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 (June 4, 9:00-12:30 and 14:30 -18:00),
- Poster Session (June 5, 9:00-12:30 and 14:00-17:30),
- Research & Innovation Forum (June 6, 16:30-18:00).

Round Tables are organized by S5 or jointly organized with other Sessions on transversal topics.

- RT4: TSO / DSO interactions (June 4, 14:30-16:00)
- RT13: Future role of the DSO (June 5, 16:30-18:80)
- RT14: Resiliency in distribution planning and operation (Wednesday, June 6, 09:00-10:30)
- RT15: New components for MV and LV DC network and integration in grid planning (June 6, 09:00-10:30)
- RT16: New Planning Guidelines for Smart Distribution Grids (June 6, 11:00-12:30)
- RT18: Distributed energy resources aggregation platforms for the provision of flexibility services (June 6, 14:30-16:00).

The 2019 S5 main session is divided into four blocks. In each block the oral presentations of selected papers stimulate the discussion among attendees. Each oral presentation in both the Main Session and RIF lasts 12 minutes. 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 accepted 158 papers (acceptance rate around 60%) divided into 4 blocks that reflect the traditional topics of S5: Risk Management and Asset Management, Network Development, Distribution Planning, and Methods and Tools. From the examination of the received valuable contributions, it emerges that the renovation of distribution planning is a matter of fact. Indeed, by following the path paved by Academia, CIRED, CIGRE, National Regulatory bodies and supranational institutions (e.g. EU), the planning methodologies used by academicians or distribution engineers always compare the operation of distribution networks with conventional planning strategies to face the expected growth of electro mobility and heat pumps and the integration of RES with least cost-high performant innovative distribution networks. In some cases, new network schemes, namely microgrids, are regarded as an opportunity to increase reliability and network efficiency with fewer investments. Particular attention is paid to develop methodologies to deal with time series of energy consumption or production, consequence of the expected connection of stationary and mobile storage, and the resort to flexibility services from active demand and generation. In this context, spatial forecast, satellite maps and GIS can dramatically improve planning, particularly in LV networks, by looking at local bottlenecks and constraints. As a general remark a greater attention to LV networks has been noticed, since those networks are the most affected by future changes. This trend is destined to increase with the development of LV specific tools or capable to deal with multiple distribution levels. Finally, new methodologies for dealing with uncertainties – probabilistic models, Monte Carlo methods, robust optimization – are definitely substituting classical deterministic approaches.

Modern distribution planning emphasizes a new role for DSOs. New markets for services and flexibility are necessary to engage customers, producers and aggregators. Legislation and regulation should have to change accordingly.

The novel distribution planning is accompanied by greater computational burden and complexity to manage time-series, uncertainties and operational optimization. New mathematical techniques designed to manage the complexity are necessary. Artificial Intelligence (AI) and data analytics can significantly help. Distribution engineers and researchers are starting to consider AI robust enough for the application on distribution system.

Finally, it is worth to highlight the great progresses on the topic of resiliency with new planning algorithms to design systems that can cope climate change effects with appropriate cost-benefit analysis for all dimensions of resiliency.

Block 1: Risk Assessment and Asset Management

Sub Block 1: Risk Assessment and Reliability assessment

Experience has shown that network performance is strongly related to its capability of facing unlikely yet severe contingencies. It is therefore crucial to be able to define which sets of events are more likely to influence grid performance, and in which way, in order to evaluate the most effective actions which can be used to mitigate the reasonably possible risk.

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

Paper 0118 aims at quantifying the impact of medium voltage components on the overall system's reliability. By considering real reliability and operational data of a European medium voltage ring, the authors identify the most critical type of components to the overall system's reliability, and the specific elements having the highest potential reliability improvement contribution. Such a tool allows DSOs to optimize their asset management procedure, identifying the needed investments to achieve certain reliability goals.

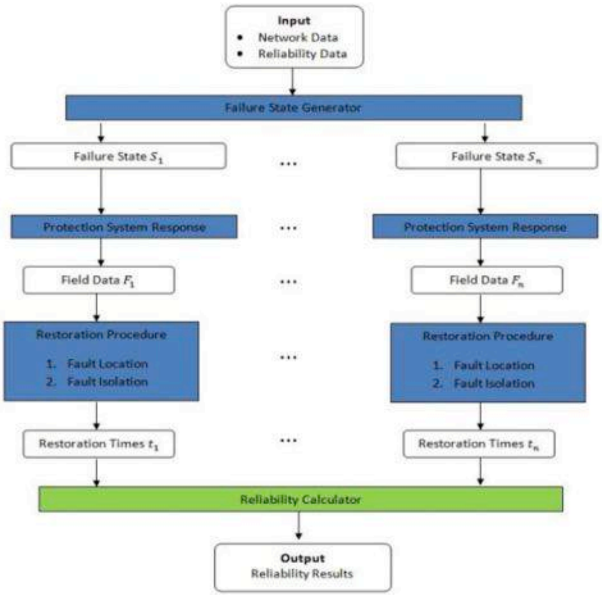


Fig. 1: General overview of the reliability assessment tool presented in Paper 0118.

In **Paper 0375**, a combined planning and simulation approach for designing Smart Grid distribution automation solutions and telecommunications networks is proposed. Results demonstrate that considering telecommunications availability in System Reliability Index estimation has the potential to both change the planned reclosers allocation on the grid and reduce the estimated solution expected benefit for a project.

Paper 0623 establishes a comprehensive evaluation system for next-generation smart distribution networks from the perspective of four aspects including supply security, supply quality, supply intelligence and supply friendliness. The effectiveness of the proposed evaluation method is carried out through the verification analysis on an actual regional distribution network.

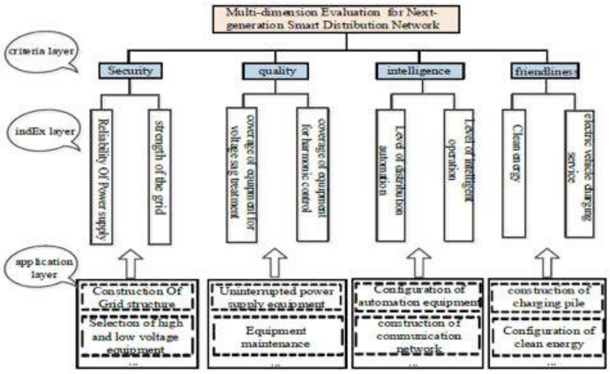


Fig. 2: High-reliability distribution network multi-dimensional indicator system (Paper 0623)

Paper 0640 suggests a new way of seeing the distribution networks, i.e. to observe the geometry features of the Distribution System Security Region (DSSR), which is, approximately, a hyper-polyhedron in high-dimensional Euclidean space. DSSR shape indices are proposed to locate network defects and have been applied to an extended IEEE RBTS-Bus4 system.

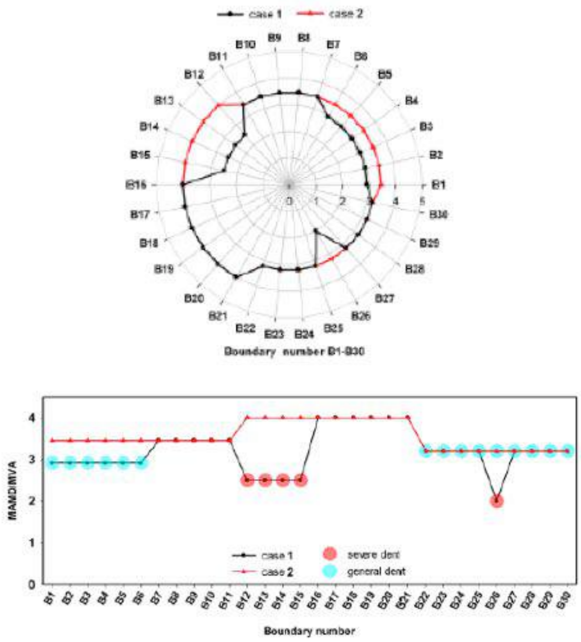


Fig. 3: Observation of the DSSR geometry (Paper 0640).

The authors of **Paper 0754** propose to improve the reliability assessment through the determination of network operating points considering new grid participants. A determination method based on clustering of time series is provided and results, based on real distribution grids, are shown. Results emphasize that the relevance of an exact determination depends on grid and distributed generator technology type.

Paper 1364 focuses on preventive maintenance actions carried out by identifying, through a genetic algorithm, assets and areas with great risk of causing grid failures. Such actions guarantee high levels of system reliability and ensure not only customer satisfaction, but also high profitability by meeting regulatory goals for power quality indexes and avoiding customers refunding due to interruptions.

Paper 2330 focuses on SAIDI originated by unplanned interruptions in MV network and on the approach of Enel regarding the selection of levers to improve reliability and operation effectiveness. The structured decomposition of SAIDI in sub-indicators enables to address the decision-making process to find out the best mix of actions for each typology of network. The proposed approach enables to set a global framework to evaluate single network performances and define customized improvement plans at Country level.

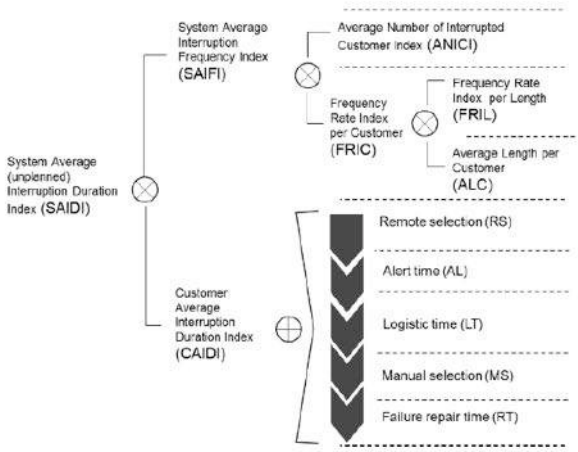


Fig. 4: Enel framework to SAIDI presented in Paper 2330.

Sub Block 2: Resiliency

Sub Block 2 deals with power systems resiliency, i.e. their ability to withstand extreme events (including, but not limited to, meteorological ones) and to contain the impact of the event in terms of number of customers involved and recovery time.

The papers presented in this CIRED address this new aspect of planning, due to climate change, from methodological, regulatory, organizational points of view.

Paper 1029 describes the Finnish regulation regime and shows the achieved system-level reliability in the past decades. The base level of interruption duration in 1996-2017 shows no significant change, but fluctuation causes uncertainty in the reliability trend. Since the interruption indexes are strongly affected from external conditions, such as storms, identifying changes in distribution reliability also implies analyzing environmental factors.

Paper 0898 focuses on the disaster preparedness before and after a hurricane in an electrical distribution system. An evaluation method of outage risks together with an optimal resource allocation strategy is presented. The proposed approach can be applied both for long term planning and optimal fast response during extreme contingencies.

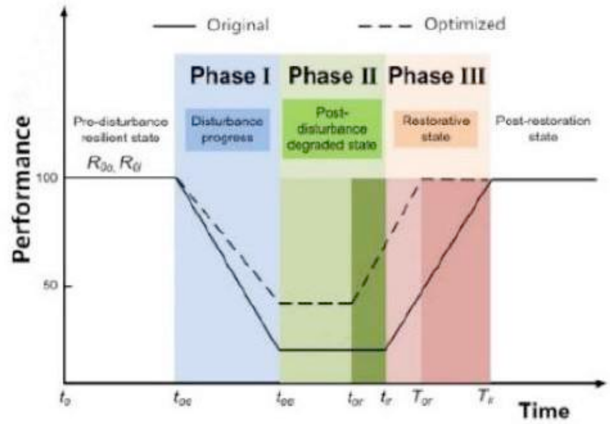


Fig. 5: The multi-phase system performance trapezoid shown in Paper 0898.

Paper 1348 deals with the DSOs need to improve the resilience of their grid not only by reducing the risks against various threats but also by enhancing their capability to respond and recover from disruptive events. Testing and exercising are some of the most effective tools for improving organizational resilience. A well-tested Business Continuity strategy provides confidence to handle a disruption, and regular training and education of operational teams and key stakeholders allow enhancing awareness and developing the skills to manage the plans in case of an emergency.

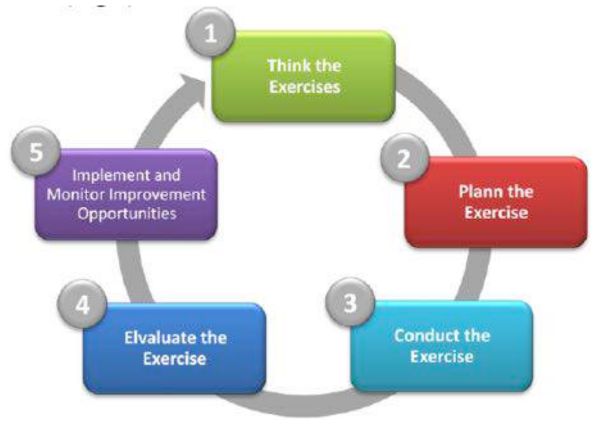


Fig. 6: Exercise execution cycle phases (Paper 1348).

The authors of **paper 1869** have developed a comprehensive methodology and tool, based on the risk concept, to assess the resilience of T&D networks as a whole. The tool is able to model detailed vulnerability curves for the components of both MV and HV grids, as well as to quantify the benefits of some resilience boosting measures, to face threats with different severities.

Paper 1651 summarizes the experience of the DSO edistribuzione with the new Italian resilience regulation, showing the pioneering approach adopted by the company to select the investments for both the network structure and the fast recovery activities.

Paper 1618 describes the methodology developed by e-distribuzione to evaluate the resilience of the MV grid against heavy snowstorms. The methodology complies with the design criteria required by current CEI EN 50341-1 standard, evaluates the event probability taking into account the daily meteorological values along the last 20 years for each Italian municipality and the impact through a graph visit algorithm.

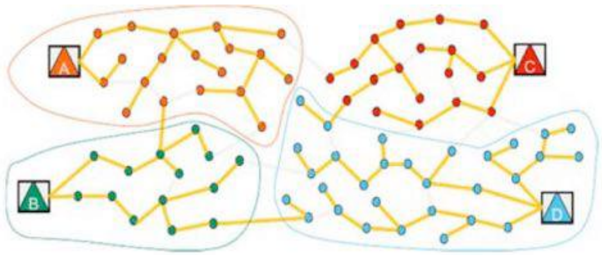


Fig. 7: Example of more resilient paths found by the graph visit algorithm (gold segments), from Paper 1618.

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. In this section methodologies are proposed to assess the issues of aging equipment and the decisions related to renewal Vs. maintenance of existing assets as well as investment optimization process.

Paper 0631 deals with long-term simulations of maintenance and renewal costs to optimize asset management. This approach avoids fluctuations in budget and at the end of the day ensures sustainable OPEX and CAPEX costs considering reliability of network.

Paper 1246 proposes a Genetic Algorithm-based methodology, which provides an optimal plan of maintenance actions considering financial restrictions. The utilization of multi-sourced data allows assessing the maintenance action benefits in terms of continuity indexes reduction. The module establishes a common basis to select an efficient set of maintenance action orders considering budget limitations.

Paper 2231 is about renewal planning of medium voltage distribution networks using asset health data as input to cost-benefit analyses of renewal alternatives. Cost-benefit analyses are performed based on the health of conductors, poles, cross arms, insulators, pole foundations and stay wires detected through inspections. Choosing the right alternative for renewal can result in great savings and a significant lifetime extension of overhead lines.

Paper 0995 presents a holistic machine learning solution to forecast current and future Power Transformers (PT) health condition. It leverages data from different sources and distinct business units. Current and future oil health conditions are forecasted. So, utility companies can save considerable resources by reducing and improving the scheduling of oil analyses, as well as increasing the quality of service.

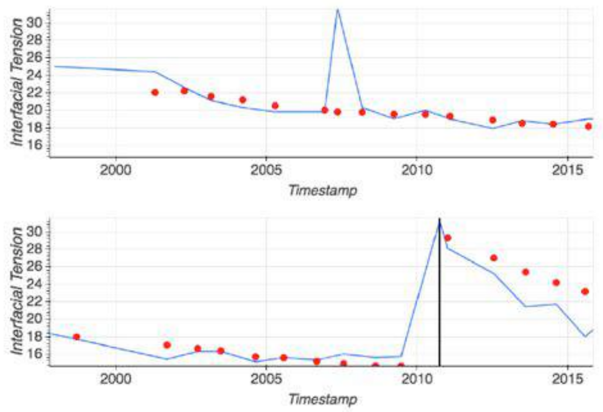


Fig. 8: Real measurements (continuous blue), detected intervention (black vertical line) and forecasted measurements (red dots) presented in Paper 0995.

Paper 1034 describes the possible improvements deriving from application of partial discharges diagnostic of MV cable lines that will be addressed by the Polish SORAL project. The outcome will be an expert tool to support a change in strategy in the MV power network management. The system will enable undertaking preventive measures reducing the number of failures.

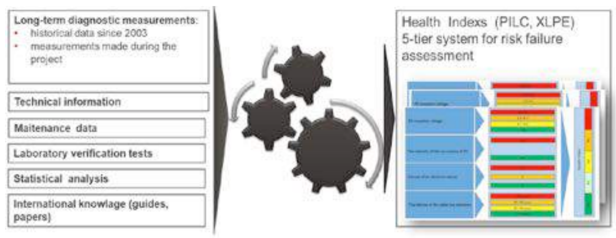


Fig. 9: The process of defining health indexes proposed in Paper 1034.

Paper 1493 deals with the Centralized Ageing Asset Database shared by Dutch DSOs. The collective gathering of the failure information and knowledge sharing, concerning maintenance and Life Cycle Management, allow the DSOs to bring their maintenance strategies for ageing assets to a higher level. This database is used both for asset management as well as education and training purposes.

Paper 0973 presents the PATH project whose purpose is to design health indicators of EDPD HV/MV and MV/MV power transformers in a short- and long-term perspective. The results enable an improved decision-making process regarding O&M actions on power transformers and also to project investment needs on an ageing fleet.

Paper 1986 presents results arising from a preliminary study preceding the demonstration work related to the IntegER project. The scope is to describe how the ageing of electrochemical batteries is influenced by the operating conditions and how this ageing affects the techno-economic capabilities of the batteries all along their lifetime.

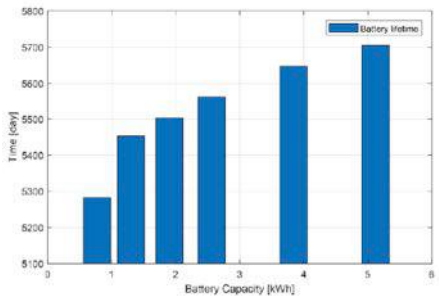


Fig. 10: Lifetime of batteries versus their capacity shown in Paper 1986.

Potential scope of discussion

The topic of resiliency is becoming crucial in modern distribution due to a clear trend that is leading to a greater frequency of extreme events. How can the different dimensions of resiliency be included in planning? Is cost/benefit analysis suitable to guide the decision making if applied to projects for improving resiliency? Can the smart grid and digitalization have a significant role to improve resiliency?

