Special Report - Session 5
PLANNING AND SYSTEM DEVELOPMENT

Fabrizio PILO
Chairman - Italy
pilo@diee.unica.it

Riccardo LAMA
Special Rapporteur - Italy
riccardo.lama@enel.com

Francisco Josè CARO MORON
Special Rapporteur - Spain
francisco.caromoron@enel.com

Introduction

The research in the field of planning for active distribution networks and smart-grids, as confirmed by the papers in Session 5, is focusing on three main areas: new load and generation models, preferably probabilistic in order to capture the inherent stochastic behavior of RES and electric vehicles; new optimization algorithm in order to rank the different available planning alternatives with a particular attention to traditional (grid reinforcement, transformer change, etc.), network and no-network solutions (novel distribution operation, demand side integration, integration of distribution storage devices); the integration and the role of ICT in distribution planning often related to reliability oriented distribution planning. In other words, the distribution planning has recently came back to a golden age with researchers and engineers challenged to make planning techniques suitable to current and future distribution systems.

A renovated attention has been given to bridge and integrate asset management, often condition based risk asset management, with planning and integrated software frameworks. The general idea is that, in order to find optimal paths for the management and the development of distribution assets, the research of single, local minima for specific problems can, in general, lead to solutions that are not really convenient from a more general perspective. In this context, but also throughout the whole Session, many authors realized that the distribution world can be better studied and captured with probabilistic methods, but these methods have been for a long time not enough used in companies because of the lack of knowledge and the inherent complexity compared with simple deterministic methods. The huge amount of data from AMR, that have to be used in future planning, is just one reason to come back to probabilistic and stochastic data analysis since it is not feasible the treatment of massive information.

Finally, it should be noticed that many papers from distribution companies deal with the problem of novel planning strategies and novel application of automation or innovative distribution schemes. Planning engineers provided with their papers valuable business cases to demonstrate that new alternatives to build new infrastructures are really ready to be deployed and can really help DSOs managing and expanding their business. This is really a good improvement if compared with the status of papers in CIRED 2011, where new planning methodologies where generally proposed by Academia and not completely accepted by industry. Now is the time to change the Regulation in order to make it possible the full implementation of modern smart grid solutions.

The S5 papers will be discussed in three events:

- Main Session (Tuesday, June 11, 9:00-12:30 and 14:00-17:30),
- Poster Session (Wednesday, June 12, 9:00-12:30 and 14:00-17:30),
- Research & Innovation Forum (Thursday, June 13, 16:00-17:30).

Two Round Tables will be organized (Thursday, June 13, 9:00-12:30):

- RT 5a - Smart Data Management for Network Planning Purposes (9:00-10:30)
- RT 5b – Joint simulation of Cyber Infrastructure and Power System for Smart Grid planning and operation studies (11:00-12:30)

The aim of this special report is:

1) to present a synthesis of the items treated in the papers,
2) to call for prepared contributions at the plenary session,
3) to stimulate the free discussion at the plenary session.

The 2013 plenary session will be divided into four blocks. Each block will be divided in two main parts:

1) oral presentations based on papers that cover general items or can stimulate the discussion (12 minutes presentation in both the Main Session and RIF),
2) discussion.

Block 1: Risk Assessment and Asset Management

Sub block 1: Risk Assessment

Last decades' 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 block 1 includes papers describing methodologies to collect, rank and assess the main clusters of risks related to the operation of distribution business.

Paper 0402 shows the most important activities for increasing the seismic reliability and presents the safety level of Electric Power Distribution Network (EPDN) in Iran. As the consequences, two guidelines have been developed and Great Tehran Electrical Distribution Co. collaborated in the mission. The Sadatabad Region was the first pilot to execute the implementation of guidelines. The paper presents the first results of this assessment.

Paper 0490 shows condition based risk models developed at Northern Powergrid, examining how actual experience has influenced further model development in particular with regard to forecasting techniques and the updating of model parameters. In Fig. 1 the evolution of forecasts related to distribution switchgear is shown.

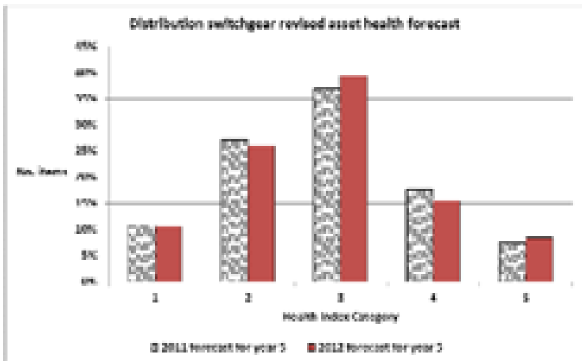

Fig. 1: The evolution of distribution switchgear health index forecast as in Paper 490

Paper 0567 describes risk management at the power distribution system of Gotland, the largest island of the Baltic Sea. The paper shortly describes some existing risk analysis methods that could be relevant to use, and summarizes and evaluates the performed risk analyses. The aim of the work is to find good risk analysis methods for a specific power system.

Paper 0779 describes how a comprehensive risk assessment of a wind generation project should be carried out and identifies the main limitations of probabilistic methods when analyzing the electrical balance of plant (EBoP) of one or only few wind farms. Different risk definitions are presented and guidelines are given on what needs to be reassessed to obtain better results and how to address the problem of minimizing the impact of major (but very unlikely) operational disruptions.

Paper 0565 describes the risk management framework and methodology focusing on its application to distribution business. As an example, results of industrial risk assessment on a pilot area of the Enel Group distribution network are presented (see figure 2 below).

