV to 20 kV and new transformers and substations (Fig. 49). The expected reduction (compared to the 2014 level) is 4.1%, plus other 2.8% of possible adjunctive positive effects. Despite the fact that the paper results are very country dependent, the methodology and the actions examined might be beneficial in countries that are facing the problem of losses reduction.

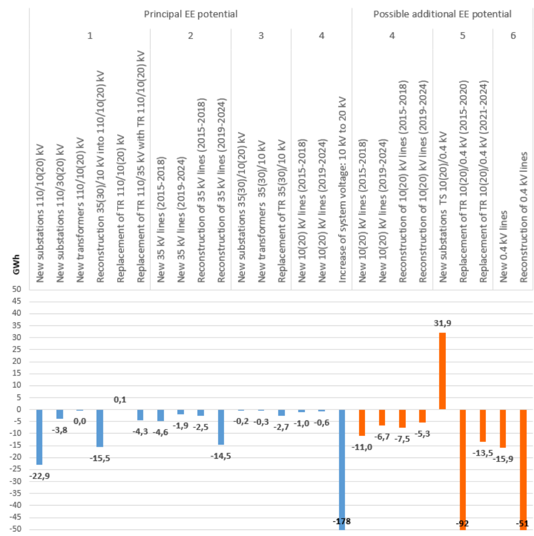

Fig. 49: Potential of actions for the reduction of technical losses in Croatia (Paper 0785).

In **Paper 1007** an hybrid configuration of Particle Swarm Optimization (PSO) method with Ant Colony Optimization (ACO) algorithm called hybrid PSO–ACO algorithm is presented for optimal network reconfiguration in distribution network in presence of distributed generation (DG) resources. The objectives are to minimize power losses as well as improve the voltage profile. MATLAB based simulation conducted on 33-bus IEEE test feeder have been used to verify the effectiveness of proposed method. Results demonstrate accuracy and efficiency of PSO–ACO algorithm.

In **Paper 1260**, peak demand calculation approach was found to be the most reliable losses calculation approach. The preliminary loss analysis showed a strong correlation between high current phase imbalance and losses (see Fig. 50). The level of phase imbalance generally decreases with the number of customers and thus the demand as diversity increases. As phase imbalance is correlated to losses, higher diversity reduces losses. The list of high losses substations that can be used as a trial for the deployment of corrective actions is one of the outcomes of the project described in this Paper. The monitoring equipment already in the trial area aids this. Preliminary exploration of cost-benefit suggests that phase balancing with power electronics may be most feasible. However, at the moment the equipment required has proven to be too costly compared to the current economics of loss reduction.

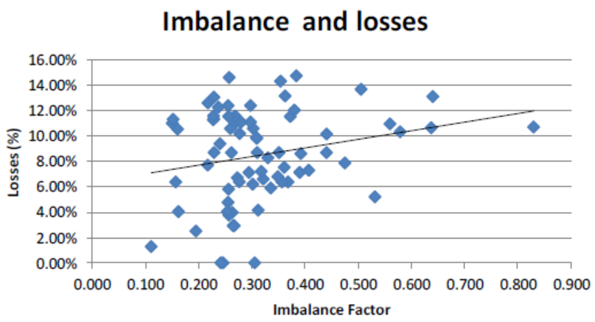

Fig. 50: Relation between imbalance and losses according to Paper 1260

In networks with high levels of energy theft, the difference between expected power flows and measurement assumes high values. Therefore the inaccuracies in electrical calculations can be very large. The objective of **Paper 1011** is to present a methodology developed in Brazil for conducting demand adjustment to better represent the load and allocate the energy theft in a sectored way, using energy balance, tacit knowledge and state estimation techniques.

In **Paper 0988**, the present regulatory prescriptions and rules for connection of generators in the Italian context are discussed and then applied to a real low voltage case study network. Several scenarios are considered to analyze how distributed generators connection options and reactive power management have influence on network losses. The Paper shows that the connection of DG does not necessarily lead to a reduction of energy losses. In order to make the study more realistic, advanced techniques for load profiling have been used. The worth of the models is that even though customers belong to the same group, each one has its own individual load consumption. With the aid of a significant case study, it has been showed that losses are influenced by the DG penetration level, the connection topology, the type of generating units (single- or three-phase), the profile of energy consumption, the unbalance of load and generation and the reactive power flows. In particular, the Paper demonstrates that reactive power regulations applied to DGs connected to LV networks could have role in sensibly increasing the network losses. In addition, the reactive power exchanged by LV DGs, together with the concept of "average power factor" having influence on end-users' reactive power behaviors, could impact on voltage regulation in upstream MV networks.

Paper 1258 proposes a classification model able to identify potential LV energy thieves by detecting areas with high non-technical losses. The inputs of the classification model are: regionalized socio-economic attributes from the 2010 Brazilian Census, attributes extracted from energy consumption and attributes extracted from the clients' registration data. In order to detect the areas with non-technical losses, it is necessary to allocate smart energy meters along the grid to provide data to be compared to the energy charged from the clients. The installation of those meters is the first step towards a smart grid. The model proposed by Paper 1258 can have an average inspection effectiveness index of 70%. However, previous experiences indicate that this theoretic effectiveness index is not verified in real inspections.