Table 1: Papers of Block 1 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0118	Identifying reliability-driven asset management strategies in active distribution grids				X
0375	A Combined Planning and Simulation Approach for Smart Grid Reliability Analysis	4			X
0623	Multi-dimension Evaluation and Investment Route for Next-generation Smart Distribution Network	1			X
0631	Asset simulation in distribution network using tools for evaluation of technical condition				X
0640	Distribution network observation based on security region geometry				X
0754	Clustering and determination of relevant network operating points in analytical reliability calculations	2			X
0898	Optimal Resource Allocation for Reducing Distribution System Risk Induced by Hurricane				X
0973	Predicting Transformer Health - PATH				X
0995	Power Transformers: Predictive Maintenance	6			X
1029	Steering effect of distribution reliability regulation				X
1034	SORAL - System for condition monitoring and failure risk assessment of MV cable lines based of off line diagnostic methods				X
1246	A Genetic Algorithm Based Methodology for Prioritizing Maintenance Actions of Power Distribution Utilities				X
1348	EDPD - Increasing DSO's Resilience by Exercising Business Continuity Plan				X
1364	GA-Based Approach for Inspection Prioritization in Electric Power Distribution Networks				X
1493	Centralized Ageing Asset Dossier database of the electricity networks in the Netherlands				X
1618	Resilience Enhancement of MV Distribution Grids Against Snowstorms	5			X
1651	Increasing resilience against extreme events in distribution networks: the DSO's experience with the new Italian regulatory framework				X
1869	Comprehensive risk-based methodology and tool for a quantitative resilience assessment of distribution and transmission systems				X
1986	Causes and consequences of batteries' ageing in grid integration scenarios				X
2231	Renewal planning based on asset health data used in cost-benefit analyses				X
2330	Enel's way to SAIDI	3			X

Block 2: Network Development

Sub block 1: Innovative Power Distribution

Innovation has been DSOs' trademark for the last 15 years and still is. It must be noted that recently, more than exploring any possible field, innovation is focusing on specific architectural topics such as off-grid solutions integrating DG and Smart Grid functionalities (advanced control and automation). In some cases, new components and introduced, expanding DSOs' possibilities in network management.

Sub block 1 deals with innovation not linked to specifically "structured" issues, describing either advanced system functionalities or non-conventional equipment integration.

The concept of Flexible Distribution Networks (FDN) is introduced by **Paper 0316**. FDN is conceived as an upgrade of the traditional open-loop distribution network evolving to closed-loop operation by replacing the tie-switch connecting the feeders with a Soft Open Point (SOP), i.e. an electronic device controlling the active/reactive flow between the feeders according to a predefined strategy (e.g. reducing losses, balancing loads, etc.). The paper presents the project of a three-terminal SOP-based pilot project of medium voltage FDN, to be located at Yanqing District, Beijing, China: the proposed operation model is described, and the expected benefits (in terms of network optimization in ordinary operation as well as of recovery of supply in case of fault) are then outlined.

A similar infrastructure is described in **Paper 1027**, in which typical AC MV networks are meshed through a MVDC link by means of a Voltage Source Converter (VSC) allowing load balancing between adjacent feeders.

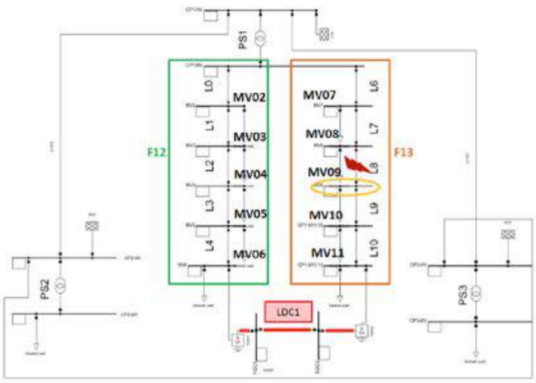


Fig. 11: Possible network topology including a MVDC link, as in Paper 1027

Different configurations are proposed for the system, also implying load-shedding functionalities when needed, and their performances are analyzed both in ordinary conditions (Optimal Power Flow) and in case of permanent failure. Simulation results remark the effectiveness of MVDC links to mesh the network: in fact, load-shedding can be fully avoided by effectively managing potential overloads.

Paper 0988 explores the effects of introducing decentralized control in LV and MV networks with embedded generation. The research, which has been partly developed within the Green Access project framework, analyzes the improvement that can be achieved in terms of Distributed Generation connectivity while adopting Congestion Management functionalities based on decentralized control, as well as in terms of continuity of supply following outages happening in the grid.

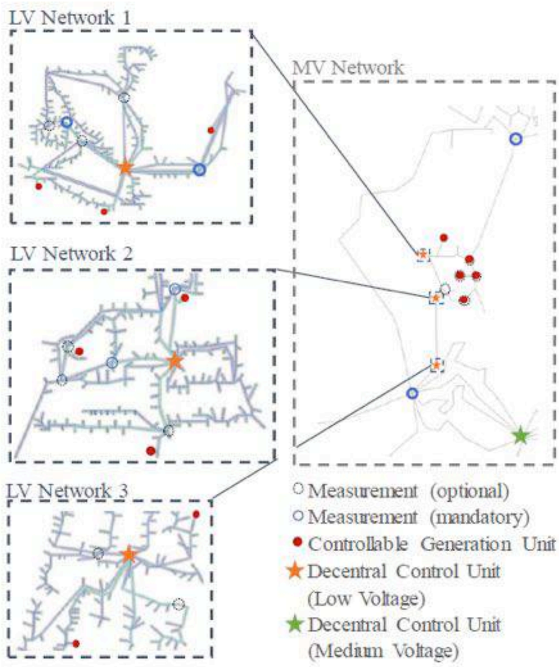


Fig. 12: Setup for Field Test and Analytical Assessment as in Paper 0988

A novel system architecture to support LV outages management is proposed in **Paper 0903**. The authors describe a comprehensive environment to perform data collection, integration and processing. Data source range from Smart Meters to Smart Boxes to LV branch, feeder and substation switches, all contributing to smart monitoring and fault management activities.

In **Paper 0980**, alternatives to massive cabling in northern countries with challenging goals in terms of duration of outages are examined. An analytical model has been developed to compare traditional as well as innovative (or, at least, nonconventional) solutions such as LVDC, BES, massive remote control, etc. Results show that, despite cabling being the most effective solution to face existing regulatory obligations, small scale LV BES can contribute to the achievement of these goals to a significant extent.

An enhancement of the existing MV scheme of Shanghai distribution network is explained in **Paper 0941**. More in detail, alternative ways of interconnecting "remote" MV sections (named K-stations, practically acting as substation MV busbar extensions), allowing higher levels of reliability, are examined. Operating models for different alternatives are defined and compared, protection systems and automation solutions are investigated, reliability analyses are operated through specific algorithms. Theoretical results show that an upgrade in the performance of the MV network is still possible, pilot projects have been planned in order to validate case study data.

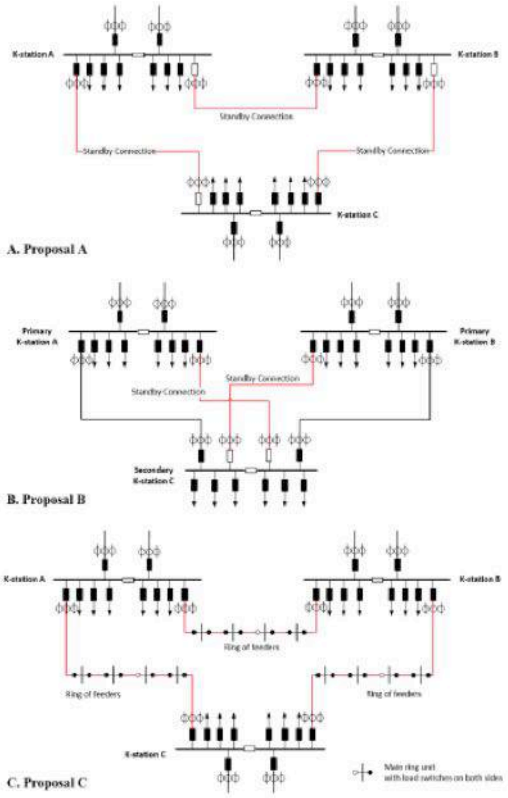


Fig. 13: Circuit configurations of a network composed of 3 K-stations (Paper 0941)

An Advanced Distribution Automation System, equipped with optic fiber and incorporating sectionalizers distributed along the feeders, is described in **Paper 1052**. The authors outline fault estimation technologies benefitting from analysis of waveform by applying artificial intelligence to collected fault data. By deepening the understanding of the failure modes and therefore improving the accuracy of the fault location, a significant reduction in emergency management and supply restoration can be expected.

Paper 0060 deals with both a nonconventional solution and a planning problem. In fact, the optimal use of on-load capacity regulating distribution transformers, i.e. MV/LV transformers whose capacity can be changed during operation by switching between the two available configurations of the windings, is discussed. The paper analyzes the benefits, in terms of energy losses, in case of the substitution of MV/LV ordinary transformers with on-load capacity regulating ones: a planning methodology is proposed in order to determine the optimal set of changes to maximize the losses recovery.

Also, in **Paper 0107**, we are facing a planning problem following the adoption of a nonconventional solution. More in detail, the paper analyzes the technological enhancement, which is being planned in order to dramatically improve the network performance, in terms of SAIDI, of the distribution network in Hanoi, Vietnam. The proposed configuration, based on the experience of the Japanese DSO (TEPCO), is based on the concept of Multi-Divided Multi-Connected (MDMC) systems combined with an extensive use of Fault Passage Indicators (FPI). Some specific cases are analyzed in deep detail, showing significant benefits in terms of SAIDI following the implementation of the proposed configuration.

Paper 0031 describes the use of a microgrid solution to supply isolated villages in extremely rural areas in Brazil. The proposed installation includes PV panels, a Diesel Generator, Li-ion batteries and a converter, that can be scaled according to the location and the size of the village supplied. The techno-economical evaluation provided shows that the planned out-of-grid solution is both cheaper than a conventional grid extension and an individual, isolated electrification.

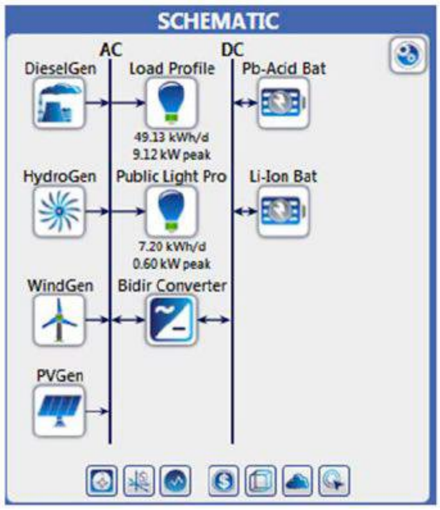


Fig. 14: Basic architecture of microgrid as in Paper 0031

Paper 1598 describes the improvements in a ferry supply station by adding to the conventional onshore infrastructure a storage system. The authors analyze the possible benefits arising from the upgrade, whose main goal is to allow charging during the short docking time while reducing peak-to-average grid load and therefore reducing the need for grid power upgrade. As the mere use of the storage system for complementing the grid in supplying the ferries does not generate a positive business case due to the cost of Li-ion batteries, a multi-service model is analyzed (e.g. selling energy to electrical vehicles in the docking area), showing promising economical results can be associated to multi-modal electrical transportation.

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, both in MV and in LV networks.

Paper 0877 presents a planning problem, yet it applies to a non-conventional installation, hence its inclusion in this sub-block. In more detail, it deals with design optimization of a hybrid stand-alone system (actually, a microgrid) to be installed in Nigeria, including some loads, PV panels, batteries and a hydrogen chain including an electrolyzer, a hydrogen storage system and fuel cells. The authors adopt two different methodologies in order to take into account the intrinsic uncertainties of the system, firstly by evaluating the impact of the uncertainties on an optimized system, secondly by performing a robust optimization through Monte Carlo simulation.

In **Paper 0044**, the SERVING project is described. SERVING is a funded project aimed at investigating the possible use of flexible loads in LV networks in order to actively manage the distribution system. More specifically, night storage heaters, heat pumps, water pumps and other devices (in the future, possibly electric vehicles) have been considered as "dispatchable" loads to be eventually used in case of network constraints. The project implied the development of individual solutions to transfer measurement values from the low voltage network and to control individual devices at customers' premises. Results show that, in order to ensure a reliable deployment of the proposed solution, enhancements are needed in industrialization of devices, quality of communication and adequacy of regulation.

Fig. 15: Functional interactions of SERVING platform, as in Paper 0044

Paper 1968 describes a proper Smart Grid project, named InteGrid, funded by the EU through the Horizon 2020 program and developed in Stockholm area. The project includes several facilities and is focused on the most relevant topics in Smart Grid concept, such as fault localization, predictive maintenance, load forecasting, voltage regulation and demand response. The authors describe the different test sites, the architecture developed and its components, the main results of the experimentation, as well as some improvements that can be implemented in order to increase the performance of the system.

Horizon 2020 is also the framework in which Nice Smart Valley (NSV), described by **Paper 2042**, is developed. More specifically, NSV can be defined as the French demonstrator within the larger Interflex project: the latter aims at experiencing the use of flexibilities in order to operate the network in an optimal way solving local constraints. The paper details the effect of the introduction of flexibility in load management in some given MV networks, showing its impacts on assessing current and voltage constraints; results show that the effectiveness of the flexibility in the resolution of most constraints strongly depends on the location and distribution of flexible loads as well as on the network structure itself.

Standardized solutions for ensuring energy supply in remote, rural areas are described in **Paper 1592**. Two different architectures, one for small-scale off-grid applications at individual level (IES), the other for energy supply of isolated communities (CES), are firstly introduced. A detailed description of the different subsystems as well as their interaction is then provided, followed by a short summary of the laboratory tests performed. Finally, an experimental installation (Enel Paratebueno Pilot Project, in Colombia), fully operating since first quarter of 2018 and ensuring an average supply of more than 150 kWh/day, is described.

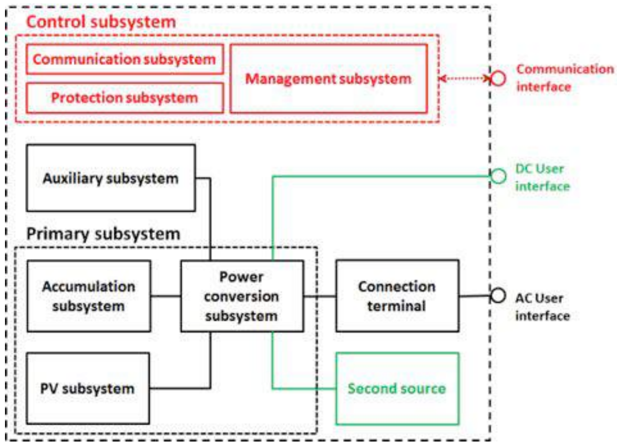


Fig. 16: PV-IES architecture (Paper 1592)

Paper 0673 describes the renewal of the MV/LV network of Gibraltar according to a Smart Grid architecture. The existing infrastructure is being upgraded installing state-of-the-art component (circuit breakers, remotely controlled switches, etc.) and connecting them to a 61850-based SCADA through fiber optic. In order to achieve higher levels of performance in terms of SAIFI and SAIDI, a simpler, more effective network structure has been developed and advanced automation techniques are being implemented.

Paper 1417 exposes a solution for full-scale integration of DER (distributed generation, storage systems, controllable loads, etc.) in the electrical system. The authors specifically focus on a systemic approach aimed at standardizing the full process, starting from DER connection, which must inevitably be managed at an individual installation level, but progressively evolving through aggregation in microgrids to be finally managed under a unified DERMS (DER Management System).

In **Paper 1874**, different solutions for microgrids supplying non-interconnected areas are examined. The comparison is related to technological solutions for LV distribution (DC, European AC, American AC) in different case studies (Dense Rural, Scattered Rural, Dense City), the main driver being the total cost of energy for the optimized technical solution. Results show that DC and European AC solutions have comparable costs when it comes to the grid, American AC distribution being less effective; in the end, DC solution seems preferable due to its side advantages, its main limitations residing in the availability of consumer appliances at 48 V.

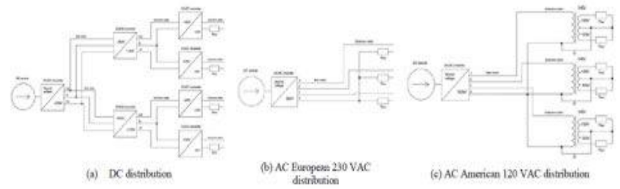


Fig. 17: Power distribution network configuration: a) DC distribution, b) AC European, c) AC American (Paper 1874).

Paper 1982 describes an Energy Management System (EMS) designed to enable a multi-energy microgrid to participate to different electricity markets. The microgrid is supposed to include the most common energy carriers, including electricity, heat and gas. The paper firstly delivers a possible model of Multi-Energy System (the microgrid), eventually including several generation facilities (e.g. PV, biogas, CHP, etc.), different loads (including non-electric ones) and introduces the possible synergies between carriers; secondly, the EMS is described in terms of algorithms for the optimization of the system as a whole; finally, a summary of experimental results is provided.

Sub block 3: DC Distribution Systems

Main research activities, here included in Sub-block 3, mostly relate to specific application topics such as integration in existing networks (generally AC ones).

Hybrid AC/DC systems including both load and generation facilities are dealt with in **Paper 0577**, introducing a comprehensive tool through which not only full AC or DC network solution can be planned and evaluated, but also hybrid configurations in which a DC subsystem is connected to a conventional AC network. A case study is presented of a typical French LV feeder, where different solutions are evaluated and compared in terms of energy losses and voltage drops under different scenarios. Results show that hybrid DC-AC networks can be an effective solution, generally implying lower losses levels, particularly in the case of small energy flows between LV and MV networks (local load-generation balance).

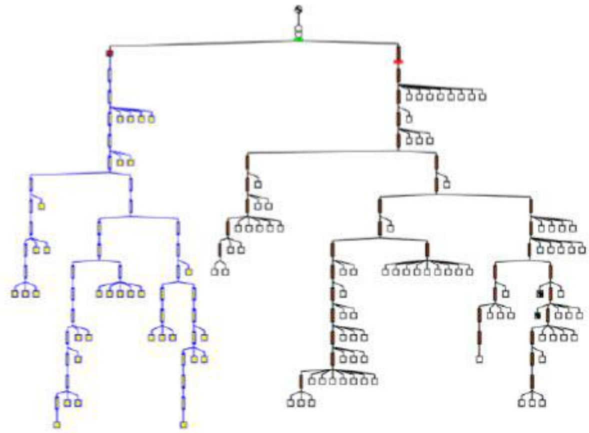


Fig. 18: Hybrid version of the LV feeder considered in Paper 0577

LVDC is often linked with rural distribution, however its potential application is more linked to the mode of generation and/or consumption than to a specific environment. **Paper 0866** describes a possible application of a DC microgrid in a residential building including PV, batteries and EVs: different grid topologies are analyzed in detail in order to define the best configuration of the DC infrastructure and the optimal positioning of the interface between the network and the individual installations. Results show that a DC infrastructure becomes more and more convenient the greater the energy exchange between DC elements of the microgrid (PV, batteries, EVs) and conventional loads.

Potential scope of discussion

Microgrids are already planned as a viable solution for electrifications of isolated areas due to their modular structure and their relative ease of installation. Can we imagine the same microgrid structure as the atomic element to build larger distribution architectures, being able to operate both as a standalone entity and as an inter-connected sub-system?