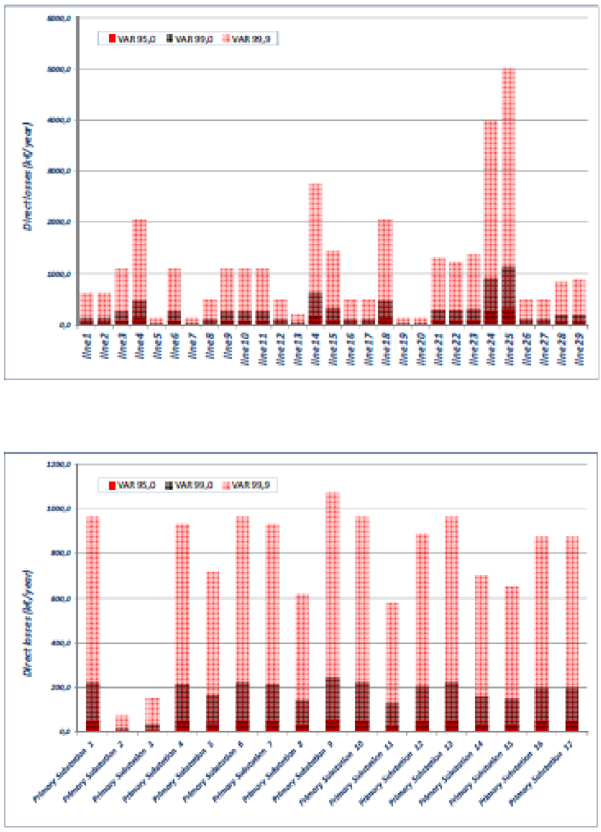

Fig. 2: Direct Losses for HV line and Primary Substation (Area A) as estimated in Paper 565

Paper 1482 describes a risk management framework that has been developed to assist the managers of the NINES (Northern Isles New Energy Solutions) project that deals with the multi-faceted challenges presented by large and complex projects. The process combines two parallel but interwoven activities; the first engages a range of stakeholders, using a decision support group system to facilitate the surfacing of risks and their ramifications, in a causal risk mapping process, while the second engages with the SSEPD (Scottish and Southern Energy Power Distribution) team to elicit expert judgment regarding specific uncertainties so as to understand the likelihood of the particular risks occurring.

Sub block 2: Reliability assessment

Reliability assessment is related to a specific risk, which is of the greatest relevance for the distribution business. As reliability is one of the main drivers in network planning and development, it is important to properly assess the classes of criticalities that significantly affect it and to monitor their evolution, particularly when the dynamics of the system are changing fast.

Sub block 2 deals with the evaluation of electrical systems or of single cases, applying reliability theories in order to find general criteria or specific solutions to enhance or maintain reliability of supply.

Paper 0208 analyses smart technologies including local supervision of network loading, special protection schemes, grid-wide supervision and dynamic rating of overhead lines. The methods have been studied through simulations on an existing 130-kV grid. It is shown that alternatives to the N-1 criterion are possible. Such alternatives (see also figure 3 below) allow much more wind power to be connected, without endangering the reliability of supply for other network users.

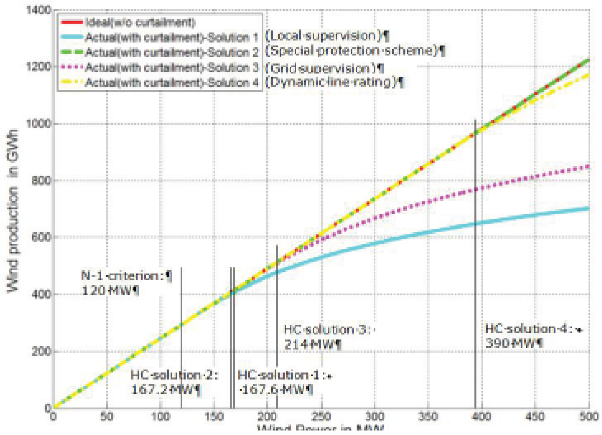

Fig. 3: Annual produced energy as a function of the installed capacity as evaluated in Paper 208

Paper 0302 describes a methodology for evaluating major system risk on distribution networks, developed for and used by a distribution network operator (DNO) located in the North of England. Its purpose is to assess and rank each primary load point across the network as regards both the probability of extreme events occurring, and their consequence, expressed as a single major system risk index (MSR). The paper concludes by evaluating the benefits of such a methodology to support long-term network planning in a whole distribution network, and by suggesting ways in which its applicability could be extended.

Paper 0577 shows how information from vulnerability analyses and existing maintenance management systems can be combined with information about threats and criticality to establish vulnerability indicators for power lines. The development of indicators to monitor the vulnerability regarding weather related threats is addressed, and the methodology is demonstrated with two case studies using data from two different network companies and selected critical power lines in their supply areas.

Paper 1072 shows, using a practical example, how the theories of reliability analysis can be applied, what kind of results to expect, and how these results can be implemented. The method is used to compare different alternatives, evaluating the expected improvement in terms of quality of supply (see figure 4).

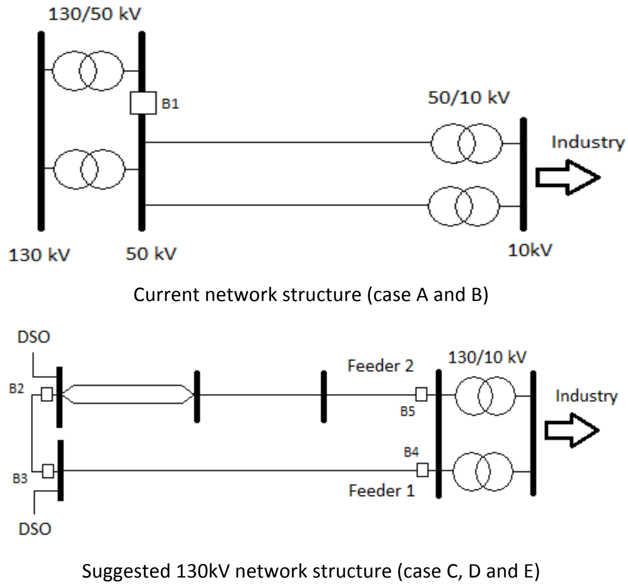

Fig. 4: Alternative network structures compared in Paper 1072

Paper 1153 describes the results of different impact factors on the reliability of MV distribution network in Slovenia in the period 2003-2010. The impact factors, according to the model in figure 5, are evaluated and their correlation with reliability is analyzed. Results show that both environmental and grid structure parameters have an influence on the overall network performance.