Paper 1286 addresses the distribution network reconfiguration (DNR) to minimize the network losses. A Multi Stage Modified Particle Swarm (MPSO) optimization is suggested to identify the optimal configuration of distribution network effectively. The proposed algorithm is composed of 3 stages: the first stage is by implementing the MPSO, the second stage is by running a Monte Carlo simulation for network analysis and search space reduction. The third stage is by performing the MPSO again after adjusting the search space. The suggested algorithm is tested via 33 IEEE network during two loading conditions: static and variable loads respectively. A benchmark comparison has been conducted to prove the effectiveness of the proposed algorithm compared to traditional optimization techniques.

Potential scope of discussion

Flexibility is the only option that can allow facing the challenges of a carbon free world. Flexibility means better knowledge of customers behaviour and better forecast of the their participation to demand response programs. At what extent flexibility can really be used for real time operation? Is it feasible to think about local real-time markets? Which is the role of storage? Which is the role of demand and local generation as service providers? Can everything be centralized under the TSO umbrella?

Table 4: Papers of Block 4 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0031	Dealing with Sparse Smart Metering Data in Techno-Economic Analysis of Low Voltage Networks				X
0179	Analysis of Probabilistic Load Flow using Point Estimation Method to Evaluate the Quantiles of Electrical Networks State Variables			1	X

0182	Long-term Forecasting of Reactive Power Demand in Distribution Networks		17		X
0222	Elektro Gorenjska CIM Project				X
0238	Advancement in State Grasping Method of MV Distribution Network for Short-term and Mid-term Planning				X
0247	Distribution Network Reconfiguration Using Hybrid Heuristic-Genetic Algorithm				X
0294	Resilience of the DSO network near 50.2Hz				X
0306	Impact of PV Distributed Generation on EDP Distribuição LV Grid Losses				X
0314	A Model to Simulate Medium Voltage Active Networks with an Aggregated View of the Low Voltage Ends		19		X
0315	Effects of Asymmetrically Connected PV and Battery Systems on the Node Voltages and Pen-conductor Currents in Low Voltage Grids				X
0367	The Impact of a Reduction in 11kV Voltage Settings in South Wales		22		X
0370	Identification of Electrical Energy Consumption Patterns				X
0380	Application of Time-Resolved Input Data for Smart Grid Simulation		20		X
0381	Utilizing Residential Flexibility in the Planning of LV-Networks				X
0489	Improved Three Phase Power Flow Method for Calculation of Power Losses in Unbalanced Radial Distribution Network				X
0577	A Comparative Assessment of a Quasi-Sequential and a Sequential Approach for Distribution Network Stochastic Analysis				X
0584	Wind power forecasting based on refined LSTAR-GARCH model				X
0600	Application and Evaluation of a Probabilistic Forecasting Model for Expected Local PV Penetration Levels				X
Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0625	Probabilistic Day-ahead Forecasting of Household Electricity Demand		18		X
0654	Analyzing the Ability of Smart Meter Data to Provide Accurate Information to the UK DNOs				X
0738	The Impact of Low Carbon Technologies on Short Circuit Levels in Medium Voltage Networks		23		X
0743	Long term forecast of local electrical demand and evaluation of future impacts on the Electricity Distribution Network				X
0785	Identifying Energy Efficiency Improvements and Saving Potential in Croatian Energy Networks				X
0805	Performance Assessment of a Three-Phase Distribution Network with Multiple Residential Single-Phase PV Systems				X
0806	Combination of Linear Power Flow Tools for Voltages and Power Estimation on MV Networks				X
0827	Advancement of Load Estimation Method for LV Distribution Facilities				X
0836	Behaviour of Street Lighting Feeders Supplying Traditional and New LED Lamps				X
0842	Improved Small Area Forecasting for Electrical Spatial Load Forecast Analysis				X
0856	Stochastic Effects of Customer Behaviour on Bottom Up Load Estimations				X
0910	Fully Automated Calculations in both MV and LV Networks				X
0932	Developing Static Model of Fault Current Limiter Technologies				X
0963	Losses		24		X
0976	Characterisation of 11kV Fault Level Contributions Based on Substation Load Profile				X
0988	Containment of Power Losses in LV Networks with High Penetration of Distributed Generation		25		X
1007	Optimal Network Reconfiguration in Distribution System for Loss Reduction and Voltage Profile Improvement using Hybrid Algorithm of PSO and ACO				X

1011	Identification and Evaluation of Energy Theft using the State Estimator in MV and LV Grids with Exogenous Parameters for Planning Expansion				X
1020	The Improved Model for the Spatial Load Forecasting of the Slovenian Distribution Network				X
1064	Load Criticalities Detection on HV/MV Substations in Multi-country Scenario				X
1071	ANDES: Grid Capacity Planning using a Bottom-up, Profile-based Load Forecasting Approach				X
1076	Accurate Determination of Distribution Network Losses				X
1175	A co-simulation approach using PowerFactory and MATLAB/Simulink to enable validation of Distributed Control Concepts within Future Power Systems		21		X
1222	Comparing time series clustering approaches for individual electrical load patterns				X
1229	Using matrix factorization for the prediction of electrical quantities				X
1247	A hybrid model approach for forecasting electricity demand				X
1258	Fraud Detection in Low Voltage Electricity Consumers Using Socioeconomic Indicators and Billing Profile in Smart Grids				X
1260	Innovative Approaches to Identification and Reduction of Distribution Network Losses				X
1286	Distribution Network Reconfiguration (DNR) for Power Losses Reduction Using a Multi Stage Modified Particle Swarm Optimization (MSMPSO)				X