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0031 Rural electrification in Brazil based on microgrids				X
0044 Providing flexibility in the distribution network – challenges and solutions				X

0060	A Planning Method of On-load Capacity Regulating Distribution Transformers in Urban Distribution Networks after Electric Energy Replacement	7			X
0107	Distribution Planning System in Vietnam for Multi-divided and Multi-connected System				X
0316	Flexible Distribution Network: Definition, Configuration, Operation and Pilot Project			X	X
0577	Hybrid AC and DC Distribution Networks Modelling and Planning using EPSL Modelica Library: Preliminary Results				X
0673	Upgrade and refurbishment methodologies apply to Gibraltar Electric Authority's power distribution system project				X
0866	Assessing Topology Efficiency in Residential Microgrids				X
0877	Uncertainty sensitivity assessment on the optimization of the design and operation of complex energy systems: two complementary approaches			X	X
0903	Efficient power outage perception and recovery processing solution in low voltage power grid				X
0941	The Shanghai Practice: Improve the Reliability of Urban MV Distribution System with K-station and its New Network Designs				X
0980	Alternative solutions for advanced security of supply				X
0988	Influence of Distributed Decentral Control Units on Reliability of Distribution Networks				X
1027	Meshing AC distribution networks: the opportunities of MVDC links	8			X
1052	Development of Advanced Distribution Automation System with Failure Cause Estimation Function	9			X
1417	Integration and aggregation of distributed energy resources – operating approaches, standards and guidelines	10			X
1592	Enel GI&N rural electrification solutions and implementations				X
1598	Multi-service charging station and/ or onshore energy storage at port for electric ferry - a case study for Norway				X
1874	Techno-economic analysis of network configuration of PV based off-grid distribution system	11			X
1968	Smart Grid Ellevio-Demo Stockholm				X
1982	A Multi-Energy Microgrid Integrating Bio-Gas Production for Local and Market Services Provision	12			X
2042	Impact of flexibility location in MV distribution – The Nice Smart Valley Case study				X

Block 3: Distribution Planning

Sub block 1: Advanced Planning

Papers in this sub block give a significant contribution to the distribution planning state of the art with different approaches taking into account multi voltage level analyses, smart meters and other measurement devices information, scenarios with distributed energy resources and electric vehicles, probabilistic load flows, artificial intelligence planning, equipment ageing.

Paper 0139 deals with the SimBench project which provides an extensive open-source dataset of typical electrical power systems with up-to-date grid data and in addition, corresponding time series for load, generation and storage. This dataset enables multi-voltage-level analyses of distribution systems and increases comparability and transparency of tools and methods for their development. The grid data and elaborated study cases are based on German distribution system operators (DSOs) planning and operational principles.

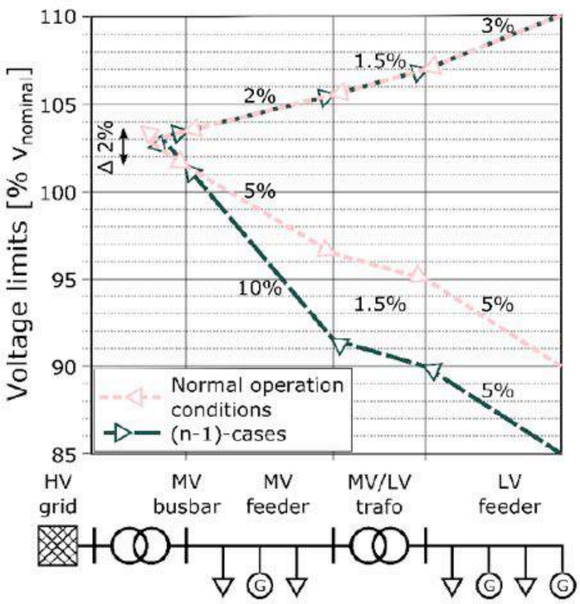


Fig. 19: Voltage limits at MV and LV levels for relevant dimensioning cases in SimBench (Paper 0139).

In **Paper 0140** the features and possible application of Public Electric utility "Elektroprivreda HZ HB, Mostar", Bosnia and Herzegovina smart metering system are presented. Smart meter data can be used for distribution grid planning and analyzing. In particular, load profiling, grid losses, peak power, consumption forecasting, voltage quality, reliability calculations and statistical analyses can be carried out for distribution grid planning. All those possibilities are validated with examples and practical case studies.

Paper 0289 evaluates the design rules for voltage variation in the Liander MV and LV-networks. It showed, among others, that the margin between the Network Code and the Liander design rules was too large and didn't take into account properly dispersed generation. By optimizing the current MV and LV network design requirements, less investments related to voltage quality are needed, resulting in significant savings.

A bottom-up scenario analysis tool, developed to automate the impact assessment of increasing distributed generation as well as demand electrification on distribution networks, is described in **Paper 0532**. This tool diversifies high-level scenarios to local specific scenarios, and subsequently uses stochastic models to evaluate the loading and voltages in the network. Load profiles are built up from individual connections and aggregated up, to achieve a consistent simulation from the LV cable level up to the high voltage substations. Using the proposed methodology forecasts can be made on the timing, location and probability of bottlenecks, for a given scenario.

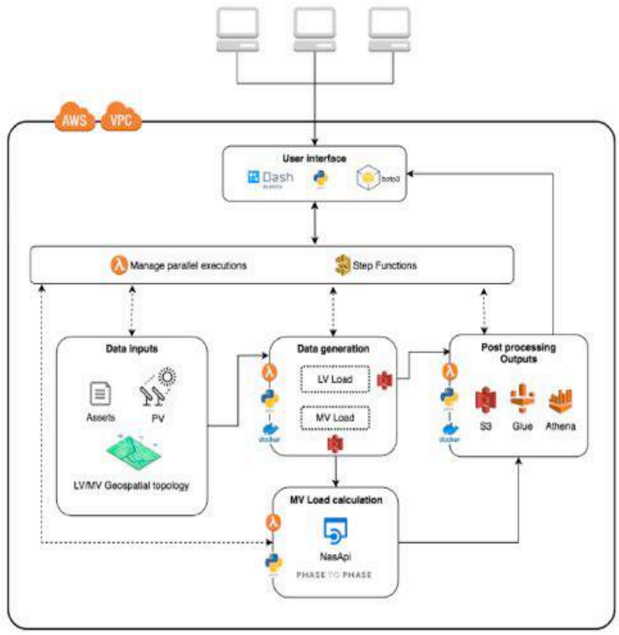


Fig. 20: Paper 0532: architecture of the scenario tool, detailing the different process steps and platforms on which they are implemented

Paper 2118 shows the benefits of automating and integrating the calculation processes performed by the various technical areas of EDP Brazilian distribution companies in order to improve the planning process. This approach enables the efficient sharing of information, significantly increasing the quality of the studies proposed in each area while ensuring the reduction of repetitive activities and the consequent misuse of resources.

Paper 1010 focuses on optimizing the medium voltage distribution network in an urban area. The planner compares an optimized target network with the present one. For the optimization task, the application uses a raster map of the city to find permissible and cost optimized cable routes taking care of supply, outage, and maintenance costs. The resulting target network has suitable cables and switches drawn automatically on the cost optimal places. The paper presents the tool which enables the planners to make the decision.

DSOs need to adapt their grid structure taking care of changing supply tasks like integration of renewable energy resources as well as market ramp-up, e-mobility and decentralized energy storage facilities. **Paper 0685** proposes a comprehensive approach exploring the full variety of possible future developments using probabilistic scenarios. The solution includes a simulation of asset condition, load flow calculation, automatic resolution of capacity- and condition-problems following planning and operation principles, a financial model, analytic views and an optimizer.

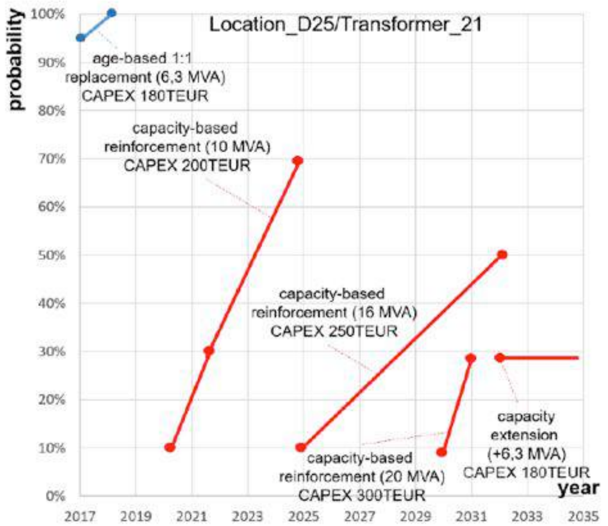


Fig. 21: Risk matrix of potential actions presented in paper 0685.

Paper 0855 deals with the criteria of the Croatian ten-year distribution network development plan, which provides budgetary and economic analyses for the projected capital investments and establishes a list of priority areas where infrastructure upgrading is needed.

In **Paper 1002** the new software QAT, based on a probabilistic approach to quality of supply assessment, developed by ENEDIS, is described. QAT, making use of Monte Carlo approach, provides a probabilistic forecast of the SAIDI regarding planned investments and maintenance programs, taking care of extreme meteorological events. This software is now integrated within decision process thanks to the restitution of new indexes aiming at evaluating distribution networks on different criteria such as reliability, quality of structure and reactivity of the operational teams.

In **Paper 1121** the revision of the ESB Network Planning Standards to facilitate the long term decarbonization of the energy sector in Ireland is dealt with. The key challenge is to develop a standard that facilitates the achievement of the aims of the Innovation Strategy and takes account the requirements of EU wide Energy Directives and Network Codes, whilst cost effectively maintaining a safe, secure and reliable distribution system.

Paper 1681 illustrates changes in load rates at distribution transformer level in different scenarios of electric vehicles and distributed generation rate. Results help DSOs to create a suitable network development strategy for the future. Results reflect the situation mainly in sparsely populated rural areas and they are based on actual network and hourly measured load data of 10000 customers for several years.

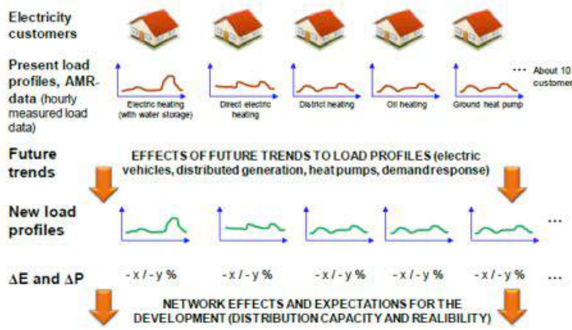


Fig. 22: Main steps of the process for estimating customer-specific changes in electricity demand (paper 1681)

In **Paper 1026,** a new approach for load modelling in LV-grids is discussed. Stochastic load modelling appears to be an effective method in LV-grids where emerging technologies like heat pumps, electric vehicle charging stations as well as distributed generation with unusual load/generation patterns are implemented. The method is applicable for long-term grid planning and scenario analysis. However, it has a strong dependence on data collection, especially smart-meter data. For this reason, the authors hope that the associated privacy challenges are overcome.

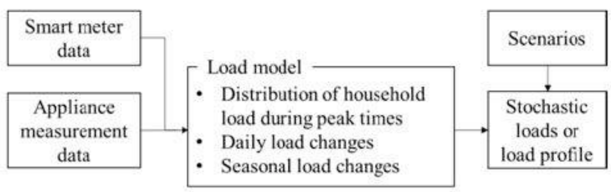


Fig. 23: Overview of the modelling framework proposed in paper 1026.

The envisaged load growth and ageing of assets require optimal distribution network replacement strategies. In **paper 2079**, the potential for cost-effective incremental enhancement of security of supply is investigated. The analysis shows that long-term economically efficient design of low voltage networks and underground medium voltage networks is according to (N-1) paradigm.

Paper 1117 shows a real-life application of artificial intelligence for the planning of green-field microgrids and finds that an estimated 30% cost reduction is possible compared to the human grid design. The artificial intelligence is able to design both generation and transport/transmission for relatively large areas and number of users but is not yet mathematically optimal. So, for the time being, it can be used to assist human planners.

A self-learning artificial intelligence for grid planning, named “Grida”, is proposed in **Paper 1116**. The performance of the abovementioned algorithm is comparable on small planning problems and slightly better on larger problems compared to currently widely used ORtools, however it does not (yet) provide optimal solutions.

The European Clean Energy Package has underlined the need of smart alternatives to network expansion able to increase the hosting capacity without compromising the quality of service. To capture the operational aspects that can affect the planning stage, the time variability of demand and generation has to be explicitly represented. **Paper 2317** compares two possible approaches: the characterization and clustering of demand and generation variability in a year versus the identification of seasonal typical daily profiles.

Paper 1321 describes a methodology and results of a case study comparing the Life Cycle Costs of four different development scenarios of the Dutch DSO Liander N.V., where large load increases are to be expected due to the Energy Transition, for the period of coming 40 years. The results show the costs to maintain or convert the existing network structures, at different voltage levels, for a loading between 100 % and 300 % of the current one.

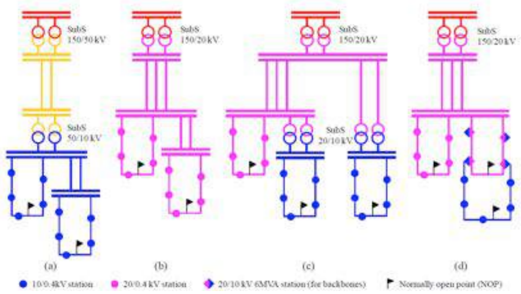


Fig. 24: Scenarios of network development considered in paper 1321: a) Business as usual, b) Complete 20 kV operation, c) 20/10 kV substations, d) 20 kV backbones; voltage levels indicated with colors: Red – 150(110) kV, yellow – 50 kV, pink – 20 kV, blue – 10 kV.

The Swiss Kalameus project, dealing with potential benefit of additional measurement devices at different levels of the distribution network for planning and operation purposes, is summarized in **Paper 1566**. Bi-directional P&Q measurement devices on each substation feeder and all DG higher than 1MW is expected effective as well as the thermal analysis of grid components instead of the traditional worst-case loading. In order to implement this analysis, further measurement data is required at the customer level (i.e. smart meters).

Paper 1877 presents a benchmark of technical energy losses by all network elements among 21 Croatian distribution areas. The results point that, in terms of technical losses, a system with direct transformation 110/20 kV and one medium voltage level (20 kV) is preferred to the current 110-35-10 kV one. Moreover, in order to optimize the investment, it is necessary to consider integrated development planning of the distribution network and the 110 kV transmission one.

Paper 2126 explores the current state of probabilistic distribution system analysis and proposes requirements for a toolset able to provide a more standardized and user-friendly approach for probabilistic distribution system analysis, specifically focusing on probabilistic load flow.

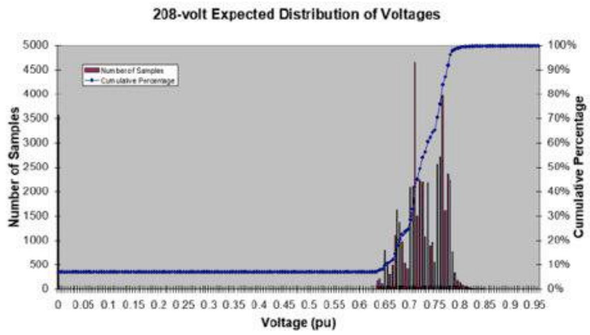


Fig. 25: Distribution of the voltage magnitudes at a 208-volt bus from a Monte Carlo fault study (Paper 2126)

Paper 2051 presents a method to determine power reserve of congested primary substations taking into account the thermal modelling of power transformers, the ambient temperatures as well as the irregularity of new consumer’s load profiles. The case study shows that this approach allows the safe interconnection of a considerable number of new consumers to real primary substation where conventional approach restricts any load interconnection.

Fig. 26: Paper 2051: Hot Spot Temperature (HST) over a year corresponding to a 10% loss of insulation life.

Paper 2018 proposes a new approach to model LV networks taking care of the emerging paradigm, involving new loads such as electric vehicles and heat pumps, distributed generation and flexibility services. Its main features are: (1) the automated importation of network models into a load flow software package, (2) a Bayesian statistical model of demand, and (3) a method for independently modelling the response of the network to sets of demand values at crucial nodes.

The power system analysis tools should harmonize the new technologies in a way that autonomous and interconnected systems can be automated, simultaneously operated and visualized for maximum grid benefit by distribution engineers. In **Paper 2267**, the authors propose a multidisciplinary and flexible framework of open source tools to support the future distribution power systems analysis, enabling the next generation of distribution system analysis tools.

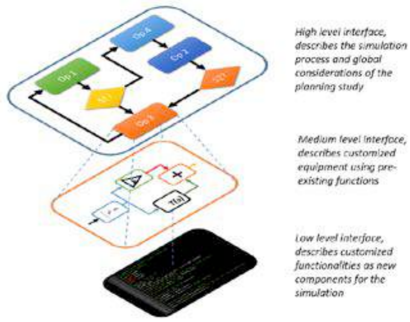


Fig. 27: Multilevel development environment (Paper 2267).

In the Republic of Croatia new regulations about connection to the distribution network were adopted during 2018. **Paper 2198** provides a detailed description of the process implemented by the Croatian DSO: decision-making criteria as well as the decision-making procedure for the determining the optimal technical solution of network user connection to distribution network.

Sub block 2: Smart Grid Planning

The majority of paper in this block are focused on the impact of smart grid in distribution planning. The most relevant novelty compared to other CIRED is the attention to LV distribution and the application of time-series and artificial intelligence. It is worth to mention the first tentative towards integrated planning of transmission and distribution networks.

Paper 2131 deals with the distribution planning and optimization process that has been followed by many authors proposing papers in CIRED 2019, theoretically and practically formalized and developed by EPRI (Fig. 28).

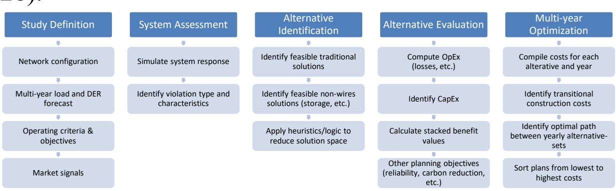


Fig. 28: Steps to the proposed automated planning and alternative optimization tool in Paper 2131

Paper 0018 deals with the problem of PV integration in LV distribution networks. The assessment of the hosting capacity of each feeder is indeed really feeder specific and in principle each LV feeder should be deeply analyzed. Such an effort is in general prohibitive and the authors propose a clustering procedure that divides feeder amongst clusters on the basis of some common features that can be identified. Then PV integration studies can be done on a feeder from the cluster that is representative of all feeders belonging to cluster. The authors used a self-organized map (SOM) neural networks and compared the results with another common technique that is called k-means. The best configuration allowed clustering 3145 into 25 clusters (Fig. 29).

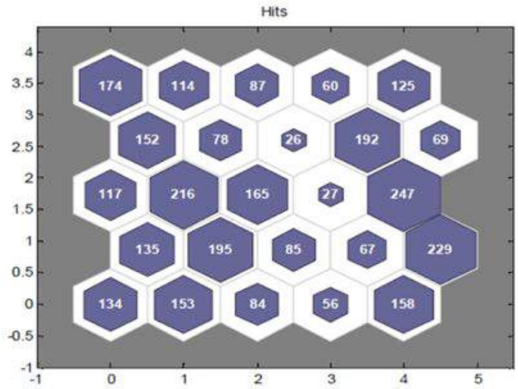


Fig. 29: Cluster of LV feeders and number of feeders per cluster (Paper 0018).

Paper 0528 covers the crucial topic of planning of distribution networks that can use innovative schemes instead of classical reinforcement/revamping plans. The proposed procedure (Fig. 30) applied onto two use cases from the Hungarian distribution network proved that innovative solution such as BESS and optimal control of inverters can allow postponing or avoiding network capital expenditures even in presence of a massive integration of PV generation. Based on the Hungarian cases, this paper has demonstrated that innovative, low-cost grid reinforcement options have the potential to postpone (UCA) or substitute (UCB) conventional grid planning strategies. Innovative planning options facilitate DSOs to (i) allow additional RESs connect to the network, (ii) reduce or avoid the risk of stranded assets investing in expensive conventional grid upgrades, (iii) enhance the investment flexibility and (iv) get insights into the performance of novel grid reinforcement options for local balancing within LESs.