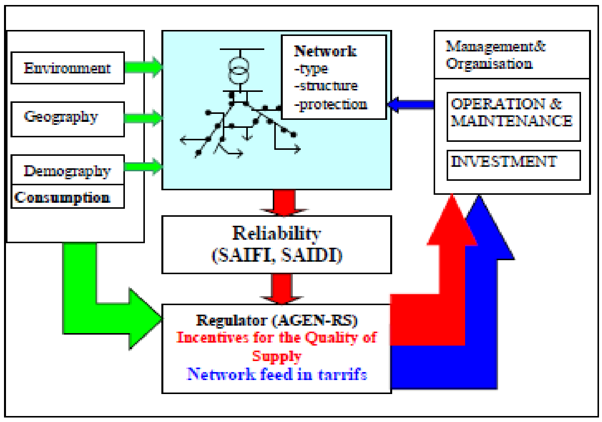

Fig. 5: Factors impacting on reliability of distribution network in Slovenia as described in Paper 1153

Paper 0363 presents the results of a survey commissioned by the Finnish Ministry of Employment and the Economy on supply interruptions and electricity supply security. The paper focuses on two main elements, the customer compensation payments and the maximum blackout duration limits. The study is based on actual large scale blackouts experienced by several distribution companies and delivers some interesting analyses about the main factors affecting network performance in case of major storms (see also figure 6 below).

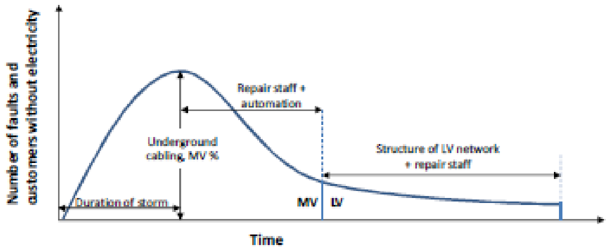

Fig. 6: Major storm curve and affecting factors according to Paper 0363

Sub block 3: Asset Management and Maintenance Strategies

Sub Block 3 deals with the Asset Management in a proper sense, by 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 0178 describes how German distribution system operators are obliged to immediate network extension in order to take up the decentralized energy in total and to ensure the complete network integration. The resulting demands for distribution system operators are dealing with even more than technical issues.

Paper 0307 presents the results of a study on the effects of asset ageing on the reliability and affordability of the collective regional electricity grids of The Netherlands. The study adopts an umbrella approach, in which different types of electricity components, or asset types, are combined in one model, which forms an outline representation of the current grid. The optimization problem has been formulated as a Linear Program.

Paper 0345 stresses that an important task of the asset management process is the evaluation of the long-range investment versus the maintenance costs. This multi-criteria task is exemplary solved on the basis of three different asset groups (power transformers, circuit-breakers and disconnectors). The aim of this paper is to solve this problem with the help of the game theory.

Paper 0848 reports on experiences from implementing a risk based maintenance strategy using a maintenance management system. The paper illustrates also benefits which can be achieved through implementing a risk differentiated maintenance strategy on a company portfolio of MV/LV substations, resulting in better risk control in addition to lower overall cost for the distribution network company.

Paper 1285 describes the ASP tool (Asset Strategy Planning) and the importance of trustable and reliable data from various departments within the company. The ASP tool is using a platform from British telecommunications plc called BT Business Simulation Framework. This is a long-term planning and simulation tool for the evaluation of different asset strategies and their impact on business.

Paper 0313 provides an overview of risk and reliability assessment techniques. Some of them are available for distribution system operators, and the others are in the process of development. The main contribution of this paper is showing the possibilities and benefits of detailed risk and reliability analysis. Six samples of findings from a research carried out over the last decade within the RCAM group (Reliability Centered Asset Management) at the Royal Institute of Technology, Stockholm Sweden, are presented (as in figure 7 below).

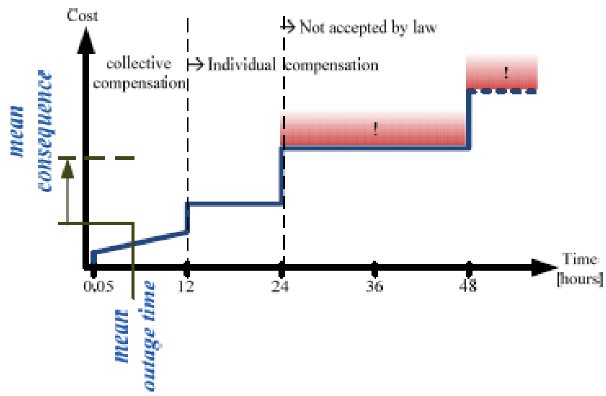

Fig. 7: Illustration of economic consequences of current Swedish regulation (mandatory customer compensation for outages above 12 hours) as exposed in Paper 0313

Potential scope of discussion
Experience of network operation shows that the circumstances resulting in the greatest consequences on the grid are often related to unlikely events severely affecting specific areas in an unforeseen manner. On the other side, risk evaluation and asset management must be based on large amounts of data in order to reach appropriate levels of significance and related forecasts make sense in the average. How can these two issues be reconciled?

Table 1: Papers of Block 1 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0178: Enhancing the asset management process for new demands of decentralized energy integration				X
0208: Risk analysis of alternatives to N-1 reserves in a network with large amounts of wind power	3			X
0302: A methodology for ranking locations according to the likelihood and consequence of extreme events	4			X
0307: Investing in the future - Long-term optimization of asset replacement in the collective regional electricity grids of The Netherlands	5			
0313: Benefits of reliability centered asset management				X
0345: Multi-criteria optimization of maintenance activities				X
0363: Emerging reliability requirements for distribution systems in extreme weather conditions				X
0402: Seismic vulnerability assessment of electric power distribution network in Iran				
0490: Managing uncertainty and updating parameters in electricity distribution asset condition based risk investment models				X
0565: Quantitative measurement of industrial risks in distribution networks	1			X
0567: Implementation and evaluation of commonly used risk analysis methods applied to a regional power distribution system	2			X
0577: Developing indicators for monitoring vulnerability of power lines - case studies				X
0779: On the assessment and management of risk in wind farm distribution systems				X
0848: Experiences from implementing a risk based maintenance strategy using an integrated network information and maintenance system	6			X
1072: Reliability analysis of distribution network investments				X
1153: Reliability Impact Factors Analysis for Distribution in Slovenia				X
1285: Strategic long term planning of asset investments in distribution network using the ASP tool				X
1482: Building a framework for integrated risk management of complex projects: the case of a major distribution network investment				X

Block 2: Network Development

Sub block 1: Innovative Power Distribution

It can be said that electrical distribution has presently become nothing but innovation: the emerging technologies which have become available to manufacturers and the increasing DSOs self-confidence have developed in managing new materials and systems constantly shift the boundaries of “ordinary” activities closing the gap between field and academy. The amount of new concepts and projects has therefore made the matter increasingly rich and diversified.