SESSION 5 - Planning of power distribution systems

Block 1 : Risk assessment and asset management

Sub-block 1 – Risk Assessment

0845 **Distribution network operator asset risk management**
D Neilson, S Bradshaw, A Santandreu, A Elena, *SP Energy Networks, United Kingdom*

Sub- block 2 – Reliability assessment

0251 **Experience and tendencies after 40 years outage data registration in The Netherlands**
H Wolse, *Movares, Netherlands,* G Geist, *Cogas Infra & Beheer B.V., Netherlands,* B Hoving, *Enexis B.V., Netherlands,* P Oosterlee, *Enduris, Netherlands,* H Polman, *Liander, Netherlands*

0140 **Evaluation of the reliability of the electricity distribution systems by DEMATEL method**
M Rahmanpouri, A mighi, *Electrical Power Distribution of Great Tehran, Iran,* J H Dehavi, *Tehran University, Iran*

0723 **Effects of configuration options on reliability in smart grids**
D Schacht, D Lehmann, L Kalisch, H Vennegeerts, S Krahl, A Moser, *FGH e.V., Germany*

0780 **A reliability and cost assessment methodology for medium voltage feeders**
C Roduner, E Taxeidis, *BKW Energie, Switzerland,* S Karagiannopoulos, G Hug, *ETH, Switzerland*

Sub-block 3 – Asset management & maintenance strategies

0553 **A mobile application for on-site risk based decision support**
G Solum, *TrønderEnergi Nett, Norway,* B I Langdal, *Powel, Norway,* D E Nordgård, *SINTEF Energy Research, Norway*

0406 **Innovative analytics to estimate the probability of failure and remaining useful life of medium voltage breakers**
M Scarpellini, K Perdon, L Cavalli, M Testa, *ABB S.p.A, Italy*

0828 **Utilities and smart asset management - challenge of the digital era**
L Kolar, P Lang, D Kouba, *E.ON, Czech Republic*

0823 **Improving asset knowledge using system management based on IEC-61850**
M Gillaux, F Lemenager, T Coste, *EDF, France*

1115 **Operational Excellence in Optimal Planning and Utilization of Power Distribution Network**
B Jamshidieini, *AEPDC, Iran/Tehran University, Iran,* K Rezaie, *Tehran University, Iran,* N Eskandari, A Dadashi, *AEPDC, Iran*

0274 **Where to replace assets? Spatial analysis on differential aging of low voltage PILC cables**
R Verweij, D V Houwelingen, A Prein, *Stedin Netbeheer BV, Netherlands*

0634 **Urban distribution network reliability simulation and strategies of successive refurbishment of distribution transformer stations**
Z Brettschneider, S Votruba, *PREdistribuce, a.s., Czech Republic,* P Skala, *EGU Brno, as, Czech Republic*

Block 2 : Network development

Sub-block 1 – Innovative power distribution

1236 **Fractal Grid - Towards The Future Smart Grid**

N Retiere, Y Sidqu, *Uni. Grenoble Aples, France,* G Muratore, G Kariniotakis, A Michiorri, R Girard, *MINES Paris Tech, France,* P Frankhauser, A Poirson, *Université de Franche-Comté, France,* J-G Caputo *INSA de Rouen, France*

0861 **Planning of autonomous smart micro grid for electrification of remote villages in MEDC**
M Sharifzadeh, F Separi, M Heydari, *MEDC, Iran*

0683 **Demonstration of remote microgrid system in Korean Island**
J Won, W Chae, H Lee, J Park, J Sim, C Shin, *KEPCO, Korea*

1287 **Challenges, Innovative Architectures and Control Strategies for Future Networks: the Web-of-Cells, Fractal Grids and other concepts**
G Kariniotakis, *MINES ParisTech, PSL-Research University, PERSEE, France,* L Martini, *RSE, Italy,* C Caerts, *VITO, Belgium,* H Brunner, *AIT, Austria,* N Retiere, *G2Elab-UGA, France*

0728 **Planning 100% renewable energy islands - the case of the Caribbean Island of Montserrat**
B Römer, Y Julliard, *Siemens AG, Germany,* K Aldonza, *GIZ REETA, Guyana,* O Lewis, *Government of Montserrat, Montserrat*

1006 **Cost-benefit analysis for using the li-ion batteries in low-voltage network for decreasing outage time experienced by customers**
O Vilppo, J Markkula, P Järventausta, *Tampere University of Tecnology, Finland,* S Repo, T Hakala, *Elenia Oy, Finland*

1030 **Measurement concept for efficient planning of distribution grids**
M Eisenreich, Y Farhat, M Freunek (Müller), *BKW Energie AG, Switzerland*

0750 **MV grids development nd automation**
D Kouba, L Kolar, J Celeda, M Jurik, *E.ON Distribution, Czech Republic*