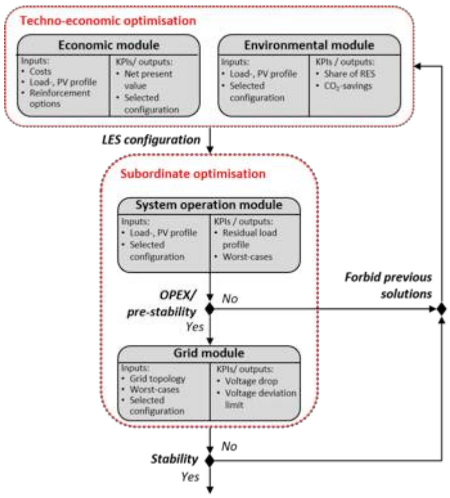


Fig. 30: Flowchart of the model proposed by Paper 0528

Paper 0773 also covers the topic of flexibility and its role in distribution planning by proposing a methodology to create a baseline for demand response activation. Results from the paper are surprising since load reductions and load increases of up to 40% and 300% of the total load respectively can be obtained but the level of uncertainty is also extremely high. Fig. 31 shows the importance of baseline for a proper activation of DR and for taking appropriate actions to avoid rebound effects.

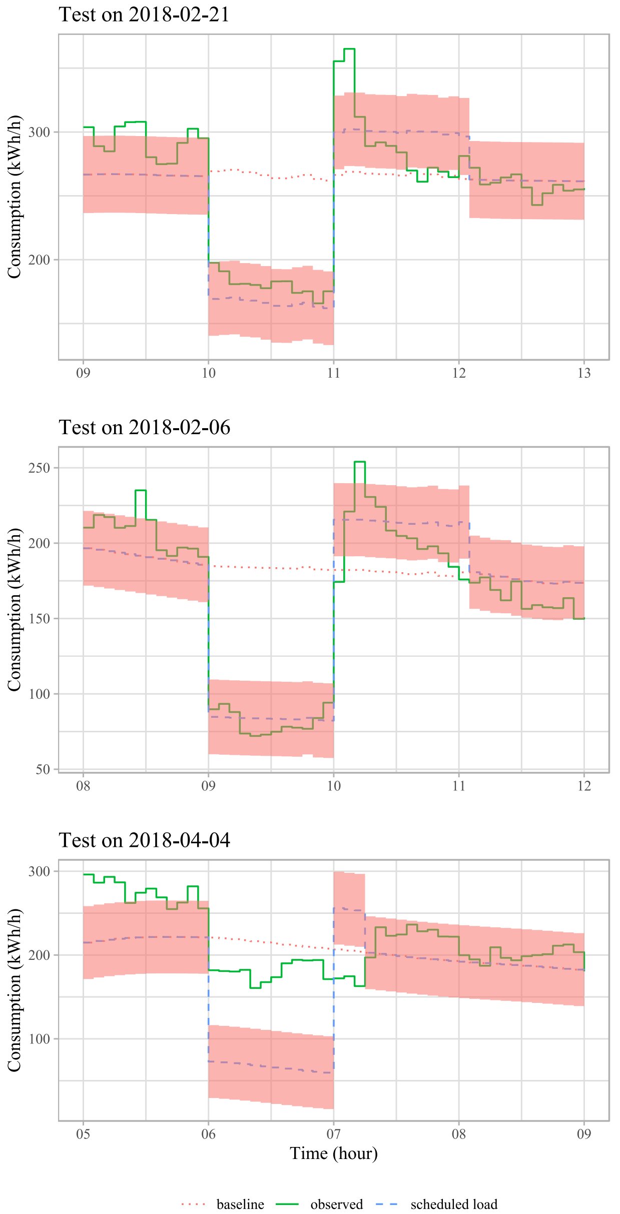


Fig. 31: Scheduled DR activation, where the aim for the observed power is to hit the expected load schedule (Paper 0773).

Paper 0691 investigates the role of flexibility in planning. Initially some real LV French test networks have been deeply analyzed to identify constraints that could happen. Secondly the amount of flexibility that can be used to fix those constraints is calculated with mathematical optimization and heuristic techniques.

Paper 1638 presents four different methodologies and tools that facilitate the assessment of flexibilities and smart grid technologies for the reinforcement of European smart grids. Nowadays, network planning is inefficient: network infrastructure is oversized to meet the worst-case scenario, which usually occurs during a few days in a year. In addition, flexibility provided by controllable loads is not taken into account at all. According to the most recent literature, the use of innovative approaches, such as innovative network equipment, flexibilities and ANM systems prove to be a feasible alternative to conventional reinforcement in the future network development process and need to be taken into account by DSOs, regulatory authorities and policy makers.

Paper 784 deals with the planning of smart grids including in the process the impact of communication systems. The authors propose and discuss a method for smart grid technologies and demonstrate that an optimization of the existing network with smart grid technologies reduces network reinforcement costs significantly while the reliability for customers and DG is on a similar and acceptable level. The extended reliability calculation enables a realistic evaluation of network and DG oriented indices.

Paper 0949 discusses heuristic planning rules applied by distribution companies in Finland (Fig. 32) The paper indicates that longer target horizons that take into account the societal cost of I^2R losses and interruption costs tends to produce networks that, viewed in terms of cradle to grave costs, are not much more expensive, but are more robust.

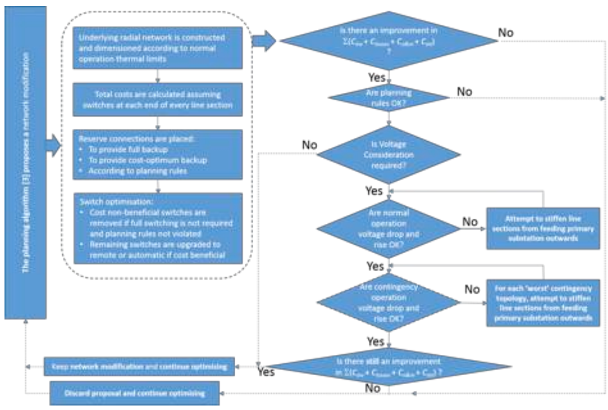


Fig. 32: Flow chart on how planning rules and voltage constraints are explicitly treated in a distribution network planning algorithm (Paper 0949)

Paper 0977 contributes to the topic of distribution planning in the area of multi-energy/multi-services networks. A multi-objective framework is proposed for expansion planning of energy hubs, natural gas and electricity distribution systems considering the uncertainties of renewable sources and demand (Fig. 33). Optimal planning problems from viewpoint of the three stakeholders, i.e. EHs owners, as well as electricity and natural gas distribution companies, are derived. Multi-objective genetic algorithm is deployed to reach the Pareto optimal solutions. The general concept is that significant savings and optimization can be obtained with the cooperation of stakeholders.

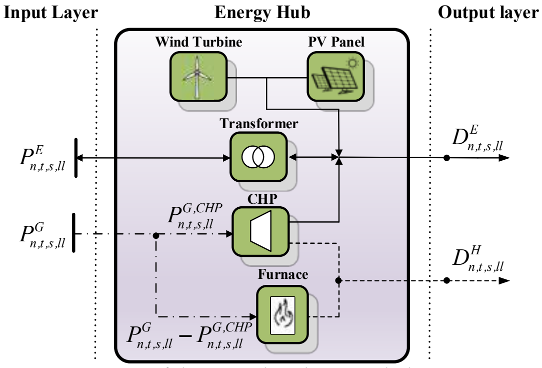


Fig. 33: Structure the energy hub (Paper 0977)

Paper 0955 offers a new methodology for modern distribution planning based on the use of time series that are crucial to integrate control strategies of generators and storage systems into grid expansion planning (Fig. 34). The methodology combines time series simulations and reinforcement heuristics to evaluate expansion planning costs, line loadings, voltages, energy and losses. Finally, it should be noted the use of AI to speed the process of calculating the network reinforcement caused by outages.

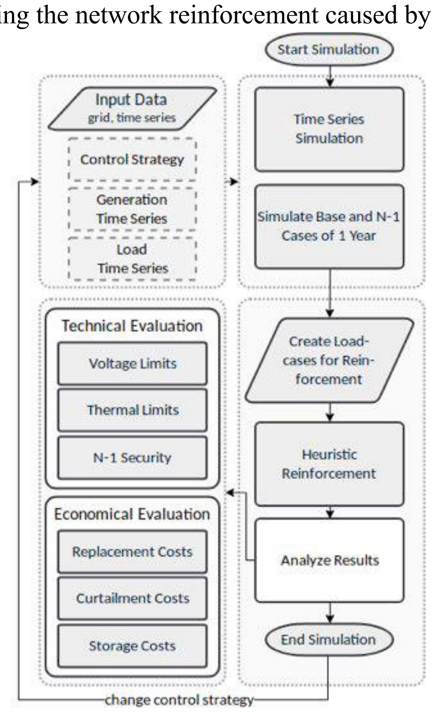


Fig. 34: Grid expansion planning framework proposed by Paper 0955

Paper 0961 applies the flexibility offered by curtailment of residential Low Carbon Technology (LCT) to distribution planning. Preliminarily, the authors observed that accurate models for LV networks are necessary. From the study clearly merges that the load growth expected in 2030 and 2040 cannot avoid the need for curtailment as a result of the growth in PV (Fig. 35). The time-series analysis of network constraints given these customer profiles allows for an understanding of how the growth in low carbon technologies and changes in end user behavior can be analyzed for network planning and control purposes. The derivation of prosumer profiles, based on the different profile classes, is one of the most useful and significant output of the research of general validity in distribution planning.

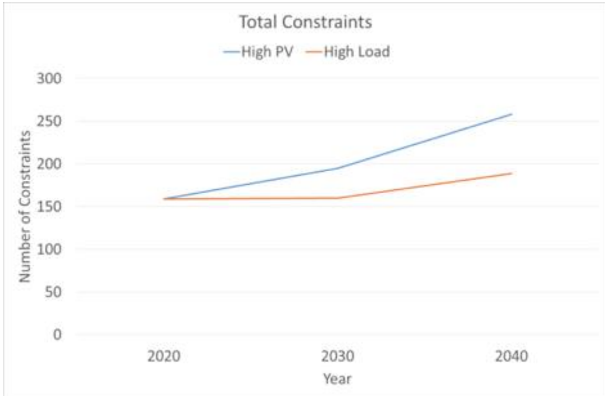


Fig. 35: Expected total constraints in LV network as shown in Paper 0961

The calculation of hosting capacity is a key point for distribution planning in LV networks with increasing LCT as PV generation. **Paper 1071** proposes a new methodology that overcomes the inherent lack of knowledge in LV distribution by exploiting real field data from smart meters and few measurements. The use of AI allows creating a digital twin of the network that can be used for any calculation and improves the quality of results compared to traditional methods. As an example, the authors showed that by simply rebalancing LV customers loads to grid hosting capacity can be doubled in a Belgian case (Fig. 36).

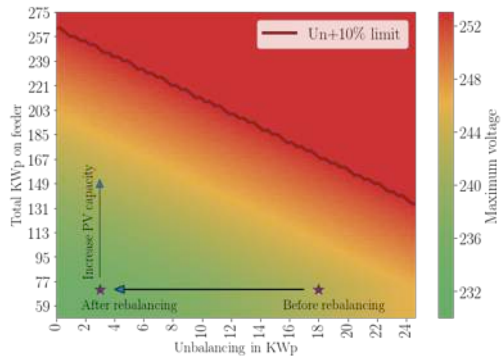


Fig. 36: PV hosting capacity as a function of imbalance (Paper 1071)

Paper 1092 focuses again on LV distribution systems and proposes a novel optimization algorithm for the decision making in the strategic network planning as external factors, such as decentral generation, are gaining a stronger influence (Fig. 41). The presented tool automates the planning process by using a genetic algorithm in order to find the optimal reinforcement plan in terms of feasibility of technical measures and their associated expenditures. It is worth to noticing that innovative measures such as voltage regulation and curtailment require fewer capital expenditures than conventional reinforcements while effectively solving network constraints.

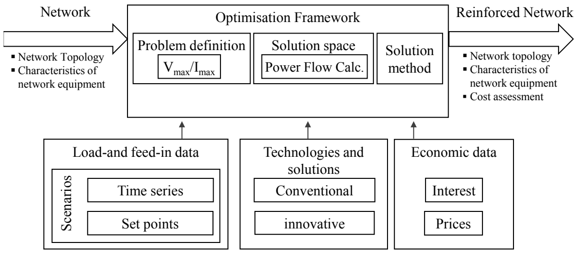


Fig. 37: Scheme of the automated network planning tool in Paper 1092

Paper 1118 again use traditional techniques as AC OPF to assess the impact of PV, EV, and Heat Pumps on the distribution grid. Innovative operational strategies are proposed as an alternative to traditional network reinforcement. As an example, the authors found in order to be cost competitive to an OLTC transformer, the available yearly budget for flexibility services from EV and HP should be 3-10 €/EV or HP, and 24-102 €/EV or HP for the traditional grid reinforcement, depending on the scenario. The rural scenario reaches the highest cost-competitive budget, due to the lower density of grid connections, meaning that the traditional grid reinforcements are more expensive per kWh consumed on the LV feeder, compared to the non-rural feeders (Fig. 38).

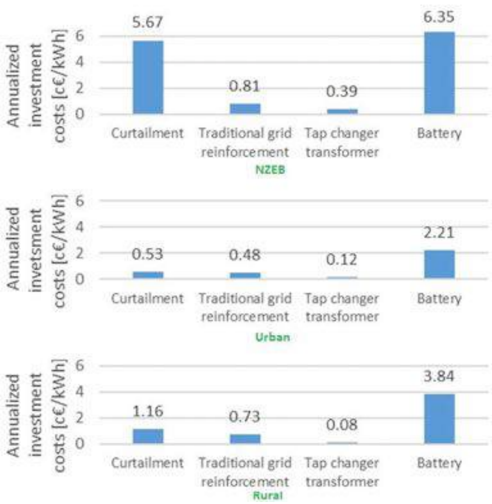


Fig. 38: Results of cashflow analysis for the annualized investment costs of the three analyzed distribution grids for 2030 and 2040 for the urban case in Paper 1118

Paper 1885 describes a methodology used to simulate and compare different solutions to improve the insertion of PV production in the LV grid (Fig. 39)**.** The methodology has been used to assess the worth and usability of OLTC in MV/LV transformers. The economic value of the OLTC shows high sensitivity to the scenarios of production and thus poor economic "robustness" despite acceptable technical performances to avoid reinforcements in this situation. OLTC could potentially help increasing PV insertion in some cases but, compared to other solutions (such as the Q(U)), is a solution to choose with care for specific cases.

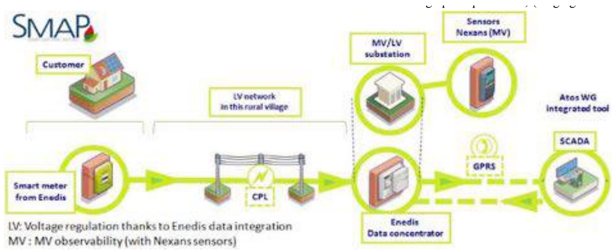


Fig. 39: Smart metering integration for voltage regulation with OLTC (Paper 1885)

Paper 1988 gives an interesting insight on the effectiveness of active voltage regulation by comparing control strategies like cosφ(P), Q(V), on load tap changer (OLTC)-transformers, line voltage regulators (LVR) or STATCOMs for the integration of decentralized energy resources (DER). In this German case, contrarily to **Paper 1885**, OLTC-MV/LV-transformers show the best effectivity. The most common voltage control cosφ(P) shows a very good performance - nearly reached by Q(V), that shows further advantages with regard to the efficiency. In both cases it is recommendable to allow a lower value for cosφ of 0.9. Both cosφ(P) and Q(V) could be used for medium penetration rates. Due to the poor effectivity, LVRs and LV-STATCOMs are not suitable for a LV-grid comprehensive voltage control and should be considered for individual short-term solutions. It was also proven, that using a combined MV/LV- planning offers a better utilization of the grid capacity and saves a lot of effort in combination with active voltage control strategies.

As demonstrated in many papers the separation of planning and operation is vanishing. In many cases optimal operation of the network can be regarded as a planning option since it can postpone expansion/reinforcement actions. In this sense, **Paper 1057** proposes the reactive power optimization in distribution networks with PV installed as a planning option. With the proposed method, voltage regulation is improved with a reduced increasing of energy losses.

The artificial division of Power Systems with boundaries between transmission, MV and LV distribution has been transposed into planning and power flow studies for many years. The inaccuracies caused by that division have been largely compensated by the reduction of complexity that has made feasible the use of specific software packages with reasonable computing time. Nowadays, dealing with different voltage levels, spanning from transmission to distribution systems is a necessity caused by the new distributed paradigm. The software package SIMONA proposed in **Paper 1142** can solve networks up to five different voltage levels and 50.000 nodes with its agent-based technology. Time-coupled assets, like storages or electric vehicles are dealt with a time-series based assessment. A genetic algorithm optimization has been coupled with SIMONA. The methodology (Fig. 40) has been applied to a small example and, when applied to larger it could be an answer to the need for integrated planning of TSO and DSO networks.

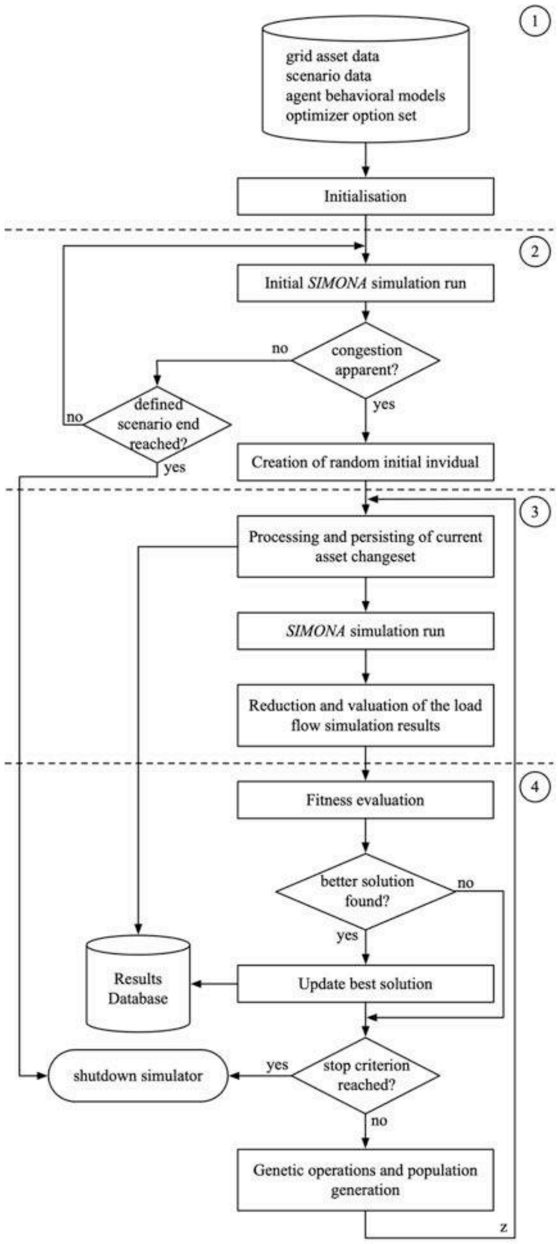


Fig. 40: Conceptual flow chart overview of the coupled simulation framework in Paper 1142

Paper 1660 deals with the integrated planning from TSO and DSO under increasing level of uncertainty. An overview of the methodologies and current challenges that relate to planning and optimization of electrical distribution and transmission systems is presented. The following issues have been addressed: 1) current practices on considering and modelling uncertainties, and risk management in generation, transmission, distribution and demand sides; 2) transmission and distribution planning under uncertainty and distributors' evaluation of recommendations on planning under uncertainty; 3) review of investment decision making processes, for transmission and distribution, in different jurisdictions and how coordination among them is done; 4) the extraction of research gaps that can are consecutively fed into an online survey.