Sub block 1 deals with innovation not linked to specifically “structured” issues, therefore including advanced system functionalities related - among others - to advanced monitoring and control, quality of service and voltage regulation.

Paper 0323 explores present “state of the art” of Advanced Metering Infrastructure (AMI) and the roles of the different involved parties. Interoperability is found to be crucial in building a coherent “information hub” at national level, which is suggested in order to manage the communication flows related to Smart Metering activities.

Paper 1246 deals with series compensation in MV feeders, and specifically approaches the mechanical impact of the installation of distributed static series compensators (DSSC) in overhead lines (see also figure 8 below). Reducing the reactance of MV feeders can help managing voltage profiles; at the same time, the installation of suspended capacitors necessarily induces additional mechanical stresses on conductors, cross-arms and poles. The paper investigates the possibility of installation of the equipment in existing lines, resulting in practical suggestions in order to minimize its impact.

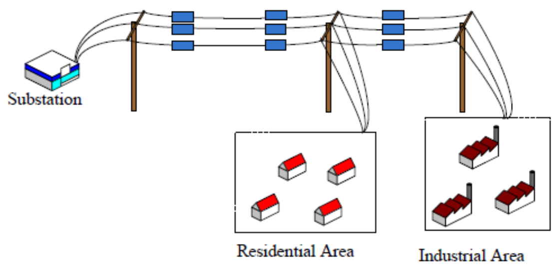

Fig. 8: Application of DSSC in distribution networks according to Paper 1246

Practical effects of the adoption of High-Temperature Superconductor (HTS) equipment in order to reduce network losses are investigated in **Paper 0816**. The authors compare different investment alternatives, including innovative network schemes made possible through HTS, in several time frames implying different price scenarios. Results show that complex distribution systems may economically benefit from the introduction of such innovative equipment, leading to savings in terms of energy losses; however, further developments are necessary in order to perform a complete comparative analyses of different investment alternatives, including reliability evaluations of conventional redundant vs. superconductor-based network schemes.

The adoption of 1 kV as an additional low voltage level is analyzed in **Paper 1420**. As most existing cables are insulated at 1 kV, it can be easily expected that increasing the reference voltage level of existing LV lines, in order to increase the maximum transmittable power, may imply smaller investments and simpler permitting processes than ordinary network reinforcements (see figure 9 below as an example). The paper focuses on 1 kV transformers for 1 kV networks, their characteristics and their optimal sizing and usage.

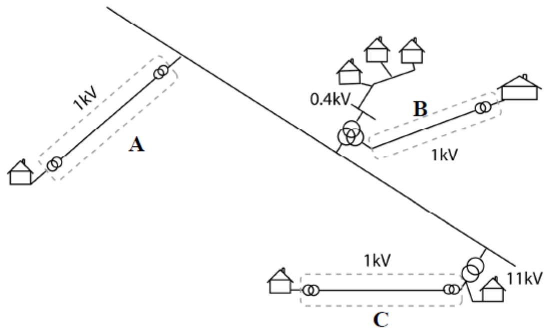

Fig. 9: Possible use of 1 kV in LV refurbishment, as investigated by Paper 1420

Most of the technical innovations, which are currently introduced in distribution network, include automation equipment, which generally requires information exchange in order to perform at its best. **Paper 1461** describes a web-service based model that has been designed to ensure proper integration of components provided by different manufacturers. A case study is exposed, centered on a SCADA system to which field measurements and status information for network monitoring are provided.

Sub block 2: Active Networks

Sub block 2 deals with innovative technologies, including advanced network operation and control, whose introduction is specifically aimed at the integration of increasing shares of distributed generation and the provision of demand response services.

Paper 1096 describes a simulation environment that can be used for the verification of pros and cons in the introduction of advanced control techniques for the management of the network. The simulator modules are based on commercially available tools and can perform both steady state and dynamic behavior analysis, also resulting in useful information in order to define the most appropriate communication needs. A future validation of the test bed though comparison with an existing electrical system is also provided.

Storage systems are a future pillar of Smart Grids and may help increasing DG penetration, but at the same time can be used to contribute to highly reliable operation. **Paper 1211** explores the economical benefits of introducing small-scale storage systems in LV networks in order to minimize the number of interruptions experienced by final customers. The applied methodology is summarized in figure 10. The results show that, even at this stage of maturity of storage systems, the expected benefits in terms of Customer Outage Costs (COC) are comparable with the installation costs of the equipment, thus making the topic attractive, at least in perspective.

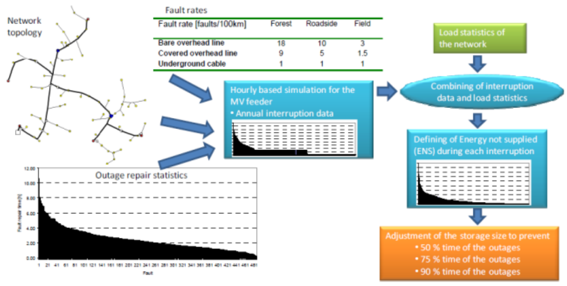

Fig. 10: Methodology to select the size of a small-scale the storage for LV installation, according to Paper 1211

Paper 1340 also deals with storage systems, but from the perspective of the simulation of their electrical behavior. Three different models are therefore proposed and described, resulting in a comprehensive set of tools to represent and evaluate different functionalities that can be granted by a storage system.