0986 **Strategic interconnected network transitioning**
M Bebbington, A Elena de Leonardo, *SP Energy Networks, United Kingdom,* R Bryans, *TNEI Services Ltd, United Kingdom*

0607 **Recognize the need for innovation and smart solutions for distribution**
D Vornicu, L Predescu, *CEZ Romania, Romania*

0305 **Innovative solution of safety corridor design for overhead lines: Increasing resilience to extreme weather events while providing environmental benefits – Results**
M I Verdelho, R Prata, S Pereira, A Couto, *EDPD, Portugal,* M Vieira, *FloraSul, Portugal,* V Tomás, *EDP Labelec, Portugal*

0347 **Reactive power management by distribution system operators – concept and experience**
W Becker, *Mitteldeutsche Netzgesellschaft Strom mbH, Germany,* M Hable, *ENSO NETZ GmbH, Germany,* M Malsch, *P&M Power Consulting GmbH, Germany,* T Stieger, *WEMAG-Netz GmbH, Germany,* F Sommerwerk, *Thueringer Energienetze GmbH & Co. KG, Germany*

0975 **Control and automation functions at the TSO and DSO interface – impact on network planning**
F Pilo, *University of Cagliari, Italy,* G Mauri, *RSE, Italy,* B Bak-Jensen, *University of Aalborg, Denmark,* E Kämpf, *Fraunhofer Institut, Germany,* J Taylor, *EPRI, United States,* F Silvestro *University of Genova, Italy*

Sub- block 2 : Smart grid systems & applications

0318 **Pioneering smart grids for Indonesia - the case of a smart grid roadmap development**
B Römer, Y Julliard, *Siemens AG, Germany,* R Fauzianto, M J Poddey, *GIZ, Indonesia,* I Rendroyoko, *PLN, Indonesia*

1272 **Flexible Network Operation**
M Istad, H Kirkeby, *SINTEF Energy Research, Norway,* P E Nordbø, O H Eliassen, R A H Hjelme, O J Hatlen, *BKK Nett, Norway*

1321 **DMS Advanced Functions for Accommodating High Penetration of DER and Microgrids**
A Maitra, T Hubert, *EPRI, United States,* J Reilly, *Reilly Associates, United States,* J Wang, R Singh, N Kang, X Lu, *ANL, United States,* A Pratt, S Veda *NREL, United States*

0374 **Challenges and opportunities of 5G in power grids**
G Bag, L Thrybom, *ABB Corporate Research, Sweden,* P Hovila, *ABB OY, Finland*

0210 **Capacity management of low voltage grids using universal smart energy framework**

E Coster, H Fidder, M Broekmans, *Stedin, Netherlands,* C Koehler, *Venios, Germany*

Sub- block 3 – DC distribution systems

0542 Construction of actual LVDC distribution line
Y Cho, H J Kim, J Kim, J Cho, J Kim, *KEPCO Research Institute, South Korea*

0732 Demonstration of LVDC distribution system in island
H J Kim, Y Cho, J Kim, J Cho, J Y kim, *KEPCO Research Institute, South Korea*

0974 Initial designs for ANGLE-DC project: challenges converting existing AC cable and overhead line to DC operation
J Yu, K Smith, M Urizarbarrena, M Bebbington, *SP Energy Networks, United Kingdom,* N MacLeod, *WSP | Parsons Brinckerhoff, United Kingdom,* A Moon, *EA Technology, United Kingdom*

1003 Comparison of LVDC distribution network alternatives: full-DC vs. link-type solutions
J Karppanen, T Kaipia, P Nuutinen, A Mattsson, A Lana, A Pinomaa, P Peltoniemi, J Partanen, *LUT, Finland,* T Hakala, T Lähdeaho, *Elenia Oy, Finland*

Block 3 : Distribution planning

Sub-block 1 – Advanced planning

0947 Key findings of DS2030 - a study in to future GB distribution network operations
S Carter, *Ricardo Energy & Environment, United Kingdom,* G Williamson, J King, *WSP | Parsons Brinckerhoff, United Kingdom,* V Levi, *The University of Manchester, United Kingdom,* J McWilliam, *Energy Networks Association, United Kingdom*

0857 Methodology to support the CapEx allocation in a global scenario with multiple companies, ENEL case study
G Palumbo, G Licasale, *Enel SPA, Italy,* A Rojas Orbes, *Enel-Codensa, Columbia*

0061 A holistic network planning approach: enhancement of the grid expansion using the flexibility of network participants
L Jendernalik, D Giavarra, *Westnetz GmbH, Germany,* C Engels, *University of Applied Sciences Dortmund, Germany,* J Hiry, C Kittl, C Rehtanz, *Technical University Dortmund, Germany*

0954 A method for flexible long-term planning with agile adaption to changing requirements
J Bader, B Heimbach, E Kaffe, D Mountouri, *ewz, Switzerland*

1237 Economically Efficient Distribution Network Design
P Djapic, G Strbac, *Imperial College London, United Kingdom*

0117 OMAP (Organisational Memory Aided Planning): an integrated planning tool using concepts of knowledge management and multi-objective optimisation
C C B Oliveira, A Meffe, D Takahata, P H Baumann, R L Marcondes, *DAIMON, Brazil,* R H Guembarovski, N Alencastro, D C S Prado , *CELESC, Brazil*