Paper 1743 can be considered another example of integrated planning since the automated grid planning allowed consideration of a large number of grids and DER scenarios for the planning of HV grids and the HV/MV substations of the involved Distribution System Operators (Fig. 41). High Temperature Low Sag (HTLS) conductors in combination with local reactive power control can be used to expand the transport capacity of the grid and therefore reduce reinforcement costs. Peak shaving in the LV level, due to the fact that it is not separately remunerated, allows a further reduction of grid reinforcement costs. These measures have an additional effect of deferring cost-intensive replacement of lines, providing the positive cost effect and more flexibility. Reactive power control increases the costs in the HV/MV substations, while the overall cost effect is still beneficial. High costs of Power-to-Gas applications are not justified by the cost-savings in the HV grid.

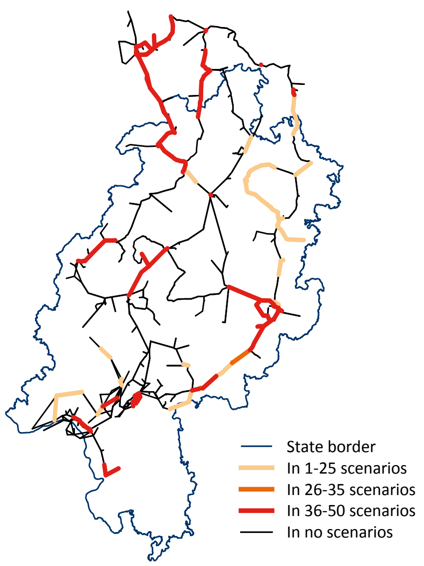


Fig. 41: Conventional reinforcement (2034, medium path): number of scenarios out of 50 in which a line is reinforced (Paper 1743)

Paper 2128 complete the analysis of Paper 1743 with a view onto MV and LV distribution systems under different scenarios of RES and DER integration with really significant results (Fig. 42). The study analyses more than

900 real distribution grids at all voltage levels. Innovative technologies can lead to large possible savings in single grids. However, considered over many grids and all voltage levels, the possible savings due to innovative technologies (excluded peak shaving) compared to the conventional measures amount to 11%. Besides peak shaving, all other considered innovative technologies mainly target voltage problems but many expected grid reinforcement and expansion costs for the HV grids as well as HV/MV transformers are caused by overloaded equipment. Although on the MV level voltage violations are a main cause of grid reinforcement, two-thirds of the overall costs arise from connecting large DER plants.

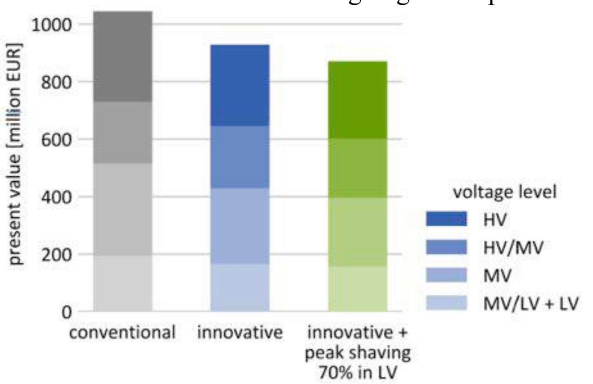


Fig. 42: Expected DER integration and grid reinforcement in Paper 2128

Paper 1778 also deals with optimal planning of High Voltage grid under an increasing presence of RES and proposes a new approach taking into account combined solution from energy storage systems and feed-in management of decentralized generation units. The necessary total storage capacity has massively decreased by 77% in comparison to the total required capacity without use of dynamic feed-in management. Hereby the modeling of the feed-in management is compatible with the current planning principles, which implies that the total of the curtailed energy of a generating plant over a year must be maintained under 3%. Computation time is very high, but the results are encouraging.

Paper 1993 presents a distribution system expansion planning method considering Integrated Energy Service Provider's (IESP) revenue on ESS is proposed and solved by Benders decomposition. As for planning master problem, siting for ESS, replacing and constructing circuits are all taken into account, while in operation sub-problem ESS operation and degradation are discussed to reduce the cost of the utility under the guarantee of IESP's revenue. Note that peak-valley price is considered in this model to ensure the profits of IESP by selling power during peak load time and charging ESS in valley time, thus helping peak shaving. The calculation results show that ESS may contribute to less cost on upgrading power lines and delay expansion of distribution system.

Paper 2301 propose an optimal location of ESS based on AC OPF algorithm that uses a convex relaxation for the power flow equations to guarantee exact and optimal solutions with high algorithmic performances and exploits robust optimization approach to deal with the uncertainties related to renewables and demand. The robust optimization technique applied to this class of problems allows explicitly considering the role of uncertainties and deciding the level of acceptable risk. As shown in (Fig. 43), the smaller the level of allowable risk the larger the number of storage devices that should be used.

Scenarios	ESS Location
Certain scenario $\boldsymbol{\Gamma = 0}$	14
Medium risk scenario $\boldsymbol{\Gamma = 0.5}$	14, 67
No risk scenario $\boldsymbol{\Gamma = 1}$	11, 14, 67

Fig. 43: ESS location as a function of acceptable risk (Paper 2301)

Paper 1345 aims at answering the question if n-1 criterion is still adequate for distribution planning or it is better to use confidence intervals. Since the forecast of RES production can never be perfect and the longer the planning period the higher the uncertainties, the authors propose to perform the security assessment using probabilistic data and confidence intervals. Having the probability of occurrence of problematic cases will certainly help in long term planning and network development investment plans. It can also help to define the base scenarios for other calculations like OPF or harmonics.

Microgrid and community microgrids can reshape the distribution system but splitting the existing network in the optimal number of MG optimally sized is still an open question. **Paper 1724** aims at contributing in the field by capturing the "built intelligence" at the city level in order to specify the number of community microgrids that could fit in a city. Specific types of community microgrids are proposed and the main sources of meta-data that could potentially assist the deployment of community microgrids are identified. The proposed framework (Fig. 44) has been applied in a neighborhood in the city of Liege, Belgium leading to the determination of the physical boundaries of a community microgrid. The aggregated PV capacity, the BESS system used as well as resultant KPIs are provided.

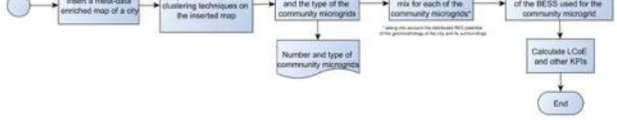


Fig. 44: Generic process chart for supporting the deployment of community microgrids through a planning system at the city level

Paper 2326 discusses the potential of Microgrid to defer or avoid investments required by conventional approach to upgrade capacity with an extension of the substation and related assets. Radial feeders are often the most unreliable part of a distribution system, so in addition to deferring substation capacity investments, the microgrid adds islanding functionality that can decrease outages. Microgrid approaches also assists feeders with high renewable generation or fluctuating loads to actively manage voltage challenges. This business case compares the microgrid alternative with numerous stacked values against the conventional capacity upgrade scenario from the perspective of a distribution utility. The results of this business case are that the microgrid is more economic than the distribution capacity upgrade due to the multiple stacked operational cost savings the battery energy storage provides. The payback period for the microgrid scenario is 4 to 6 years less than the conventional upgrade investment (Fig. 45).

	Scenario 1: Distribution System Upgrade	Scenario 2: Microgrid 3h Battery with reliability reward	Scenario 3 : Microgrid 2h Battery, no reliability reward
CAPEX	5 MUSD	7.8 MUSD	5.2 MUSD
OPEX	27.3 MUSD	21.9 MUSD	21.5 MUSD
Revenue	32.7 MUSD	34 MUSD	32.7 MUSD
Net Present Value	0.4 MUSD	4.3 MUSD	6.0 MUSD
Internal Rate of Return	10%	15%	21%
Payback Period	10 years	6 years	4 years

Fig. 45: Comparison of conventional planning and MG (Paper 2326)

Paper 2150 proposes an optimal planning method for Local Energy System (LES) based on the energy hub model Fig. 46. Uncertainty quantification is done with global sensitivity analysis (GSA) towards robust design. First, a deterministic planning optimization is conducted to acquire the basic case of installation decisions for LES. Second, uncertainty analysis is carried out based on deterministic results, with proper distribution of variation for uncertainty parameters introduced and large size sample collected with Monte Carlo method. Finally, GSA is conducted for each uncertainty source to carry out quantitative investigation in terms of uncertainty impact on planning results.

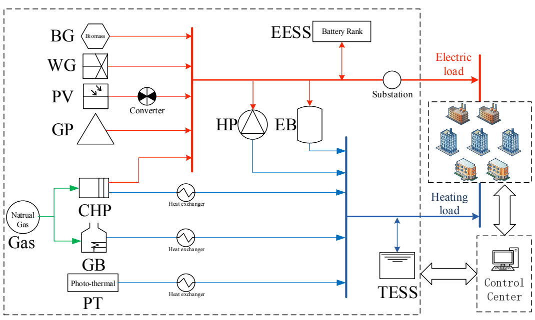


Fig. 46: Local Energy System topology based on energy hub model (Paper 2150)

Planning the electrification of rural areas is another topic of the highest interest not only of distribution companies but of the entire Society for its social and economic implications. **Paper 1133** gives a real contribution on the topic with a quantitative approach to choosing between on and off grid solutions. A new optimization methodology is developed to evaluate the best electrification solutions at LV scale within villages, combining both the grid reticulation and the individual solutions for the potential customers (Fig. 47). The tool is able to provide a load forecast at building level by mixing GIS and field information of the villages and to perform a techno-economical optimization of the low voltage grid and individual solutions such as Solar Home Systems (Fig. 48). This model appears to be of great interest for rural electrification planning, being able to determine quickly and effectively the best electrification solutions at low voltage scale within rural and unelectrified villages.

Fig. 47: Aerial view of Kokoloko village (Niger) with an LV network traced manually (Paper 1133)

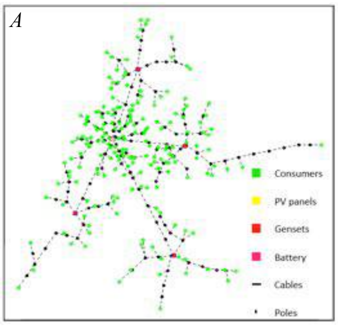


Fig. 48: Optimal minigrid for the Kokoloko village (Paper 1133)

Hybrid AC-DC microgrids are examined by **Paper 2047** in order to allow the direct integration of AC and DC loads and generators. The paper proposes a novel stochastic approach for planning and design of hybrid microgrids within a market environment. The method evaluates the amount of active power generated by WT and PV that can be delivered to the load, and the amount of active power injected or absorbed from the grid. Scenario based approach is used to model the uncertainty related to the wind speed, solar irradiation and load demand. The objective of hybrid AC-DC microgrid planning problem is maximizing the net social welfare by simultaneously maximizing consumers' payments and reducing total planning cost.

Paper 2308 deals with the optimal planning of natural microgrids as the networks in non-interconnected islands.

The authors propose a generalized planning approach that addresses the operating strategy, the achieved energy and economic benefits and the optimal sizing of system components. The introduction of Renewable Energy Sources is a separate objective in the optimization process, besides the cost of energy. This multi-objective approach allows a direct evaluation of the trade-off between cost reduction and RES exploitation potential, which is a core issue when seeking high utilization degrees of available RES energy (Fig. 49).

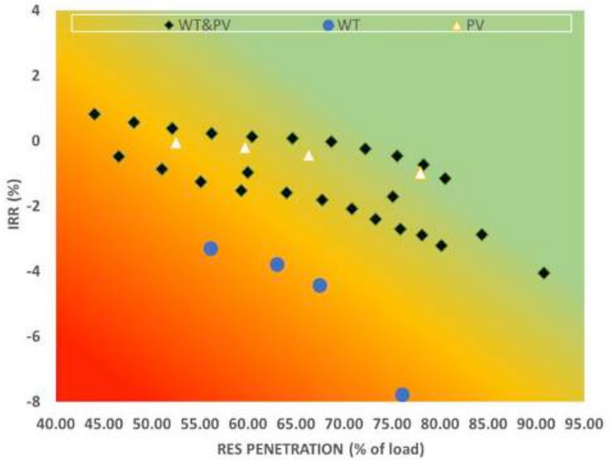


Fig. 49: Two-dimensional representation of results in Paper 2308. Better trade-off solutions with good economic output and RES penetration are obtained with a combination of WT and PV

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

Installation of advanced components in a finite number of network sites, such as substations, ranks among the most effective ways to enhance network performance. It may be done to improve voltage profile, to increase continuity of supply or to reduce short-circuit currents or voltage dips, but the process is more or less the same.

Sub block 3 deals with specific planning problems, related to optimal placement and sizing of discrete components. In most cases, therefore, the content of the paper consists in newly-developed or adapted algorithms to find optimal placement conditions.

Paper 0939 proposes an Optimal Mix model – calculating specific, integrated business cases for roll-out of reliability improvement options such as intelligent secondary substations, fault predictors and circuit breakers. Involving grid planners and policy makers early-on in the development process has led to faster validation and acceptation of the model's results. The model taking into account regional differences as well as the intuitive visualization of the results in a web-based user interface have been instrumental in this process**.** The paper shows that grid-specific calculations outperform generic placement rules for optimal location of reliability-oriented network elements. Moreover, the model results show that integral business case decision for placement of reliability improvement options can cut cost significantly.

Paper 2030 deals with the optimal allocation of voltage regulators (VR) that is largely affected by the operation of the OLTC in the primary substation. The optimization problem is solved with a Genetic Algorithm suitably adapted. The assumption of ignoring OLTC's operation at primary substation for VR placement is not valid and it leads to misplacement of VRs and miscalculation of net profit of DSO. For VR placement studies, it is recommended to consider the voltage control algorithm of the OLTC's AVR available at PS.

Paper 2035 tackles the issue of optimal energy storages devices in the distribution networks. Cost-benefit analysis is used to assess the impact of energy storage on distribution reliability. The impact of energy storage size and technology as well as the sensitivity of the initial SOC is studied and a comparison also provided. Both economic benefits in absolute terms and benefit-cost ratios are used in the analyses. The principal findings indicate that while vanadium redox flow batteries have higher investment costs, they show less sensitivity with respect to storage size.

Paper 2090 proposes a new algorithm for large scale optimal deployment of remote-controlled switches (RCS) with the aim to increase overall reliability. The optimization is risk oriented and covers different uncertainties related to the position and amount of RES-based generation; a full integration with GIS platform is a worth key point of the procedure. A general result is that the number of RCS should not exceed 19 % of the total candidate positions.

Sub block 4: EV Accommodation Planning

Papers in Sub Block 4 deal with the planning of distribution infrastructure under the expected growth of EV. Greater attention has been paid to the consumption pattern of EV with good models that exploits GIS and graphical maps to better allocate consumption from EV. Common to many papers, and indeed really necessary, is the use of probabilistic methodologies to deal with the inherent high level of uncertainties related to electro mobility and the application of time-series.

The impact of EV on the distribution system has been is the topic of **Paper 0135** that analyses the real charging pattern of EV in Korea as measured by Kepco. The paper has the merit to show real patterns differentiated by region, season, and type of usage (Fig. 50). The first preliminary analyses confirm a peak in the morning for recharging at job and in the evening (till 11 p.m.) for at home slow charging. The correlation of charging patterns with seasons is small, whereas no correlation has been found with regions.

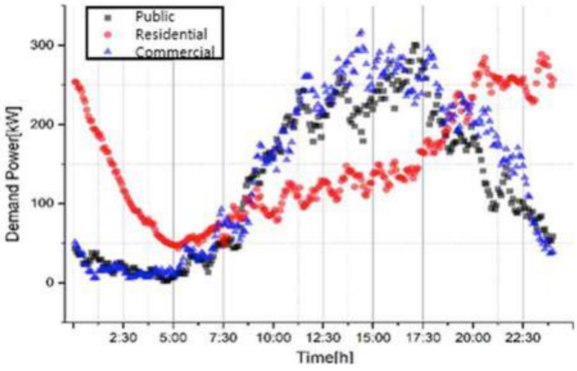


Fig. 50: Measured charging patterns in Korea as in Paper 0135

The authors of **Paper 0135** conclude that charging must be accompanied by optimal operation in order to minimizes the harmful impact of EVs on existing assets. **Paper 0892** proposes an optimization algorithm to enable the connection of a large number of Plug-in EVs (PEVs) to the grid. Therefore, a Teaching and Learning Based Optimization method is proposed in order to control the charge or discharge of the plugged-in EVs in cooperation of PVs in the distribution electric power network. PEVs should be charged during the day hours and discharged at the peak hours (Fig. 51). Discharging PEVs at peak hours causes less active power losses in the grid and some part of load demands are provided locally through the PEVs. Optimization method proved successfully alleviate the PEVs penetration impact in cooperation of PV generation units.

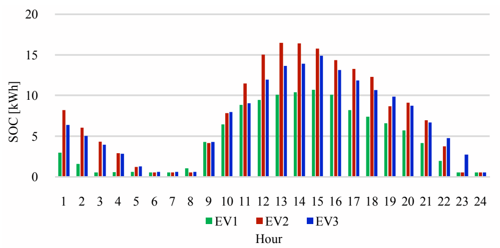


Fig. 51:Aggregated Battery SOC plan in 24-hour duration (Paper 0892)

Paper 0938 examines the expected impact of EV charging in the Austrian suburban LV networks. The investigated suburban low-voltage grid could face inadmissible voltage range deviations per EN 50160 at an EV-penetration of only 10 % (Fig. 52). Moreover, an increased share of electric vehicles leads to critical voltage unbalances (around 40 % EV) and thermal overloads (around 20 % EV). Voltage deviations can be reduced significantly by using charging infrastructure equipped with voltage dependent active power control or switching to three-phase charging with reduced power. These measures prevent inadmissible voltage range deviations and voltage unbalances as well as critical thermal conditions even at an 80 % electromobility penetration.

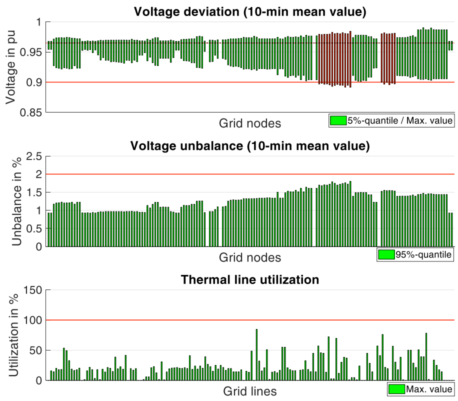


Fig. 52: Voltage range deviations, unbalances and thermal utilizations for 10% EV-penetration (Paper 0938)

Paper 0966 proposes a good methodology for assessing the expected impact of PEV on the French distribution network. Even though the methodology is tailored on the French case, it is indeed of general validity and capable to consider uncertainties related to the usage of PEV and the typical heterogeneity of MV and LV networks. The uncertainties considered are the possible locations of charging station on distribution networks, the rated power, the time of connection, and the daily connection frequency and energy charged for each category of PEV. The methodology is currently based on Monte Carlo (but future works aim to go beyond cumbersome Monte Carlo). It is worth to notice that expected LV reinforcements account for 1 billion euros to connect 9 million EVs. These expenditures can be reduced by 25% if charging is moved to off-peak hours and by 40 % with further charging optimization.