The models range from 1-hour to 1-minute to < 1 second step representation, according to the simulation perspective. In detail: larger time-span models can be adopted for capacity estimation and storage sizing; intermediate time-span values are suitable for analyzing the capability of a storage to smooth the injection profiles supplied by distributed generation; high-resolution dynamic simulation is required to evaluate possible storage support during disturbances.

Paper 1237 analyzes the possible use of final customers' flexibility, provided they are equipped with communication devices, which allow information exchange and coordination. Some simulations are run in order to investigate the flexibility of a "virtual plant" of this kind can provide to a stakeholder such as a DSO or a TSO in order to accommodate higher shares of distributed generation.

Sub block 3: Smart Grid Systems and Applications

Notwithstanding the vast majority of developments in distribution system architectures are highly innovative, proper reference to Smart Grid implies the presence of specific set of functionalities and some enhanced flexibility compared to conventional, however advanced, solutions.

Sub-block 3 deals with Smart Grids from this specific point of view, including mostly papers that explicitly mention or recall those characteristics, be it within a more high-level general approach (describing "roadmaps" or evolutionary processes) or detailing some reference Smart Grid infrastructure.

Paper 0718 describes the role of a Smart Operator, taking care of all duties related to the optimal usage of an existing LV network infrastructure appropriately "enhanced" through non-conventional components and through communication and control capabilities. The paper outlines the main characteristic of a funded project that is expected to deliver a demonstration grid in 2013. Equipment and functionalities which are going to be experimented include: Voltage Controlled Distribution Transformers equipped with OLTC, centralized storage system for voltage regulation in LV systems, remotely controlled LV switches, charging stations for EV.

An advanced automation system, resulting in a "self-healing grid", is presented in **Paper 0726** (see also figure 11). Authors describe the implementation of i-Net, a Smart Grid project based on a reference architecture that has been over-imposed on a conventional MV network by adopting innovative equipment and communication and control capabilities, aimed at achieving higher standards in terms of protection functionalities and continuity of supply. Key components of this Smart Grid solution include: continuous monitoring equipment, "intelligent" substations, an optic fiber communication infrastructure and smart metering.

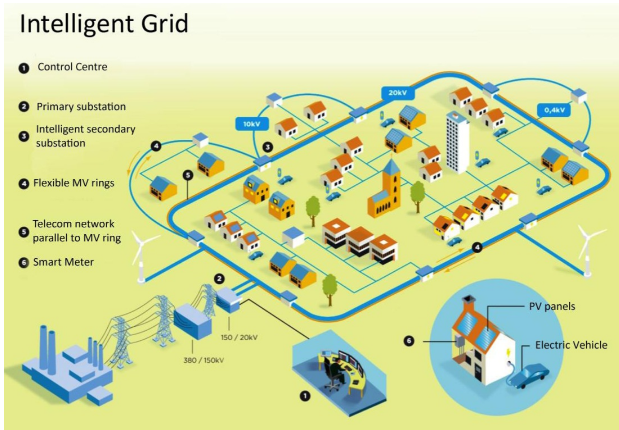

Fig. 11: A representation of i-Net as in Paper 0726

A possible Smart Grid roadmap for Iran is described in **Paper 0487**. Starting from an overview of formalized ongoing processes in other Countries, the authors describe the proposed approach and examine in detail the main drivers leading the transition through Smart Grid in Iran. All main topics related to advanced network management (automation, Smart Metering, Demand Response, Electric Vehicles, etc.) are included into a comprehensive framework inspiring future activities.

Benefits related to the introduction of MV circuit breakers in Ring Main Units instead of switch disconnectors are described in **Paper 0283**. More specifically, the paper presents a specific application of this MV component within an architecture, including fault passage indicators, which allows advanced automation functionalities; protection system and communication requirements are described in detail (see also figure 12 below), and some possible strategies for gradual introduction of RMU are outlined, both in case of entirely new installations and of refurbishment of smaller portions of existing networks. Circuit breakers, combined with FPI, are also suggested as an effective solution for protection of MV/LV transformers.

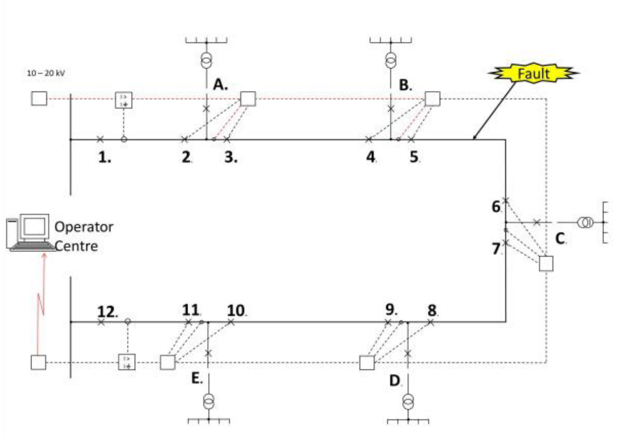

Fig. 12: Fault selection process as described in Paper 0283

Paper 1245 summarizes the present state of Smart Grid initiatives in Slovenia and outlines a Smart Grid Implementation Plan aimed at an optimal introduction of innovative technologies. “Smart” solutions are clustered and evaluated, taking into account research and deployment activities as well, in order to compare their costs and performances to conventional ones. Results show that the implementation of smart grids could lead to smaller amounts of investments in Slovenia for the period from 2011 until 2030. At the same time, it is suggested that investment in Smart Grid do not fully replace those in ordinary equipment, which are still needed although in a smaller quantity.

The impact of Smart Grid functionalities on continuity of service is investigated in **Paper 0667**. The authors analyzes the contribution that some set of functionalities currently related to Smart Grid, such as advanced fault detection and network automation, can provide in reducing customers’ number of interruptions and their duration, resulting in quantifiable economical benefits.

Smart Grid architectures generally imply the availability of a communication infrastructure; in case of Smart Grid functionalities including tele-protection, the reliability characteristics of the communication system are crucial for proper operation. **Paper 0906** describes a methodology to assess the performances of clusters of IP-based applications, resulting in a specification of requirements for the communication system.