0708 Impact of meshed grid topologies on distribution grid planning and operation
D Wolter, M Zdrallek, M Stötzel, *University of Wuppertal, Germany,* C Schacherer, I Mladenovic, *Siemens AG, Germany,* M Biller, *FAU University Erlangen, Germany*

0727 A new approach to large distribution network optimization using modern implementation of benders decomposition
N D'Addio, M Forbes, *Queensland University, Australia,* A M A K Abeygunawardana, G Ledwich, M shafiei, *Queensland University of Technology, Australia*

1218 Determination of Relevant Network Planning Cases
S Patzack, H Vennegeerts, A Moser, *FGH e.V., Germany*

1031 Artificial intelligence potential in power distribution planning
A Van der Mei, J P Doomernik, *Duinn, Netherlands, Enexis, Netherlands*

1025 Grid planning by integrate customer meters
N Andersreen, H Vester, T H Bentsen, *SEAS-NVE, Denmark*

1034 Grid value and defection: a demand perspective
A Van der Mei, *Duinn, Netherlands,* J Doomernik, *Enexis, Netherlands*

0383 **Local forecasting could identify future LV bottlenecks**
M Klerx, S Cobben, *TU Eindhoven, Netherlands,* A Jongepier, *Enduris BV, Netherlands*

0868 **Assessment of the impact of demand side management on distribution network voltage stability**
X Tang, J V Milanovic, *The University of Manchester, United Kingdom*

0258 **Optimal sizing of distribution network transformers considering power quality problems of nonlinear loads**
S Bahramara, *Islamic Azad University, Iran,* F G Mohammadi, *Kurdistand Electrical Power Distribution, Iran*

0677 **Case Study of the distribution system planning for a multi-divided and multi-connected system.**
M Miyata, S Koizumi, M Watanabe, *TEPCO Power Grid, Japan,* M Kuroiwa,*Tokyo Electric Power Company Holdings, Japan*

0394 **On the use of the game theory to study the planning and profitability of industrial microgrids connected to the distribution network**
C Stevanoni, F Vallée, Z De Grève, O Deblecker, *University of Mons, Belgium*

0841 **A comparison of convex formulations for the joint planning of microgrids**
B Martin, E De Jaeger, F Glineur, *UCL, Belgium*

0393 **Suitable methods for neutral grounding of Xining's distribution networks**
A Ettinger, T Connor, *Siemens AG, Germany,* Q B Liu, *State Grid Qinghai, China,* H B Xue, Y J Tang, G H Song, *State Grid Xining, China*

Sub- block 2 – Planning of active networks and smart grids

0204 **Flexibility options for medium voltage grid planning**
T Kornrumpf, M Zdrallek, *University of Wuppertal, Germany,* M Roch, *Stadtwerke Radevormwald GmbH, Germany,* D Salomon, *Wupperverband, Germany,* P Pyro, I Hobus, *Wupperverbandsgesellschaft für integrale Wasserwirtschaft, Germany*

0360 **Multi-temporal robust expansion planning of distribution grids considering uncertainties and curtailment of RES**
J Ziegeldorf-Wächter, A Moormann, S Krahl, A Moser, *FGH eV, Germany*

0831 **Automated smart grid planning considering flexibility options and voltage regulating assets**
S Koopmann, F Potratz, P Goergens, M Cramer,*RWTH Aachen University, Germany*

0571 **Planning of flexible power source in power distribution systems with high penetration of dispersed generation**
W Sun, K Tian, S Jia, *University of Shanghai for Science and Technology, China*

0771 **Active distribution network planning based on a hybrid genetic algorithm-nonlinear programming method**
N Koutsoukis, P Georgilakis, N Hatziargyriou, *NTUA, Greece*

1357 **Demonstration of an actively managed planning approach for connection of renewable generation**
S Conner, G Harrison, *University of Edinburgh, United Kingdom*

1042 **Smart planning: an innovative tool for the investment planning of smart distribution networks**
P Chittur Ramaswamy, C Del Marmol, D Schyns, F-X Bouchez, S Rapoport, *Tractebel, Belgium,* D Vangulick, *ORES, Belgium*

0569 **Behaviour analysis of an operational planning tool facing activation probabilities, for near optimal operation of smart grids**
J Sayritupac, E Vanet, R Caire, C Larios, *G2Elab, France*

0855 **Effects of network reinforcement options on energy losses**
S Blake, I Sarantakos, P Taylor, *Newcastle University, United Kingdom*

1027 **Flexibilities in grid planning : case studies on the French distribution system**
J Boubert, A Bouorakima, Y Desgrange, *Enedis, France*

0048 **Comparison between static and dynamic curtailment of RES in probabilistic high voltage distribution grid planning**
P Wiest, K Rudion, S Eberlein, *University of Stuttgart, Germany,* A Probst, *Netze BW GmbH, Germany*

1106 **An Analytical Method to Assess the Impact of Distributed Generation and Energy Storage on Reliability**

of Supply
A Escalera, *IMDEA Energy, Spain/University Carlos III de Madrid, Spain,* B Hayes, *NUI Galway, Ireland,* M Prodanović, *IMDEA Energy, Spain*