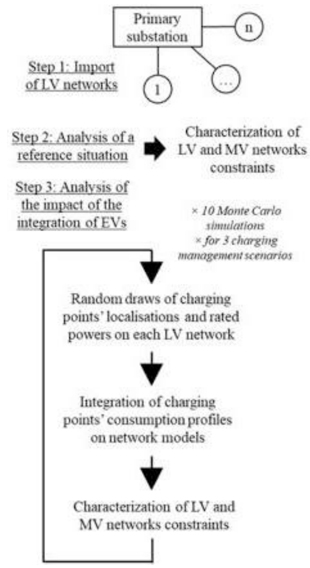


Fig. 53: Methodology to assess LV limits caused by EV proposed by Paper 0966

Paper 1056 investigates over multi-year horizons on the impact of the EV connection to the HV/MV primary substations in France. The approach is again stochastic with the application of Monte Carlo methodology that provides a much more comprehensive view of how EVs load profile may be in future (Fig. 54). Therefore, the assessment of the potential EV impact on HV/MV substation can be achieved by fixing a certain risk level. Further simulations and analysis of different cases can be performed to show, for different geographical areas, the evolution of the ratio p.u. or kW/EV depending on the EV fleet size at a given risk level.

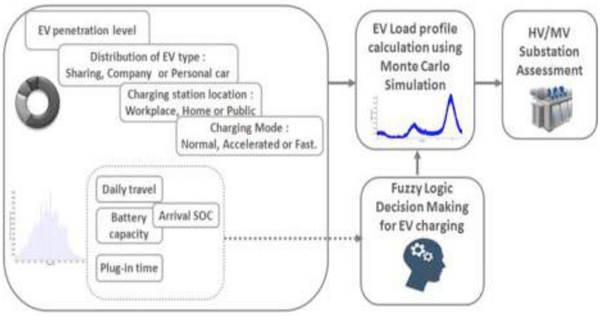


Fig. 54: General description of the methodology proposed in Paper 1056

Finally, **Paper 1955** also exploits Monte Carlo to deal with the uncertainties that affect the assessment of the impact of EV on the Swiss LV distribution networks. The main causes of uncertainties are: first, the often still opaque knowledge of today's state of the grid; second, the speed of EV market penetration; third, the evolution of EV load patterns; fourth, the spatial distribution of EVs. The paper proposes a very well detailed Monte Carlo based approach with interesting proposal on results representation; among them the geographical representation of likely outcomes is of greatest significance to planners (Fig. 55). Monte Carlo simulations can span an exploration space and provide a quantitative estimation of the likelihood of certain outcomes, conditionally to a given input set of assumptions. Nevertheless, it is difficult to justify a priori that a certain set of assumption is more representative or likely than another. It becomes therefore paramount for grid planners to extend the data gathering infrastructure, to use the acquired knowledge to constantly update grid models that can represent the space of possibilities of the near future. Monte Carlo simulations can then be used iteratively.

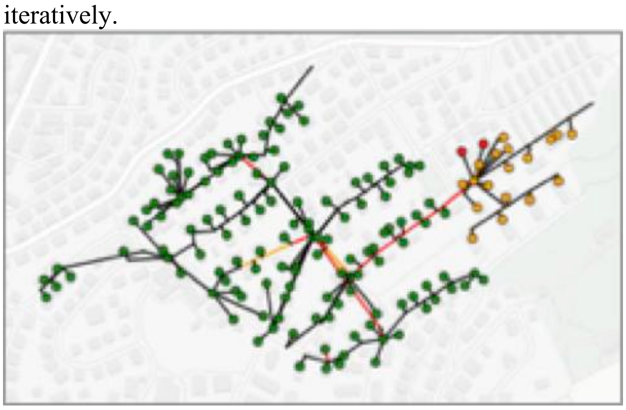


Fig. 55: Example of traffic light geographical visualization. Green elements are the ones that never experience violations; red elements are violated in 100% of MC simulations; orange elements are violated in at least one MC-variation (Paper 1955)

Papers 1726 analyses the impact of EV in the South Tyrol region (Italy). The study shows that the impact will be quite limited in the next few years and gain importance approaching year 2030 and onwards (Fig. 56). Significant investments in the grid have to be made. Alternative design and investment options (e.g., peak shaving) can allow to reduce expenses, as demonstrated by the deep dive studies carried out in two pilot areas. The paper does not consider the impact of distributed generation, local storage and load increase other than for E-mobility.

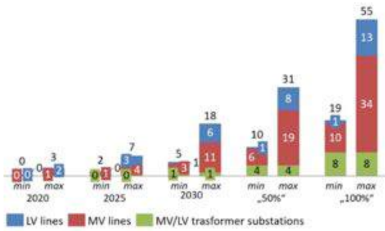


Fig. 56: Expected capital expenditures due to EVs in South Tyrol MV and LV distribution grid (Paper 1726)

Paper 1556 deals with the impact of EV and Heat Pumps (HP) on the distribution network of Stockholm. The combined impact of such high power/highly coincident load can be devastating for the existing networks. The analysis in the paper is carried out for six critical loaded hours and during the course of a critical day. Again, results showed that load management strategies made it possible to increase the level of penetration of PV and HP loads at a decrease of cost per additional load. For the case of PEVs the level of penetration was increased by up to 3 times as for the uncontrolled case. These results serve to identify possible limitations and capacity shortages in the network to allow for the smooth planning of a robust energy infrastructure for the future. The methodology has to be improved to allow the simultaneous consideration of EVs and HPs.

Paper 1565 deals with impact of EV, distributed generation and heat pumps in the Flemish distribution network. The proposed NGIN Insights analytics platform aids business experts in making better and more informed data-driven investment decisions. To demonstrate the potential and added value of the NGIN solution, a case study with an impact analysis for different growth scenarios regarding electric vehicles and photovoltaic systems on the Flemish low voltage grid is presented. The simulations showed that large-scale EV rollout has huge impact on the Flemish LV grid, requiring significant grid reinforcements. In order to keep societal costs at an acceptable level, accompanying measures and incentives to reduce grid impact of EV charging should be introduced.

Urban mobility in electric buses is developing quickly and requires attention to be optimally integrated to the distribution network. **Paper 1581** reveals that overnight depot slow-charging should be preferred from a distribution grid perspective to keep reinforcement expenses minimal. However, constraints over battery size might require some opportunity charging stations to be installed. They could have a greater impact on the distribution grid due to important stochastic effects and a higher peak power per bus and should therefore be kept minimal from a distribution grid perspective. Charging control may also be beneficial when using opportunity charging to limit the use of available power during the distribution network's peak time (Fig. 57).

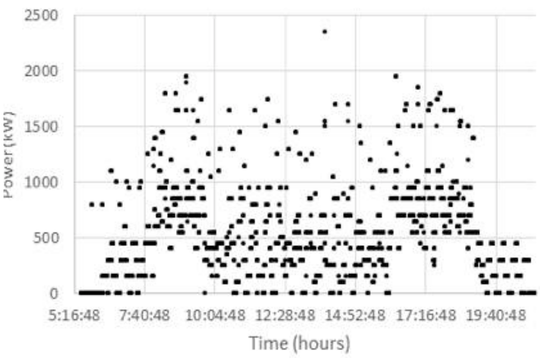


Fig. 57: Power required by the examined bus line (10 km length) in case of the use of a mix of charging stations (Paper 1581)

Electric mobility can anyway be also positive for the power system, as showed by the authors of **Paper 1491** who analyzed the influence of large penetration of electric vehicles and RES in Croatia. The results show that additional storage in form of EVs enables increased production from RES and decreased need for building additional conventional fossil fueled thermal power plants to cover peak loads. Furthermore, the transmission losses in the power network are also reduced.

Finally, **Paper 1673** gives a very significant contribution on the prediction of e-mobility that is the real basis of any study on the impact on the distribution network. The proposed methodology can predict the number of electric vehicles on different aggregation levels. Beside the usage for local grid planning purposes, the aggregated information (on secondary substation level) can also be used for additional purposes (Fig. 58).

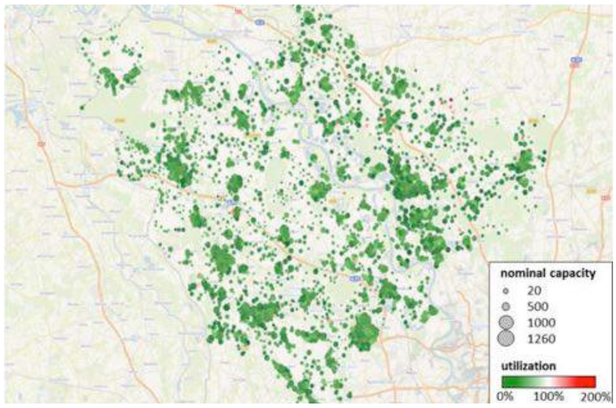


Fig. 58: Utilization of secondary substation with e-mobility in 2020 (Paper 1673)

Potential scope of discussion

The transition from deterministic worst-case analyses to probabilistic network planning has just started, yet it already seems that an accurate evaluation of network criticalities requires instead serial load flow calculations based on time series made available by, or determined through, Smart Meters' measurements for both final and active customers. This implies new tools, new algorithms but, even before that, huge amount of data to be managed and handled: is distribution ready for Big Data and Artificial Intelligence or, maybe better said, is Big Data "big" enough for the distribution business?

Table 3: Papers of Block 3 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0018	Low voltage feeder clustering based on SOM for determining the capacity of feeders to accept PVs				X
0135	The representative charging pattern for EVs based on the actual EVs charging data for distribution system planning				X
0139	General planning and operational principles in German distribution systems used for Simbench				X
0140	Distribution grid planning and analyzing using smart metering data				X
0289	Optimization of maximum allowed slow voltage variation between medium voltage and low voltage networks				X
0528	Development of an assessment model for DSOs to determine the technical and economic potential of local energy systems				X
0532	Development of a Bottom-up Scenario Analysis Network Planning Tool				X
0685	An extensive supply and grid analysis solution using multiscenarios,				X

	simulation & optimization applied in a real target grid planning process				
0691	Evaluation of Flexibility Volumes for Constraint Resolution in LV Distribution Networks – The Nice Smart Valley Case				X
0773	Baselines for evaluating demand response in the EcoGrid 2.0 project		14		X
0784	Reliability Calculations with Smart Grid Technologies in Distribution Grids		15		X
0855	Shaping the Future Croatian Distribution Network with the Ten-Year Network Development Plan				X
0892	Teaching-Learning Based Optimization Method for PEV Scheduling Incorporating PV Units				X
0938	Evaluation of grid relieving measures for integrating electric vehicles in a suburban low-voltage grid		18		X
0939	Value optimization of existing MV grids through a continuous cost benefit analysis				X
0949	Impact of Voltage and Network Losses on Conductor Sizing and Topology of MV Networks with High Penetration of Renewable Energy Resources				X
0955	Time Series Based Power System Planning Including Storage Systems and Curtailment Strategies				X
0961	Impact of Prosumer Growth on Flexible DER Through Curtailment Assessment				X
0966	Evaluation of the long-term impact of EV development on French distribution networks: technical characterization and integration costs evaluation				X
0977	Multi-Objective Stochastic Expansion Planning of Multi-Carrier Energy Distribution Networks Considering Customer-Owned DG Units				X
1002	A Monte-Carlo approach for quality of supply simulation				X
1010	Regularly Optimized Medium Voltage Network As A Target For Planners: A Case of Helsinki City				X
1026	Using stochastic modelling for long-term network planning of LV distribution grids at Dutch DNO				X
1056	Stochastic Electric Vehicle Load Modeling for HV/MV Substation Constraint Assessment				X
1057	Reactive Power Optimization Method Incorporating Economic And Action Number Constraints of Control Devices				X
1071	Increase Photo Voltaic hosting capacity using data-driven network modeling				X
1092	Automated Planning of Smart Low Voltage Networks Using an Evolutionary Algorithm				X
1099	Large scale agent-based simulation of distribution grid loading and its practical application				X
1116	Grida: introducing a self-learning artificial intelligence for autonomous network planning				X
1117	Artificial Intelligence planning of two real-life microgrids				X
1118	Optimal Integration of Electric Vehicles, PV, Heat Pumps in Existing Distribution Grids in the Netherlands				X
1121	Stakeholder Engagement in the Revision of ESB Networks' Planning & Security of Supply Standards				X
1133	Low voltage electrification approach in rural areas: arbitration between on and off-grid solutions		16		X
1142	Automated time series-based grid extension planning using a coupled agent-based simulation and genetic algorithm approach				X
1321	A Life Cycle Cost study on the impact of the energy transition on the choice of voltage levels in the distribution grid				X
1345	Reliability and security of unbalanced distribution grids based on probabilistic (N-1)-Criterion with distributed renewable energy sources				X
1491	Influence of large penetration of electric vehicles on increasing the flexibility of the systems with a large share of renewables based on the case study of the Republic of Croatia				X
1556	Case Study on the Effects of Increasing Electric Vehicle and Heating Loads				X

	on a Distribution Network in Stockholm				
1565	Data-driven asset management with the NGIN analytics platform: Assessing EV and PV impact on the Flemish LV grid				X
1566	Results of the KALAMEUS Project: A Comprehensive Measurement Campaign for a more efficient Planning and Operation of the Distribution Grid				X
1581	Predicting the impact of electric bus charging on distribution power grids				X
1638	Assessment of Flexibilities and Smart Grid Technologies in the Planning and Operation of Congested European Distribution Networks				X
1660	Review of transmission and distribution investment decision making processes under increasing energy scenario uncertainty				X
1673	Local e-mobility prediction and deviated grid development based on data analysis		19		X
1681	Effects of the future trends in distribution networks				X
1724	A conceptual framework for supporting the deployment of community microgrids using meta-data assisted clustering techniques				X
1726	EV diffusion in South Tyrol: development of the charging infrastructure and assessment of its impact on the distribution network				X
1743	Automated Planning of High Voltage Grids for DER Integration Studies – Results of a study for the German State of Hesse				X
1778	Optimal Planning of High Voltage Distribution Grids under a Combined Use of Energy Storage Systems and Dynamic feed-in Management				X
1877	Recommendations for Distribution Network Planning Based on Benchmarking of Energy Losses in Croatian DSO Network				X
1885	Comprehensive framework for PV integration with an OLTC in a rural distribution grid within the SMAP project				X
1955	Taming uncertainty in distribution grid planning – A scenario-based methodology for the analysis of the impact of electric vehicles				X
1988	Effectivity of active voltage control concepts in distribution grids				X
1993	A Distribution System Expansion Planning Method Considering Integrated Energy Service Providers' Revenue on Energy Storage Investment				X
2018	Novel Analysis Techniques for LV Network Planning using Smart Meter Data				X
2030	Investigation of the Impacts of Primary Substation's OLTC on Voltage Regulators Placement in Distribution Systems				X
2035	Economic Evaluation of Energy Storage used for Reliability Improvement in Distribution Networks				X
2047	Optimal Configuration of Hybrid AC/DC Microgrids				X
2051	Application of dynamic transformer ratings to increase the reserve of primary substations for new load interconnection				X
2079	Long-term Economically Efficient Design of Low and Medium Voltage Distribution Networks				X
2090	An empirical study on risk assessment and reliability improvement of large-scale distribution grids considering chaotic installation of DERs				X
2118	BI & Analytics for smart planning in distribution systems			X	
2126	Exploring the Requirements and Considerations for a Probabilistic Simulation Toolset Leveraging OperDSS				X
2128	DER Integration Study for the German State of Hesse – Methodology and Key Results				X
2131	An Advanced Distribution Planning and Optimization Process				X
2150	Planning Integrated Energy Systems in Local Communities under Uncertainty				X
2198	Universal procedure for determining the optimal connection to the distribution network				X
2267	The Next Generation of Distribution Analysis Tools			X	
2301	Optimal location of energy storage systems with robust optimization				

2308	Planning Tool for Non-Interconnected Islands				
2317	Comparison of models and tools for distribution planning		X		
2326	Microgrid Value Stacking to Defer Distribution Capacity Upgrades of Radial Feeders		X		

Block 4: Methods and Tools

Sub block 1: Load/Generation Modelling and Forecasting

Load forecast is a planning activity that has traditionally been conducted starting from elementary data drawn from experience or based on assumptions about simultaneity of consumption and level of use of appliances. Only recently, the availability of huge amounts of hourly data coming from Smart Meters made it possible to use "atomic" components of consumptions. At the same time, new kind of loads have been introduced, virtually devoid of any past reference, and "smart" functionalities have appeared, leading to volumes and rules of combination which may significantly differ from the historical ones. Finally, distributed generation has become an acquired taste for MV and LV networks, and needs forecast tools as well.

Sub block 1 deals with methodologies to make use of available individual data and/or new logics of elementary management to build analytic or synthetic models that may accurately represent the complexity of "smart" loads and distributed generation.

A comprehensive survey of state-of-the-art forecasting techniques for active network planning is delivered in **Paper 0294**: the study has been carried on through a structured questionnaire submitted to a population of 71 utilities, among which 28 answered. The most common practices are summarized as well as the "hot topics" that, according to the perception of participants, need to be improved. Main findings include the following: opportunities arise from best practice sharing; forecasting techniques for DER still need standardization and development; customers´ behavior models must and will improve according to the increasing information available.

In **Paper 2046**, the uncertainties related to long-term evolution of loads are examined (see Fig. 59).

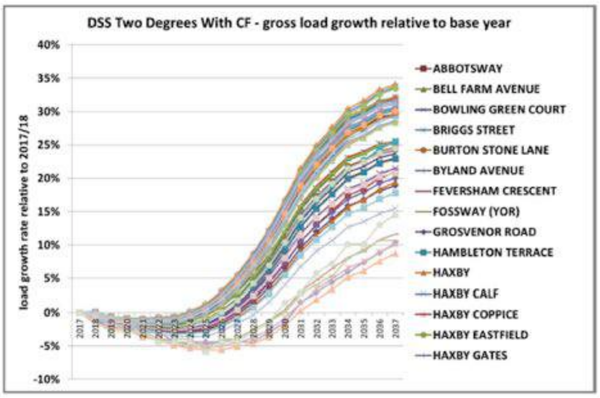
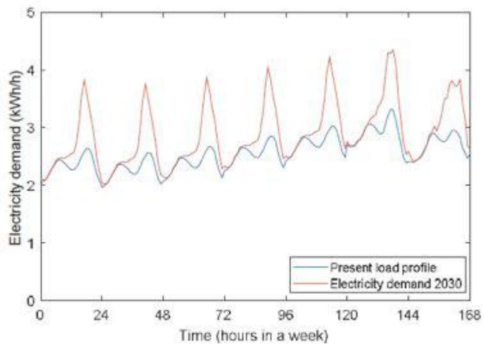


Fig. 59: Load growth across distribution substations (years 2017-2037) according to Paper 2046

Heat pumps, electric vehicles, distributed generation, storage and customer flexibility provide challenging scenarios in which load forecast is going to be harder not only for the lack of historical data or for the intrinsic volatility of some entities, but also for the reduced observability of pure load while mixed with embedded generation. Gross load and net load concepts are introduced and discussed, and a methodology is proposed to assess the long-term evolution of load under different scenarios.