Sub block 4: DC Distribution Systems

The possibility to have a DC distribution in MV or LV networks has recently became fashionable again; this cannot be surprising, as the vast majority of new generation and new load is represented by DC equipment, which would easily suit to a DC grid. At the same time, proper integration of DC portions with the existing, conventional AC grid must be investigated and ensured.

Sub block 4 goes deeper into this topic and delivers some interesting hints about individual components, implementation strategies and global system evaluation, all related to DC technology.

Protection systems’ effectiveness is crucial in future LVDC development. **Paper 1330** examines the behavior of a given network in terms of short circuit current, comparing simulation results to those coming from the application of IEC 61660. To do that, a test network, represented in Fig. 13, is defined and analyzed. Results show that short circuit currents determined according to IEC 61660 are accurate enough when it comes to steady-state values, while they may be underestimated, compared to those coming from simulation, in case of transient phenomena. In detail, peak values determined according to IEC 61660 are less severe and decay time is significantly shorter than the corresponding simulated values.

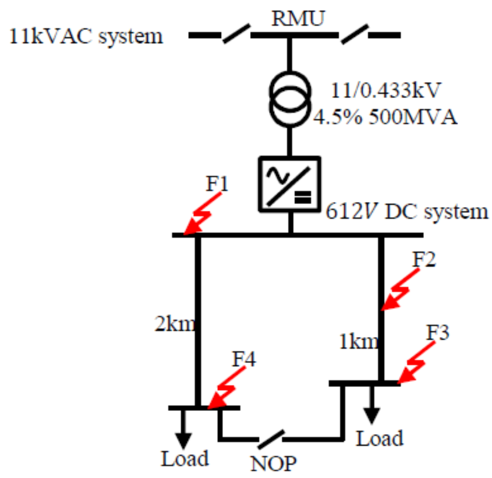

Fig. 13: LVDC network model used for short-circuit calculations in Paper 1330

Paper 1292 exposes a comprehensive system approach to a LVDC system, starting from the evaluation of all possible benefits and challenges of this solution. The selected approach helps underlying the relationship between use cases, linked to specific reference users, and optimal DC system configuration and sizing. The paper recommends a gradual standardization process in order to maintain an adequate level of flexibility in DC networks design at a stage in which technology is not yet completely mature.

Paper 1039 shows how existing MV feeder may be conveniently transformed into unipolar or bi-polar LVDC systems. A comparison between the three phases systems is then performed, evaluating their performance in terms of reliability, energy losses and equipment costs, in order to define the economical LVDC penetration rate (see also Fig. 14). The first results show that, under present economical conditions, transformation of MV branches into LVDC systems may be beneficial in case of high shares of connected DG and of severe reliability requirements from customers' side.

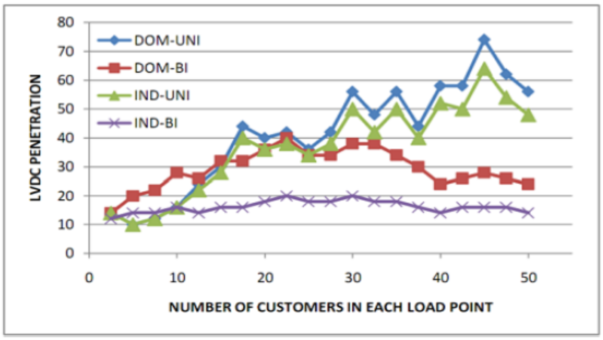

Fig. 14: Minimum economic LVDC penetration rate for domestic and industrial loads as determined in Paper 1039

A complete evaluation of the potential of adopting LVDC in a Finnish distribution utility (Elenia Oy) is exposed in **Paper 1151**. Following the positive results from a pilot implementation, the authors describe a full development process, starting from the definition of a reference LVDC architecture. The transfer capacity of LVDC system is evaluated in order to understand where they can replace existing MV branches while complying with all physical and contractual constraints regarding components' utilization and quality of supply. Results show that, under these conditions, almost 20% of the existing MV network operated by Elenia Oy could be successfully converted into LVDC.

Paper 1439 shows the other side of DC, dealing with the HV connection of large wind farm. The paper, compared to two established solutions such as HVAC submarine connection and traditional HVDC with centralized DC conversion, proposed an alternative approach to HVDC based on a decentralized installation of AC/DC converters at MV level and modular Hybrid MVDC/HVDC transformers.

Potential scope of discussion

The innovation in distribution systems requires new components and new ways of integrating them into existing or innovative architectures; technological scouting leads to the discovery of unconventional components which have not necessarily been built for public distribution. This may bring to the construction of electrical systems in which the "customary" or tailor-made part accounts for more than usual, standardization rules being largely unavailable. However, in order to maximize the collective benefits through appropriate share of knowledge and experiences, standards are necessary and must be defined as soon as possible. What would a possible path to standardization in this field look like ?

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0283: Smart Ring Main Unit Reduces Outages to a Minimum				X
0323: Interoperability of AMI systems				X
0487: The challenges in developing a smart grid roadmap for the distribution network of Iran				
0667: Potential for improved reliability and reduced interruption costs utilizing smart grid technologies				X
0718: Improving quality of supply and usage of assets in distribution grids by introducing a "smart operator"	10			X
0726: iNet, the reality of an intelligent distribution network	11			X
0816: Investigating the potential impact of superconducting distribution networks			X	
0906: QoS assurance in smart grid for IP based applications of Mashhad Electric Energy Distribution Company				
1039: Determination of LVDC System's Economic Penetration Rate in MV Branches				
1096: A testbed for the assessment of active network management applications using simulation and communications emulation				X
1151: The utilization potential of LVDC distribution	12			
1211: Utilization of energy storages to secure electricity supply in electricity distribution networks				X
1237: Flexibility dynamics in clusters of residential demand response and distributed generation	8			X
1245: Smart grids implementation plan in Slovenian distribution networks				X
1246: Feasibility study of application of DSSC in distribution networks	7			X
1292: A system engineering approach to low voltage DC distribution				X
1330: The effectiveness of using IEC61660 for characterizing short-circuit currents of future low voltage DC distribution networks				X
1340: Storage simulations for distribution system analysis	9			X
1420: System topologies and transformers for 1kV networks				X
1439: Offshore renewable plant HVDC power collector and distributor				X
1461: Power system information integration technique based on service oriented architecture				X

Block 3: Distribution Planning

Sub block 1: General Planning

The papers of Sub block 1 refer to general planning algorithms that are proposed to solve classical distribution planning problems as the optimal feeder or the location and design of substations. The optimization is led by economic reasons or by the need of improving both reliability and power quality. Technological novelties such as Smart Meters or advanced sensors stay "behind the scene", offering more sophisticated inputs to a planning process that, nevertheless, still remains conventional.