0991 **Distribution grid planning considering smart grid technologies**
B Nasiri, C Wagner, U Häger, C Rehtanz, *TU Dortmund University, Germany*

1093 **Technical Comparison of Measures for Voltage Regulation in Low-Voltage Grids**
J Bogenrieder, O Glass, P Luchscheider, C Stegner, J Weller, *ZAE Bayern, Germany*

1118 **Analysing the Effect of Increasing Renewable Capacities in Great Britain on the Regional Allocation and Wholesale Prices**
S Lupo, A E Kiprakis, *University of Edinburgh, United Kingdom,* M Ruppert, V Slednev, *Karlsruhe Institute of Technology, Germany*

1210 **Risks of Determining the Optimal Technical Solution of Power Plant Connection to Distribution Network**
M Cavlovic, *HEP-ODS d.o.o., Croatia*

1248 **An Analytical Method to Assess the Impact of Distributed Generation and Energy Storage on Reliability of Supply**
A Escalera, *IMDEA Energy, Spain/University Carlos III de Madrid, Spain,* B Hayes, *NUI Galway, Ireland,* M Prodanović, *IMDEA Energy, Spain*

1367 **Towards more cost-effective PV connection request assessments via time-series based grid simulation and analysis**
A Ulbig, S Koch, *Adaptricity, Switzerland,* C Antonakopoulos, *ETH Zurich, Switzerland*

0400 **Utilizing observability analysis to cluster smart inverters on secondary circuits for residential deployment**
D Montenegro, M Bello, B York, J Smith, *Electric Power Research Institute (EPRI), United States*

1004 **Cost/benefit analysis for energy storage exploitation in distribution systems**
G Celli, F Pilo, G Pisano, G G Soma, *University of Cagliari, Italy*

0848 **Evolution Of Electrical Distribution Grid Sizing Considering Self-Consumption Of Local Renewable Production**
A Rogeau, T Barbier, R Girard, *MINES ParisTech, France,* N Kong, *ENEDIS, France*

Sub-block 3 – Optimal placement of power and control discrete components

0154 **Optimal recloser deployment to leverage self-healing: a techno-economic robustness assessment**
E Rodrigues, I Miranda, N Silva, *Efacec, Portugal,* H Leite, *University of Porto, Portugal*

1242 **A Methodology to Allocate Automatic Recloser in Large Power Distribution Networks**
C F M Almeida, J CC Amasifen, R A Spalding, E L Ferrari , N Kagan, *University of Sao Paulo, Brazil,* H Kagan, *Sinapsis Inovacao Em Energia, Brazil,* D Mollica, A Dominice, L Zamboni, M A P Fredes, G H Batista, *EDP, Brazil*

0030 **Risk based procedure for network automation planning in radial distribution networks with distributed generation**
Ž Popović, *University of Novi Sad, Serbia,* S Knezević, *Schneider Electric DMS NS, Serbia*

0026 **Evolution Of Electrical Distribution Grid Sizing Considering Self-Consumption Of Local Renewable Production**
A Rogeau, T Barbier, R Girard, *MINES ParisTech, France,* N Kong, *ENEDIS, France*

0020 **Optimal allocation of capacitor devices on MV distribution networks using crow search algorithm**
A M Shaheen, *South Delta Electricity Distribution Company (SDEDCo), Ministry of Electricity, Egypt,* R A El Sehiemy, *Kafrelsheikh University, Egypt*

1346 **Simultaneous optimization of tie switches placement and reserve capacity margin of Sub-Transmission substations considering the conflict between Short-term and Long-term planning**
M Hoseinpour, M-R Haghifam, S M Miri Larimi, *Tarbiat Modares University, Iran,* M Zangiabadi, *Newcastle University, United Kingdom*

Sub-block 4 – EV accommodation planning

1281 **Evaluation of the Impact of Plug-In Electric Vehicles in Greek Distribution Network**
E Voumvoulakis, E Leonidaki, G Papoutsis, N Hatziargyriou, *HEDNO, Greece*

0551 **Optimal planning of EV charging network based on fuzzy multi-objective optimisation**
K Qian, *State Grid Corporation of China, China,* J Gu, X Zhang, H Zhou, *Nantong University, China,* C Zhou, *Glasgow Caledonian University, United Kingdom,* Y Yuan, *Hohai University, China*

0802 **Impacts of fast charging of electric buses on electrical distribution systems**
D Steen, L A Tuan, *Chalmers Univ. of Tech, Sweden*

Block 4 : Methods & tools

Sub-block 1 – Load/generation modelling & forecasting

0842 **Improved small area forecasting for electrical spatial load forecast analysis**
J McCann, A Chabrol, S Quinn, *ESB International, Ireland*

0182 **Long-term forecasting of reactive power demand in distribution networks**
C Kaloudas, R Shaw, *Electricity North West Ltd, United Kingdom*

0370 **Identification of electrical energy consumption patterns**
V Pereira, P Mousinho, L Jorge, *EDP Distribuição, Portugal*