Paper 1785 presents a methodology to estimate electricity demand profiles for residential customers taking into account the effects of EVs, PV systems and heat pumps. Some examples of the future electricity demand curve with and without the estimated changes in electricity demand are shown in Fig. 60.

a)



b)

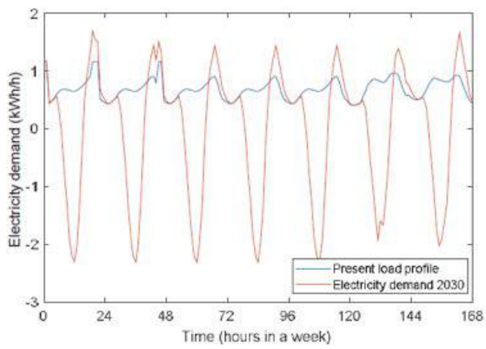


Fig. 60: Current and 2030 daytime electricity demand of one customer in a winter (a) and summer (b) week according to Paper 1785

Paper 1088 exposes an analysis of generation, demand and prize at distribution level by means of two different clustering techniques, namely the hierarchical clustering method (HM) and the artificial neural networks (ANN) method. The availability of these data is needed in order to evaluate the economic feasibility of Smart Grid infrastructures. The approach presented has been applied to Portuguese historical data sets of hourly consumption, wind generation and gross market prices of a complete year. As a result, the methodology applied provides characteristic profiles for prices, load and generation (essentially wind) that can be used to simulate typical and representative days of a whole year.

Paper 0257 introduces Non-Intrusive Load Monitoring (NILM) in order to determine to which extent the existing load can be effectively used for regulation purposes, with a specific focus on air-conditioning equipment. The individual steps of the NILM process are detailed, starting from data acquisition and clustering (of voltage and current parameters) and ending with the determination of the air-conditioning potential for demand response services. The proposed methodology is then applied to a case study of a building (including 135 households); results show that a significant contribution can be expected from demand response - without affecting users' comfort - as the air-conditioning power consumption can be reduced of approximately 30%.

GIROSCOP (**Paper 1063**) is a tool developed by EDF R&D to provide French DSO Enedis with load and generation scenarios for planning purposes. GIROSCOP is able to generate a large number of consistent and significant load-generation combinations related to huge systems (> 2,000 HV/MV substations). The system uses multi-year archives of meteorological data, observed consumption and production datasets to provide M joint scenarios of consumption and production (wind and solar power) at a 10-minute time step. In Fig. 61 the input datasets of GIROSCOP (in grey) and the output dataset (in green) are shown, while the high-level program structure is represented in the middle of the picture.

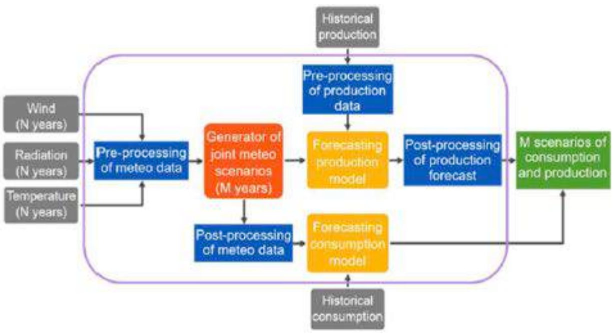


Fig. 61: Methodological Chain of GIROSCOP (Paper 1063)

While most utilities only rely in internal available information (e.g. data from Smart Meters) in order to forecast the distribution and evolution of load, there is undoubtedly room for incorporating explorations of the open world according to the Big Data paradigm. **Paper 1053** describes an approach to spatial load forecast in which internal data are combined with external information publicly available (Open Source). The real case of characterization of residential areas in the city of the Henan Province in Chine is investigated; results show that a more reliable forecast can be achieved by adopting the methodology exposed in the paper, thus enabling a better planning exercise.

Paper 1068 introduces a methodology for annual load flow estimation at MV/LV transformer level. The idea here is to achieve load profiles for distribution transformers in order to shift from worst-case, deterministic planning to statistical evaluations. To do so, the proposed methodology has been designed to integrate permanently recorded data at MV level with mobile measurements at transformer level. These two sets of data allow the determination of: a) seasonal dependence of daily peak load; b) seasonal dependence of load profile shape; c) load profile at transformer level. Each one of the three representative elements provide valuable information to the planner, as well as the annual LV load profile for distribution transformer coming from the combination of the three variation drivers (see Fig. 62),

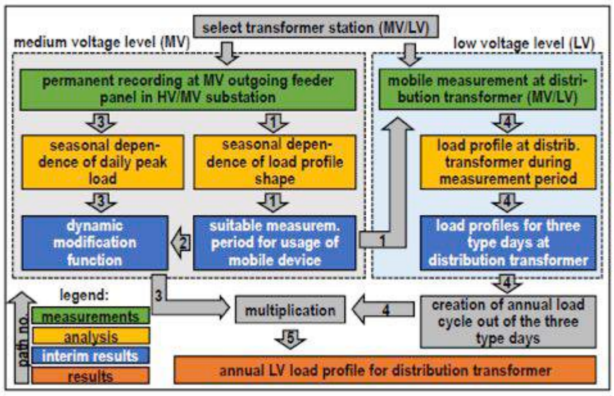


Fig. 62: Overview of methodology for annual load profile estimation at distribution transformers level (Paper 1068)

Paper 0559 introduces a tool for short-term load forecast at MV/LV level, to be used for congestion management purposes. The tool, developed as a Dutch demonstrator within the framework of Horizon 2020 InterFlex project, provides a 48 h rolling window load forecast. In order to deliver the best possible results, three different models are compared: a Linear Regression model, a XGBoost Regression model, and a Random Forest Regression model. Among them, the XGBoost regression model proved to ensure the best performance. Results show that this performance can be improved by applying time series decomposition and introducing weather information and time-related features.

Paper 0420 deals with the use of Smart Meter data for LV planning purposes. The whole process, from raw data collection to consumption models definition, is summarized; privacy issues are also taken into account. Authors describe the activities which are needed in order to get robust information for long-term planning while limiting the time of observation and the resolution of archived data. Results show that in order to reach reliable models, an observation period of one month per year can be adequate, provided appropriate corrective factors are introduced.

Paper 0891 investigates the possibility of using synthetized load profiles coming from real metering data with no significant loss of significance. To do that, results from profiles obtained by data clustering and characterized through Markov processes have been compared with those coming from real measurements adoption. Authors show the two approaches lead to acceptable accuracy even for LV consumers with intrinsic volatility and inherent cluster classification errors: it may be noticed that the inevitable limitations introduced through simplification do not affect the accuracy of the simulation in real LV planning cases, leading in practice to negligible differences.

Paper 1568 aims at defining future consumption modes of final customers in the "heating market", including gas and electric options for residential heating. The behaviors of the customers are therefore modeled according to the main factors driving their energy choices. The paper includes: an overview of the mathematical structure of the model; the description of the technical solution chosen to perform modelling and simulation; an exhaustive catalogue of all data resources of relevance used in the process. The final conclusions summarize the most relevant findings coming from the performed simulation, as well as some open points that will be deepened in future developments.

Integrating EV in existing networks is without doubt one of the key planning issues presently and in the very next future; a first step to deliver consistent network planning is the availability of EV consumption forecasts. However, due to the novelty of electromobility, no historical consumption data are available; a different approach, based on external data, is therefore needed. Paper **1825** describes a methodology to synthetize residential load profiles according to a psychological behavior model in which the residents are represented as independent, desire-driven software agents (Fig. 63). Some of the desirable actions include/imply transportation issues that are therefore included in the model, together with their characteristics (such as fuel type, etc.), which in turn ends providing consumption quantities and patterns according to the type of mobility the worker (without EV, with EV living 5 km far from work, etc.). The generated data can be used for grid planning purposes.

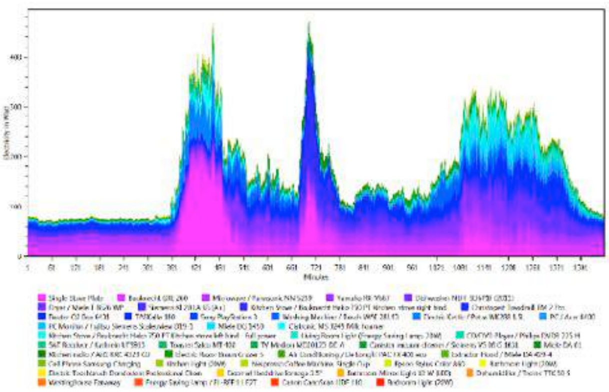


Fig. 63: Example of an average yearly electricity profile according to methodology exposed in Paper 1825

Paper 0620 describes a methodology to calculate the daily load profile at city level with a specific focus on EV charging contribution, for both uncontrolled and controlled charging types. More in detail, the impact is determined according to a multi-step process starting from the requested charging power of uncontrolled plug-in electric vehicles, then determining the probability of each charging start time at the workplace and at home, finally, after estimating the state of charge of the battery, combining the individual consumptions in order to calculate the impact on the network (Fig. 64). The results may represent a useful input in order to determine future strategies to optimize the daily load profile and reduce the need for network reinforcements and expansions.

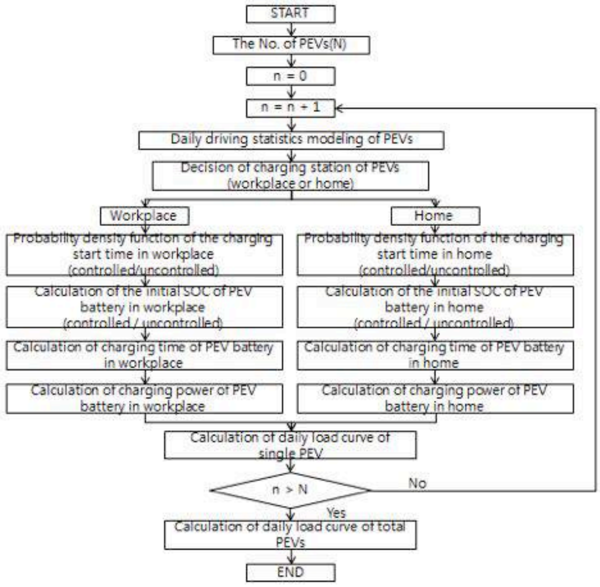


Fig. 64: Flowchart to calculate daily load curve of total PEVs (Paper 0620)

Paper 1857 describes an easy-to-use PV generation forecast algorithm, developed in order to achieve prediction data at small-scale installation level. The basic input for the system relies on environmental (irradiance) estimated data; however, the characterization of the installation itself is not derived from detailed modeling of the PV infrastructure, but comes from a learning process based on analysis of past performance, that is absolutely reasonable provided small structure are to be represented. Results show that the modelling of the PV panel is accurate.

Paper 1987 also deals with PV production estimation, with a specific focus on day ahead forecasts. The model proposed is a statistical-indirect method based on artificial neural networks (ANN), using weather forecast of the main variables (sun radiations, ambient temperature, air humidity, etc.) for the next day as input data, as well as the values of past 5-days available measures. The estimator is quite simple and may perform forecasting alternatives based on different concepts, such as the structure of the ANN adopted or the weather variables introduced; only few weather variables must be monitored at installation level, and the estimator adapts itself through an iterative daily process. As an example, the estimator performance during some days in 2018 is provided. Developments and improvements are envisaged in the next future in order to refine the model including additional variables.

The shift of paradigm from deterministic to probabilistic network planning implies establishing reliable methodologies to represent load behavior according to statistical parameters. **Paper 1125** describes a methodology that allows characterizing the probability density function for power consumption, in different nodes of a network at a given time. Starting with the clustering of available consumption data it is in fact possible, through statistical combination rules, to determine aggregate probability density profiles for each node, enabling much more detailed analyses compared to the traditional, deterministic approach (see Fig. 65).

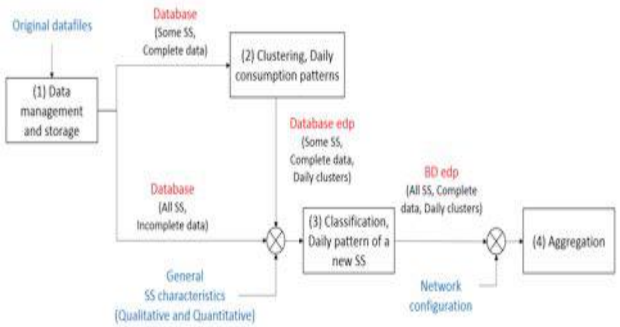


Fig. 65: General structure of the framework and interconnection between procedures in Paper 1125

Sub block 2: Network Modeling and Representation

Introducing new equipment (e.g. including static converters) and developing new functionalities within a distribution grid may imply that the conventional ways of describing individual components and/or network behaviors must be changed, modified or simply adapted.

Sub block 2 deals with the development of innovative equivalents, consisting either in an advanced modelling of individual elements or in a synthetic representation of full systems or relevant network subsystems to be adopted in specific network calculations.

Paper 2107 focuses on synthetic representation of distribution grid at MV level. The idea behind the paper is that, provided enough data can be found in order to represent a MV grid influence area, the electric distribution infrastructure can be determined to some extent according to some clustered reference models. Publicly available information (such as geospatial data, demographic, etc.) are all collected and used, in combination with real network characteristics, to help defining the "distribution task" according to which an effective grid topology can be designed. Applications of the model to real operating grids shows a good match between real networks and the generated reference topologies, the little deviations (e.g. in positioning of MV/LV substations) being more than justified by the simplifications introduced in the model.

In **Paper 1102**, a simulation of the enhancement of the performance of the network due to the combined introduction of fault passage indicators and remotely controlled switches in order to developed self-healing systems is performed. The methodology presented makes use of an event tree analysis and defines the switching sequence for each simulated failure event. According to the sequence defined, the fault localization time is determined as well as other fault-related values (partial interruptions for each cluster of affected customers, etc.), hence all reliability indices can be calculated. The methodology has been implemented in a prototype tool and has been tested on a sample grid and on real MV distribution grids in Norway, providing realistic results.

Paper 0758 deals with an original topic: the conversion rate of planned investments and how it can be effectively predicted (see Fig. 66). The idea behind the paper is that if we are able to foresee the success rate of an investment plan, we can also improve it. To do so, the authors have developed a model that, according to the practical results, can effectively support the prediction of project investment conservation; it is reported that it can effectively control the average investment conversion rate in more than 90%. By benefitting of an accurate prediction model, it can be expected that early warnings can be given to the projects with the low predicted investment conversion rate.

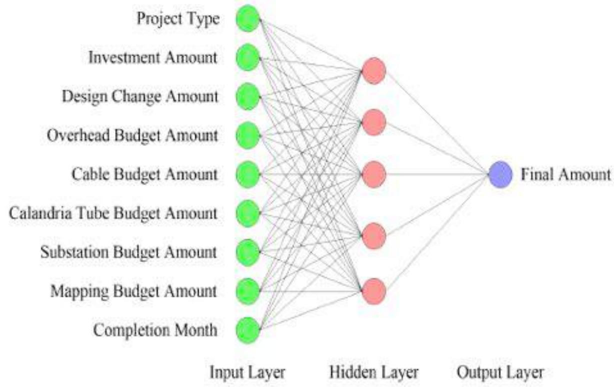


Fig. 66: Proposed structure of the optimal investment conversion prediction model (Paper 0758)

Paper 1972 introduces a probabilistic model to determine an accurate, season-dependent current rating of overhead lines, for network planning purposes. The model allows calculation, for each given line, of admissible current values for individual season of the year based on available time series: within the methodology, a climate model and a thermal model of the lines are used. Combination of probabilistic rating and dynamic curtailment is also investigated. Results show, as imagined, that transmission planning and operation may essentially benefit from the application of such a technique during winter time. A further development for the methodology, including dynamic current rating, is foreseen in order to enhance its benefits.

A proper detection and representation of Hi Impact – Low Probability (HILP) events is crucial to trigger resilience initiatives. **Paper 1779** focuses in the characterization of the exposition of a real distribution network to flood events. By representing the distribution network as a graph and the flooded area as a polygon, finding the intersections between the two sets of entities it is possible to determine which interventions (e.g. switch opening) must be adopted in order to isolate the inoperative (flooded) areas (Fig. 67). By using these algorithms, it is possible to optimize and automate all the data processing steps, significantly reducing the computational times and increasing the quality of the analysis. It can be imagined that the systematic implementation of this tool can improve a DSO response to this kind of extreme events.

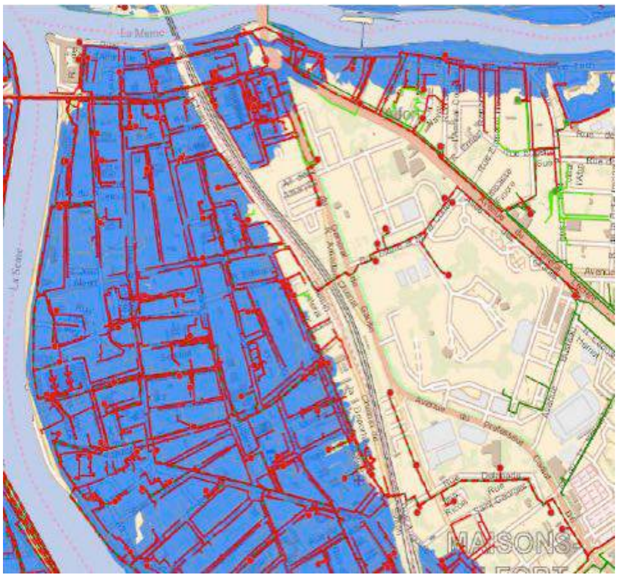


Fig. 67: Flood impacts on MV network in Paper 1779

Paper 1523 deals with the simulation of a complex infrastructure connected to a conversion station in Mendrisio. In order to determine the real ampacity resulting from the interactions between more than 20 different cable systems a specific algorithm has been developed: quickness and flexibility were needed in order to manage project changes with little or no previous notice, ensuring the availability of cable ratings in any case. To do so, an iterative method was chosen, based on the IEC 60287-3-3 and fully integrated into the existing framework of the web-based cable calculation tool.

Augmented reality is quickly becoming a widely available platform to support field activities in the distribution business: in fact, the large amount of operational data typically available in distribution makes many implementations possible with limited incremental costs. **Paper 1495** presents a simple yet fascinating augmented reality feature: the visualization of MV underground networks. A proof of concept (POC) performed in Elenia (Finland DSO) is described: it must be noted that, in order to provide a reliable visualization of the infrastructure, an accurate localization is needed. Once the underlying information is made available, the interface between the network information system and the augmented reality rendition can easily be ensured through available Smartphones.

A fractal analysis of the electrical distribution network of Grenoble is presented in **Paper 1752**. The authors introduce a fractal characterization of the infrastructure in order to investigate its properties, e.g. in terms of scaling (self-similarity at different spatial levels), analogies with other networks (namely vs. road network), concordance with distribution of built-in areas. By applying this methodology, it is possible to determine cases of under- or over-development, simply comparing the degree of coverage of the grid with the other "fractalized" infrastructure. An adapted method to assess the distribution of voltage drops within the explored network is also introduced. As the methodology seems a promising one, some other possible uses for fractal analysis are foreseen (see Fig. 68).

Fig. 68: Grenoble's power network (blue line), road network (red line) and built-up footprints (dotted pastel), see Paper 1752

Sub block 3: Load Flow and Short Circuit Calculations

Sub block 3 deals with classical calculations widely used in network planning or in components' sizing. Some of the papers refer to specialization of well-known methodologies in order to assess individual problems; in other cases, the challenge is to simplify existing models in order to be able to manage large volumes of data. Furthermore, new methodologies are eventually proposed to approach emerging topics like distributed energy resources and taking advantages of smart metering.