Some papers are mainly focused on algorithms for expansion planning in the medium and long term. Some propose well-known techniques adapted to a particular case study, some others develop novel implementations or adaptations of new techniques.

Paper 0227 describes some planning techniques that have been developed in order to take into account real data coming from Smart Meters or Power Quality measurements. These information can be used to fine-tune investment plans in order to avoid unnecessary expenditures, such as network reinforcements not related to ascertained criticalities. Results show that in several cases the conventional values commonly adopted in traditional network planning, such as P_{max}, may be significantly overestimated, potentially leading to more-than-conservative investment plans.

A way to use Smart Metering data to optimize LV network condition is presented in **Paper 0609**. A systematic collection of metering data is operated and, by introducing load values as input just as network topology and electrical characteristics, load flow calculations are run, analyzing previously happened operational conditions; the whole process is represented in Fig. 15. Criticalities can therefore be found on the basis of real load conditions, and interventions on existing network can be planned, starting from simple phase balancing. A small-scale case study is described, in which the described methodology is applied to 350 LV feeders.

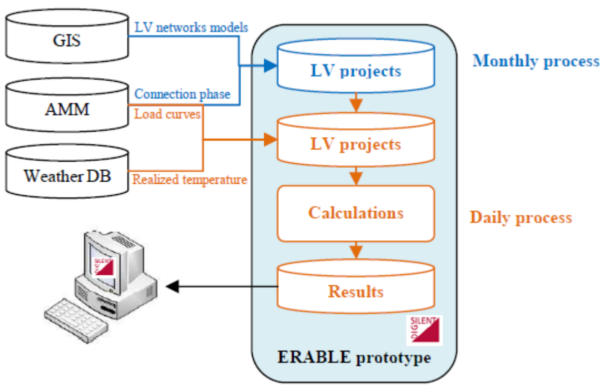

Fig. 15: General architecture of the prototype presented in Paper 0609

If distributed generation may undoubtedly represent a new challenge for network planning, also "traditional" passive loads may result in unconventional common mode behaviors in specific geographic conditions which are far from being "average"; more than this, specific appliances may have an uneven penetration in different areas. Starting from this general consideration, **Paper 0868** develops a probabilistic approach to traditional and future load forecast in order to define more accurate criteria for determining the contemporaneous effect of different technologies for loads and generators.

A planning tool for LV network planning, combining a geographical information system with genetic algorithms, is presented in **Paper 1144**. Authors describe the process through which an optimal MV planning is obtained by using both GIS capabilities and GA functionalities to define electrical and topological feeder characteristics.

A planning tool integrating GIS functionalities and electrical calculations' capabilities is presented in **Paper 0182** (see also Fig. 16). The potentialities that such a system, combining geographical information about the network with state-of-the-art electrical design algorithms, can offer in network planners' everyday activities are shortly outlined.

Fig. 16: Geographical representation of a MV network as described in Paper 0182

Paper 0351 investigates utilization level of MV/LV transformers. The relationship between this parameter and minimum total investment cost in two reference situations are studied in order to define standard parameters for network planning. Results show that not necessarily the highest utilization levels of transformers result in lowest investments.

A methodology to assess wide distribution areas, taking into account uncertainty of data, in order to foresee future criticalities and plan network expansion is exposed in **Paper 0548**. Authors deliver an accurate description of the process, based on a k-means cluster algorithm, and of its application to a case study of a portion of an urban network including 3 11 kV feeder, 69 MV/LV transformers and 19 km of LV feeders.

Paper 0624 approaches a multi-stage grid expansion problem also including topological changes and storage devices. To solve the problem, authors propose a so-called "Split & Stint" algorithm of heuristic type; some case studies (as shown in figure 17) are exposed in order to validate the methodology in some reference networks.

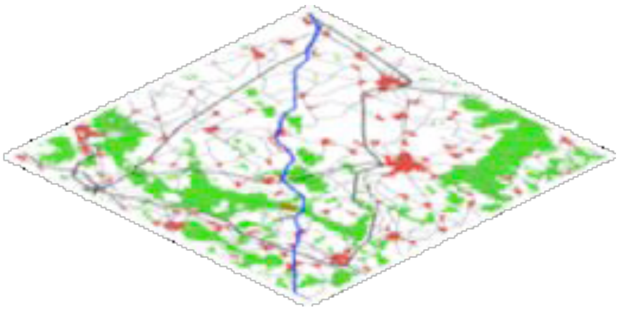

Fig. 17: Example of a cost map as defined in Paper 0624

A comparison among most commonly used multi-objective approaches to network planning is performed in **Paper 0347**. The study evaluates strengths and weaknesses of several sets of methodologies with reference to main objectives such as continuity of supply, investment reduction, loss reduction, and so on. Results show that some methodologies may ensure a better composition of a wide range of conflicting objectives, while others are more effective in pursuing the most relevant among them.

Paper 0132 compares the return of a given investment under different economical conditions, performing a sensitivity analysis related to parameters such as energy price, inflation, etc.. The authors show that an accurate choice of the evaluation factors is pivotal in formulating robust investment plans.

Optimization of LV network, also considering the possibility to build and operate some portions of it as DC systems, is dealt with in **Paper 1063**. A complete evaluation of different alternatives, including hybrid AC/DC solutions, is performed in a given network, finding the optimal solution for each one of them, and taking into account investment, loss and also customer interruption costs. Authors claim that, in the examined case, hybrid AC/DC network implementation is more economic than pure AC and DC networks.