0584 **Wind power forecasting based on refined LSTAR-GARCH model**
H Chen, *State Grid Jiangsu Electric Power Company, China,* R Li, *Chinese Society for Electrical Engineering, China,* Y Wang, C Xu, *Southeast University, China*

0600 **Application and evaluation of a probabilistic forecasting model for expected local PV penetration levels**
R Bernards, *TU Eindhoven, Netherlands,* R Verweij, E J Coster, *Stedin BV, Netherlands,* J Morren, H Slootweg, *Enexis BV, Netherlands/ TU Eindhoven, Netherlands*

0625 **Probabilistic day-ahead forecasting of household electricity demand**
A Gerossier, R Girard, G Kariniotakis, A Michiorri, *PSL Research University, France*

0654 **Analysing the ability of smart meter data to provide accurate information to the UK's DNOs**
G Poursharif, A Brint, *The University of Sheffield, United Kingdom,* M Black, M Marshall, *Northern Powergrid, United Kingdom*

0743 **Long term forecast of local electrical demand and evaluation of future impacts on the electricity distribution network**
N Kong, M Bocquel, G Pelton, P Cauchois, *Enedis, France,* T Barbier, R Girard, E Magliaro, G Kariniotakis, *MINES Paris Tech, France*

0836 **Behaviour of street lighting feeders supplying traditional and new LED lamps**
A Ilo, E Torabi, W Gawlik, *TU Wien, Austria,* G Wötzl,*TU Wien, Austria, MA 33 - Wien Luechtet, Austria*

0827 **Advancement of load estimation method for LV distribution facilities**
H Wada, H Nomura, E Umemura, *Chubu Electric Power Company Inc., Japan*

0856 **Stochastic effects of customer behaviour on bottom up load estimations**
J Heres, V van Westering, *Alliander N.V, Netherlands/Delft University of Technology, Netherlands,* G van der Lubbe, D Janssen, *Radboud Universiteit Nijmegen, Netherlands*

1020 **The improved model for the spatial load forecasting of the Slovenian distribution network**
M Grabner, Z Bregar, Š Ivanjko, L Valenčič, *Milan Vidmar Electric Power Research Institute, Slovenia*

1064 **Load criticalities detection on HV/MV Substations in multi-country scenario**
G Palumbo, S Morel, G Bruno, F Viapiana, *Enel S.p.A., Italy,* C F Gomez-Arbelaez, , *CODENSA-Enel, Columbia*

1247 **A hybrid model approach for forecasting electricity demand**
J Teixeira, S Macedo, S Gonçalves, A Soares, *EDP Distribuição, Portugal,* M Inoue, *EDP Brasil, Brazil,* P Cañete, *Brazil, HCD, Spain*

1222 **Comparing time series clustering approaches for individual electrical load patterns**
Z De Greve, F Lecron, F Vallee, *University of Mons, Belgium,* G Mor, D Perez, S Danov, J Cipriano *CIMNE, UPC, Spain*

1071 **ANDES: Grid Capacity Planning using a Bottom-up, Profile-based Load Forecasting approach**
P van de Sande, M Danes, T Dekker, *Alliander N.V, Netherlands*

Sub-block 2 – Network modelling and representations

0222 **Elektro Gorenjska CIM project**
B Rozic, D Mlakar, M Gruden, *GDB d.o.o., Slovenia,* N Petrovic, *Elektro Gorenjska, Slovenia*

0932 **Developing static model of fault current limiter technologies**
A Kazerooni, G Tsigara, N Murdoch, *WSP | Parsons Brinckerhoff, United Kingdom,* J Berry ,*Western Power Distribution, United Kingdom*

0315 **Effects of asymmetrically connected PV and battery systems on the node voltages and PEN-Conductor currents in low voltage grids**
M Wagler, R Witzmann, *Technical University of Munich (TUM), Germany*

0314 **A model to simulate medium voltage active networks with an aggregated view of the low voltage ends**
A Pagnetti, G Malarange, *EDF R&D, France,* F Pilo, S Ruggeri, *University of Cagliari, Italy*

0380 **Application of time-resolved input data for smart grid simulation**
A Shapovalov, C Kittl, C Rehtanz, *TU Dortmund University, Germany,* L Jendernalik, A Schneider, D Giavarra, *Westnetz GmbH, Germany*

1175 **A co-simulation approach using PowerFactory and MATLAB/Simulink to enable validation of distributed control concepts within future power systems**
K Johnstone, S M Blair, M H Syed, A Emhemed, G M Burt, *University of Strathclyde, United Kingdom,* T Strasser, *AIT Austrian Institute of Technology, Austria*

1229 **Using matrix factorization for the prediction of electrical quantities**
F Lecron, Z De Greve, F Vallee, *University of Mons, Belgium,* G Mor, D Perez, S Danov, J Cipriano *CIMNE, UPC, Spain*

Sub-block 3 : Load flow & short circuit calculations

0238 **Advancement in state grasping method of MV distribution network for short-term and mid-term planning**
H Ishikawa, T Yamada, K Sada, *Chubu Electric Power Company Inc., Japan,* T Takano, N Itaya, *Mitsubishi Electric Corp, Japan,* H Ohtsu, *Mitsubishi Electric Information Network Corp, Japan*