Paper 0133 analyzes, in a case study, how the improper choice of a mathematical model to represent the lines of a primary distribution system may affect the results obtained with the load flow. Based on the assessments made it is shown that, in the Brazilian electrical system, the effect of line modeling for some large networks with relatively low charge density may cause a significant impact on the calculated power flow results.

The proper modelling of inverter-based generators as current sources in the superposition method is investigated in **Paper 0212** and a simple short-circuit current calculation method is derived (Fig. 69). The advanced method is applicable to IEC 60909 standard and enables the consideration of dynamic reactive power support of inverter-based generators.

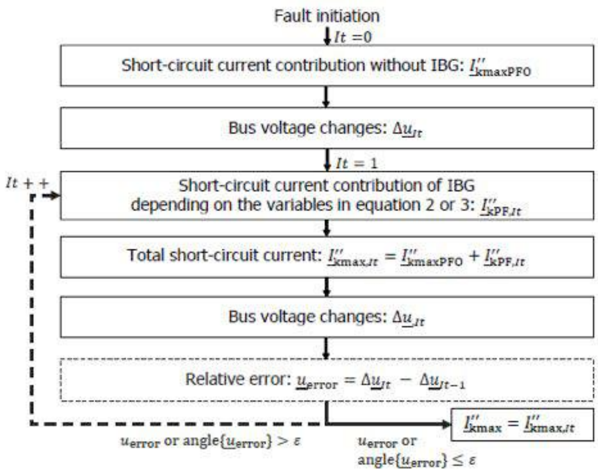


Fig. 69: Iterative short-circuit current calculation proposed in paper 0212

Paper 1630 proposes a fast-linear load flow algorithm suitable to simulate both the LV and MV networks all together. The algorithm is applied to the grid of Alliander DNO. Using this method, congestion problems in both the LV and MV grid can be determined with huge detail.

The authors of **Paper 0131** developed and implemented an automated methodology that assists a Brazilian DSO in planning and operation activities in order to offer predictive solutions for load shedding. The methodology developed in this research addresses the problem, seeking to minimize the number of consumers without electricity supply and the number of switching operations, considering multiple criteria.

Distributed Energy Resources are becoming more and more attractive to ancillary services markets and their continuous evolution will gradually replace the flexibility of conventional power plants. **Paper 1728** shows how the tool for reconstructing the equivalent capability of distribution networks can be effectively used in order to investigate the issues related to the participation of distributed resources to the ancillary services markets.

The demand of electrical energy in Finland followed a nearly linear growth trend for a long-time making demand forecast relatively simple. However, in the last decade the growth has stalled due to energy efficiency policies. Moreover, in sparsely populated areas the population is continually decreasing. These changes in the operational environment pose challenges to demand forecasting. **Paper 1756** introduces a method that uses decomposition and time-series analysis of open data to forecast future electrical energy demand (Fig. 70).

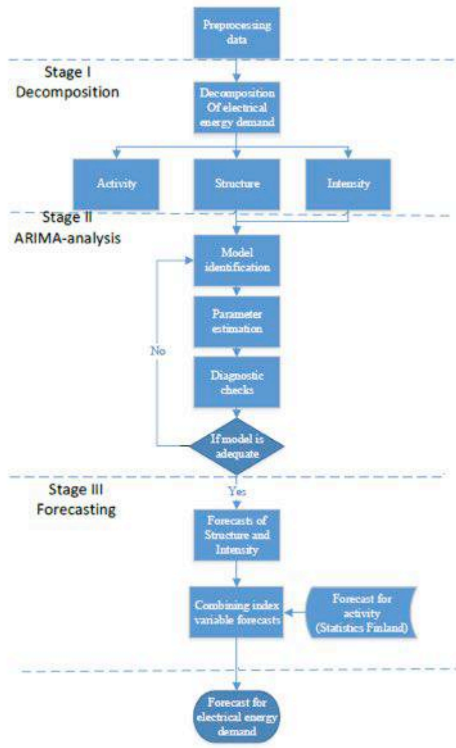


Fig. 70: Methodology proposed in paper 1756 for electrical energy consumption forecasting

In **Paper 2008**, game theory is introduced to model the joint planning of energy storage systems (ESS) and renewable energy sources (RES). The model is built by taking the power supply company, consumers and independent operators as the three players and their life cycle income as payoffs. The results have shown that, for consumers who invest in a PV installation, the profit is increased and the time of return on investment is decreased thanks to the electricity price framework.

Reliable models for loads and generation are essential for the long-term development of the distribution and transmission grid: DSOs will exploit data from smart meters, sensors, control systems etc. to make better load estimations and forecasts. At the same time, load flow calculations evolve following a probabilistic approach, reducing the risk of over-sizing and over-investing. **Paper 1672** deals with probabilistic load flow starting from new load and generation modelling and compares its results with those coming from today's deterministic methods.

Distribution System Operators (DSO) are nowadays confronted with a rapid rise of renewable energy resources, leading to increasing grid congestion events into the distribution grid. In order to tackle these bottlenecks, DSOs are investigating several strategies including flexibility activation. The authors of **Paper 1578** developed a tool able to optimize with a good performance the day-ahead operational planning (Fig. 71).

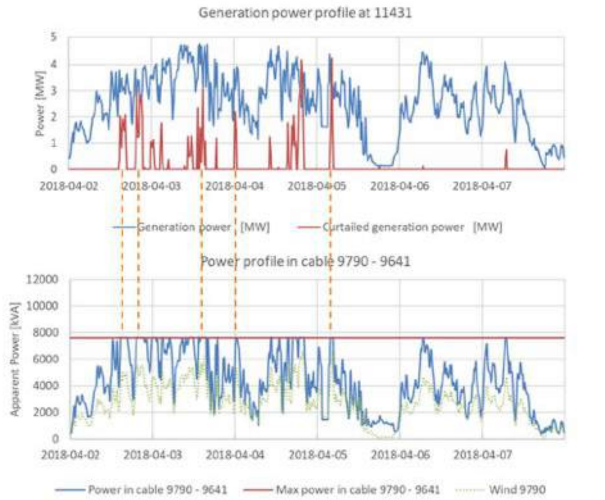


Fig. 71: Paper 1578: example of grid congestion management through flexibility activation: wind farm curtailment to respect the MV cable rating

Paper 1633 introduces a tool to evaluate the performance of a state estimator, applied on a real LV network of the Swiss DSO Romande Energie equipped with Smart Meters as well as GPS synchronized high precision measuring devices. Load flow calculations and estimations using a weighted least squares formulation are compared in Fig. 72.

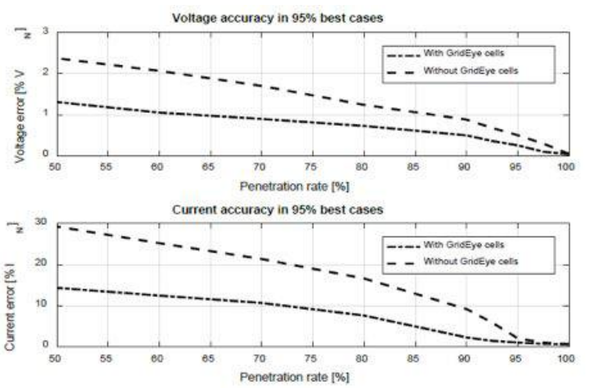


Fig. 72: State estimation performance evolution with the smart meter penetration rate, evaluated in paper 1633

Sub block 4: Energy Losses

As the focus on efficiency in the electric sector, both from the Regulatory and the DSOs point of view, increases, it becomes more and more relevant being able to minimize the amount of energy that enters the distribution network without being delivered or billed to the final customer. Furthermore, the presence of DER in the distribution grid provides challenges as well as opportunities in terms of losses, making it more difficult to identify their patterns while enabling a more flexible management.

Sub block 4 therefore deals with algorithms and methodologies aimed at evaluating technical losses, either developing models to estimate their entity in active network scenarios, or identifying non-technical ones, detecting fraudulent consumption as well as direct theft.

In **Paper 0978**, future scenarios and trends for the electric systems are examined with reference to their impact on (technical) losses. Decarbonization of heat and transportation, customer flexibility, distributed generation are issues which will drive future demand, the way in which its coverage will be ensured and that, ultimately, will impact network losses. The paper proposes an overview of present losses evaluation techniques, of their representation through parameters and indexes, of their relationship with peak load and load profiles; then, a specific focus on how demand growth and customer flexibility can impact network losses is provided. A four-step approach is presented in order to show how evolutionary demand growth, uncontrolled DG development, DSO actions (carried out irrespective of losses or specifically addressing losses) will affect technical losses in the mid-long term (see Fig. 73).

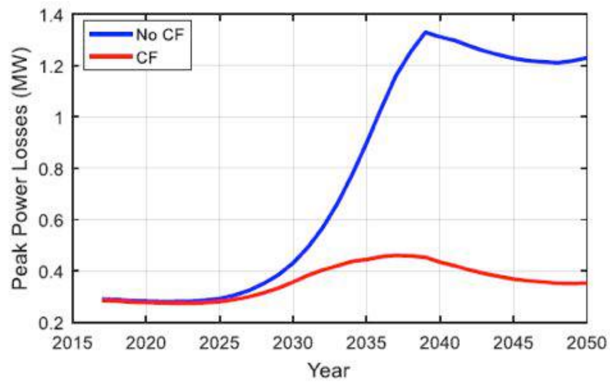


Fig. 73: Power Losses Calculated at Peak Demand with and without Customer Flexibility (CF) for each year 2017-2050 (Paper 0978)

Paper 1234 introduces a technique for detection of anomalies in customer consumptions' database. In detail, the tool described, named BIAT (BDGD Integrity Assurance Tool), was developed within the framework of the Research and Development Project of ANEEL (Brazilian Electricity Regulatory Agency), proposed by the Equatorial Group (CEMAR and CELPA). The tool is essentially a binary classifier that assesses if a given value representing the consumption (kWh) is an outlier or not, according to its relative position with reference with consumption clusters. To group adjacent points in clusters, two methodologies were adapted for one-dimensional data and to act as binary classifiers, the DBSCAN (Density-based spatial clustering of applications with noise) and the K-Means. Results show that the tool has proven quite reliable in the classification of outliers.

In **Paper 0042**, a probabilistic methodology to detect frauds in energy consumption by monitoring the metering data is presented. As honest customers largely outnumber the fraudulent ones, the available dataset resulting of an unbalanced nature, specific algorithms are needed in order to face the problem through machine learning techniques. In fact, according to a conventional approach where samples are randomly selected, the machine learning training performance could be poor: while selecting an appropriate combination of positive class against negative ones, the efficiency of the training can be enhanced. In order to do so, the author proposes an importance sampling model specifically suited for the case as it is assumed to be able to deliver a reasonably accurate estimation of the probability of rare events.

Paper 1798 describes an original application of machine learning in order to detect non-technical losses, combining electrical consumption data with third-party information, i.e. cellular data record. The idea behind the methodology is that, being both electrical consumption and cellular traffic good proxies of human activities, a significant correlation between them must be shown. By detecting through machine learning the violations of commonly detected correlation patterns, it is possible to discover possible theft/fraud areas.

Paper 2228 exposes an analysis of the differences in the calculations of technical losses when performed with energy values, in comparison with the same calculations performed with power values. The system analysed was an IEEE study network of 24 buses and 17 loads and a 24-hour load diagram, which were entered into an INESC TEC developed, power flow calculation program. Results show that significant discrepancies may arise while comparing the two techniques, the losses calculated with the use of energy values resulting lower than those determined through power values (see Fig. 74).

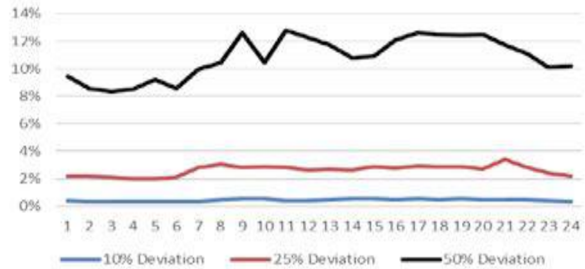


Fig. 74: Relative difference of loss calculation between power and energy values, according to Paper 2228

The impact of reactive power phase displacement and harmonics on network losses is investigated in **Paper 2196**. The authors describe a comprehensive analysis carried on by field measurements and calculations. Results show that the effect of harmonics is generally low, resulting in a losses' reduction - if removed - of no more than 10% in lightly-loaded feeders, even less in heavily-loaded feeders. As can be imagined, the contribution of reactive power is way more significant, particularly in the case of commercial feeders in which a power factor correction could eventually reduce losses up to 36%. In any case, field measurements show that phase displacement is generally smaller than the one adopted for planning and that it is strongly dependent from network topology.

In **Paper 1819**, a LV losses estimation tool for smart grids, based on clustering techniques, is described. The proposed approach includes: a clustering phase, in which feeders are characterized through their representative parameters; a reduction phase, through which the feeders are described with a reduced set of two coordinates; a clustering phase, carried on using a k-means algorithm and reducing feeder complexity to three clusters; a simulation phase, after which a correlation is established, for each given cluster, between feeder energy input and its losses. Some real cases are investigated, showing the proposed methodology can effectively be adopted instead of conventional, time-consuming, load flow calculations.

Paper 1939 also presents a methodology, suitable for planning purposes, to assess energy losses in LV grids including DG and storage systems and taking into account unbalanced operation. In the paper firstly, a calculation of the cost of delivering 1 kW of peak loss as a function of network parameters is performed for a conventional LV feeder, then the effects of PV and storage installations are included in order to adapt the conventional model to smart grid environments. Some applications to real network are then operated in order to validate the enhanced model (Fig. 75).

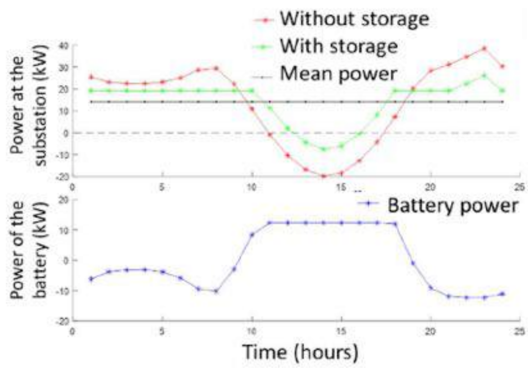


Fig. 75: Storage strategy to minimize peak power, according to Paper 1939

Paper 1212 describes the activity of an interdisciplinary work group implementing a Big Data system centered on the characterization of substations and benefitting from the large volumes of available Smart Meter data. The authors provide a valuable description of the project from both the technical (scope, technical content, results) and the specific Big Data (competences needed, data collecting, validation and analysis methodologies, etc.) point of view. Among the results of the project, an accurate evaluation of transformation losses is reported.

Paper 1722 introduces a bottom-up approach to network losses in order to reduce the inaccuracies coming from traditional ways to quantify losses across voltage levels, utilizing metering data to calculate losses as the difference between energy entering and exiting the system. The methodology described in the paper gives detailed information on the loss characteristics of networks, which in turn makes identification of high loss assets in increasingly complex networks easier. The exposed methodology has been tested in different HV and MV networks including - at HV level - both interconnected and radial HV as well as embedded generation. Results show that the increased volatility of load and the intermittent embedded generation may significantly assess losses.

Potential scope of discussion
Smart Grids imply flexibility and adaptability are brought into distribution networks. The new paradigm of distribution management is based on the capability of the network to understand operational conditions and to modify according to pre-defined guidelines. However, to get the full benefits of this evolution we must be able to take into account the expected, and possibly the unexpected, system flexibility behaviors. How can we represent the adaptive strategies a Smart Grid can pursue to make optimal use of them in planning, avoiding unnecessary over-sizing of equipment? How can be obtained reliable profile of EV consumption? What is the expected level of confidence?

Table 4: Papers of Block 4 assigned to the Session

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
0042	Application of importance sampling method for non-technical losses detection in electrical distribution systems using Smart Meters				X
0131	Methodology for Load Shedding Actions Planning in Medium Voltage Electric Distribution Systems				X
0133	Investigating the Impact of representation of MV power lines in the distribution system for the studies of power flow considering DG				X
0212	Advanced Modelling of Inverter-Based Generators for Short-Circuit Current Calculations Based on IEC 60909-0:2016			X	X
0257	The Application of NILM in Demand Response				X
0294	Survey of Distribution Planners on Current Forecasting Practices and Concerns				X
0420	Applying smart meter data to low voltage network planning				X
0559	Short-term load forecasting on MV/LV transformer level				X
0620	Analysis of Daily Load Curve by taking into consideration Electric Vehicle by Charging Station in Seoul of South Korea				X
0758	Research and Application of Project Investment Conversion Prediction Based on Improved BP Neural Network				X
0891	Data Analytics and Stochastic Simulation Methods for Risk-Controlled Network Planning: Validation Case Study		20		X
0978	Enhancing the Understanding of Distribution Network Losses				X
1053	Residential Area Spatial Load Forecasting Method Based on Big Data Mining Technology				X
1063	GIROSCOP: a generator of consumption and production joint scenarios for the Distribution System Operator (DSO)				X
1068	Methodology for Annual Load Profile Estimation at the Outgoing Feeder of Distribution Transformers in Urban Areas				X
1088	Providing simulation scenarios for the electricity grid in a smart grid environment				X
1102	Reliability analysis methodology for smart fault handling in MV distribution grids				X
1125	Probabilistic models in power distribution electrical networks				X
1212	Big Data challenges - a multidisciplinary team approach		25		X
1234	Simple technique for detection of outliers in one-dimensional numerical data used for pointing out anomalous consumption				X
1495	Utilization of augmented reality in underground network visualization on field				X

1523	Ampacity calculation of multi-system cable crossings at 40 MVA frequency converter station Mendrisio				X
1568	Scenario Analysis Heating Markets - Effects to Future Energy Grids				X
1578	A case study to assess data management and performance of optimal power flow algorithm based tool in a DSO day-ahead operational planning platform				X
1630	Combined Medium Voltage and Low Voltage simulation to accurately determine the location of Voltage Problems in large Grids				X
1633	Performance evaluation of distribution system state estimator using different measurement devices				X
1672	Probabilistic load models and Monte Carlo simulations used in distribution system planning				X
1722	Advanced Modelling of Complex Networks to Reduce Losses				X
1728	Effects of Distribution System Characteristics on TSO-DSO Ancillary Services Exchange		23		X
1752	Analyzing the fractal behaviour of the distribution power grid in the city of Grenoble- France			X	X
1756	Electricity demand forecasting 2030 by decomposition analysis of open data				X
1779	Using Big Data analytics to improve flood resilience of the distribution grid				X
1785	Electricity demand profile for residential customer 2030				X
1798	TLC Pointer – The use of geospatial data for non-technical losses detection		24		X
1819	Energy losses estimation tool for Low Voltage Smart grids				X
1825	Synthesizing Electromobility Charging Profiles		21		X
1857	PV Predictions Made Easy: Flexibility Through Simplicity				X
1939	Integration of storage and PV in the DSO power losses cost assessment method for LV planning studies				X
1972	Determination of Constant Seasonal Values for the Current Rating of Overhead Lines in the Network Planning				X
1987	An Adaptive Photovoltaic Production Estimator Based on Artificial Neural Networks				X
2008	Game Approaches for joint peak shaving planning in industrial park distribution networks				X
2046	Managing uncertainty in load related investment decisions				X
2107	Modelling of Synthetic Power Distribution Systems in Consideration of the Local Electricity Supply Task		22		X
2196	Impacts of reactive power and harmonics on LV network losses				X
2228	Loss Calculation with Smart-Meters Measures in Distributed Systems				X