0031 **Dealing with sparse smart metering data in techno-economic analysis of low voltage networks**
F Vallée, M Hupez, F Toubeau, Z De Grève, *University of Mons, Belgium*

0179 **Analysis of probabilistic load flow using point estimation method to evaluate the quantiles of electrical networks state variables**
G Plattner, *EDF - R&D, France,* H Farah Semlali, N Kong, *Enedis, France*

0976 **Characterisation of 11kV fault level contributions based on substation load profile**
P Edwards, *WSP | Parsons Brickerhoff, United Kingdom,* J Berry, *Western Power Distribution, United Kingdom*

0367 **The impacts of a reduction in 11kV voltage settings in South Wales**
G Shaddick, A Green, *University of Bath, United Kingdom,* M Watson, *Western Power Distribution, United Kingdom*

0381 **Utilizing residential flexibility in the planning of LV-networks**
J Reinders, R Bernards, *TU Eindhoven, Netherlands,* D Geldtmeijer, J Morren, H Slootweg, *Enexis BV, Netherlands/TU Eindhoven, Netherlands*

0738 **The impact of low carbon technologies on short circuit levels at medium voltage networks**
J Berry, *Western Power Distribution, United Kingdom,* A Kazerooni, M Eves, *WSP|Parsons Brinckerhoff, United Kingdom*

0805 **Performance assessment of a three-phase distribution network with multiple residential single phase PV systems**
S Bhagavathy, N Pearsall, G Putrus, *Northumbria University, United Kingdom,* S Walker, *Newcastle University, United Kingdom*

0910 **Fully automated calculations in both MV and LV networks**
F Provoost, F Smits, *Alliander, Netherlands,* L W Jansen, *Phase to Phase, Netherlands*

0577 **A comparative assessment of a quasi-sequential and a sequential approach for distribution network stochastic analysis**
M Hupez, Z De Grève, F Vallée, *University of Mons, Belgium*

0806 **Combination of linear power flow tools for voltages and power estimation on mv networks**
J Buire, X Guillaud, F Colas, *L2EP, France,* J-Y Dieulot, *CRIStAL, France,* L De Alvaro, *Enedis, France*

0294 **Resilience of the DSO network near 50.2Hz**
D Vangulick, T V Cutsem, *ORES, Belgium/University of Liège, Belgium,* D Ernst, *University of Liège, Belgium*

Sub-block 4 – Energy losses

0963 **Losses**
M Bebbington, W Mantle, *SP Energy Networks, United Kingdom,* R Bryans, *TNEI Services Ltd, United Kingdom*

0306 **Impact of PV distributed generation on EDP Distribuição LV grid losses**
M I Verdelho, R Prata, *EDPD, Portugal,* P Carvalho, J Machado, *IST/INESC-Id, Portugal*

1076 **Accurate Determination of Distribution Network Losses**
A Urquhart, M Thomson, *Loughborough University, United Kingdom,* C Harrap, *Western Power Distribution , United Kingdom*

0489 **Improved three phase power flow method for calculation of power losses in unbalanced radial distribution network**
T Alinjak, K Trupinic, *HEP ODS, Croatia,* I Pavic, *FER, Croatia*

0785 **Identifying energy efficiency improvements and savings potential in Croatian energy networks**
T Baricevic, M Skok, *EIHP, Croatia,* S Zutobradic, L Wagmann, *HERA, Croatia*

1007 **Optimal network reconfiguration in distribution system for loss reduction and voltage profile improvement using hybrid algorithm of PSO and ACO**
M A Heidari, *SHEDC, Iran*

1260 **Innovative Approaches to Identification and Reduction of Distribution Network Losses**
J Acosta, C Higgins, *TNEI, United Kingdom,* M Hughes, *Element Energy, United Kingdom,* T Manolopoulos, *SSEN, United Kingdom*

1011 **Identification and evaluation of energy theft using the state estimator in MV and LV grids with exogenous parameters for planning expansion**
D Duarte, D Kondo, F Matsuzaki, J Guaraldo, M Souza, *Sinapsis, Brazil,* H Silva, M Ferreira, *Electrobras Alagoas, Brazil,* R Silva, *Eletrobras Rondônia, Brazil,* L Brito, R Ross, *CEPEL, Brazil,* N Kagan, , *USP, Brazil*

0988 **Containment of power losses in LV networks with high penetration of distributed generation**
G Celli, N Natale, F Pilo, G Pisano, *University of Cagliari, Italy,* F Bignucolo, M Coppo, A Savio, R Turri, *University of Padova, Italy,* A Cerretti *e-distribuzione SpA, Italy*

1258 **Fraud Detection in Low Voltage Electricity Consumers Using Socioeconomic Indicators and Billing Profile in Smart Grids**
J Pulz, R B Muller, F Romero, A Meffe, *Daimon, Brazil,* A F Garcez Neto, A S Jesus, *Sulgipe, Brazil*

1286 **Radial Distribution Network Reconfiguration (DNR) for Power Losses Reduction Using a Modified Particle Swarm Optimization (MPSO)**
I Atteya, H Ashour, *Arab Academy for Sciences and Technology, Egypt,* N Fahmi, D Strickland,*Aston University, United Kingdom*