Continuity of supply (CoS) as a function resulting from the combined effect of past investments, ageing and weather conditions is analyzed in **Paper 0415**. The proposed methodology assesses a specific CoS indicator, namely TIEPI, expressing it as a statistical function that can be forecasted, within a confidence interval, once the abovementioned drivers are defined.

Network planning traditionally relies on "static" performances of standard components; however, dynamic rating of their characteristics may lead to different conclusions, resulting in a significant reduction in planned investments. **Paper 0807** describes a study on a real portion of a 132 kV distribution network to which large amounts of wind generation are to be connected. Real-Time Thermal Ratings (RTTR) are used to evaluate the capabilities of several proposed overhead lines, also depending on their real route and the resulting thermal bottlenecks. Results show that dynamic rating may lead to different conclusions than a static one: in details, it appears a wind farm of 140 MW can be connected to a conductor which could accept 90 MW according to its static rating.

Sub block 2: Automation and Reactive Compensation Planning

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, but the process is more or less the same.

Sub block 2 deals with specific planning problems, often related to optimal placement and sizing of discrete components such as actuators, fault passage indicators, capacitors' banks, fault current limiters, and so on. In most cases, therefore, the content of the paper consists in newly-developed or adapted algorithms to find optimal placement conditions.

Combined optimization of network expansion and automation is examined in **Paper 0187**. In this case, however, priority is given to the definition of the network expansion problem, automation being taking into account by simply assuming a certain reduction in resupplying time intervals. A case study is run on a 24-node test network, represented in figure 18, and it is shown that the proposed algorithm, based on a profit-maximizing model, can lead to more expensive solutions than the minimum-cost model; nevertheless, investing more money to get more profits can lead to better results in a competitive environment.

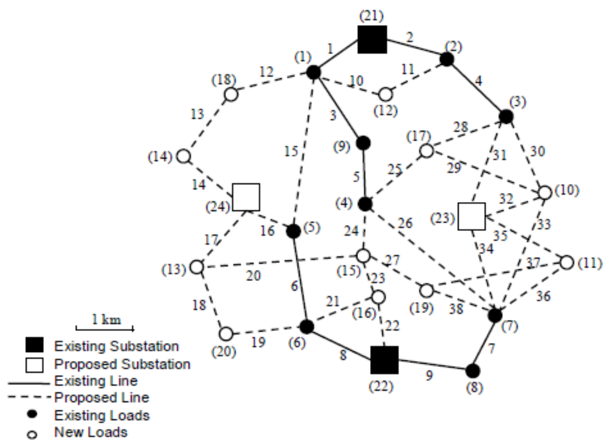

Fig. 18: 24-node test network under study in Paper 0187

Paper 0087 deals with reactive power compensation by resorting to the installation of capacitor banks in MV radial lines. The problem consists in finding the optimal capacitor sizing and placement in order to maximize investment profitability resulting in a reduction of energy losses; voltage variations in the nodes are assumed as negligible. For solving the problem, a combined heuristic and interval mathematic method is used. Successful implementation of the method is described using a ninebus test distribution feeder.

A complete overview of the fault repairing process is provided in **Paper 0553**. The authors describe in details this strategic activity and the interrelations and information exchange between field crew and the internal functions involved. The systems and tools adopted are also indicated and synthetically described.

Paper 1243 explores the benefits that storage systems can provide to a distribution network integrating renewable energy generators. The authors present a planning algorithm that simulates the yearly operation of distributed energy storage units connected at the MV level to maximize the profit drawn from market operation while respecting voltage and reserve requirement constraints. The different storage capabilities are represented and modeled, and the problem is defined in the form of a non-convex non-linear optimization problem, and then split in a master and a slave problem. The proposed algorithm is then applied to a standard 69-bus network.

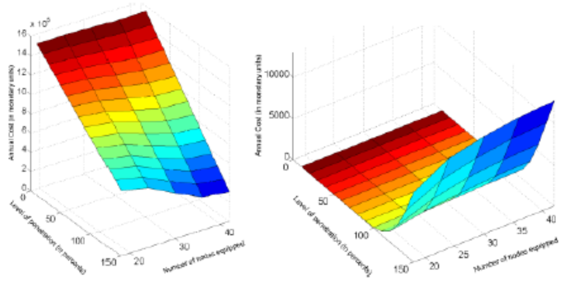

Fig. 19: Total annual scheduling cost and Cost of voltage control for various deployment scenarios as in Paper 1243

Paper 0124 is about optimal placement of fault current limiters. These devices can be usefully adopted in case short-circuit current exceeds components' capabilities; the placement of these equipment can therefore be optimized in order to achieve the highest levels of effectiveness. In the paper a harmony search algorithm is used in order to solve the problem of containing fault current within the admissible boundaries while minimizing the quantity of installed devices.

Sub block 3: EV Accommodation Planning

The increase of the consumption related to EVs in the near future is not a debatable matter anymore, however it is not easy to foresee at which extent it will happen. At the same time, it can be expected that EVs can also contribute as active components of the network, provided they can be managed in a V2G perspective. This conceptual framework encourages the development of model and algorithms related to EV behavior and the evolution of network structure and performance.

Sub block 3 deals with methodologies to analyze the evolution of the electricity needs and capabilities related to EV and to plan the expansion of the distribution network in an optimized way.

Paper 1266 describes the 2030 scenario for the metropolitan area of Milan, assuming a massive penetration Fast Charging EV and stations for electric mobility in the existing fuel stations. The study shows that, as a general rule, it can be expected that some criticalities occur in distribution network as peak loads required by EV generally happen at the same time than existing peaks; however, robust urban grids are more likely to be able to support the increasing load than rural ones. The paper also investigates the use of storage systems in hybrid FC/fuel stations to mitigate the effect of EV.

The same described effect in the case of electric hybrid vehicles is investigated in **Paper 0186**. Authors start from considering the technical characteristics of existing PHEV and develop an analytical model assessing the impact of massive introduction of the technology. Results show that combination of existing load peaks and future ones related to PHEV may severely affect the distribution grid.

Also **Paper 1500** deals with the expected impact of Fast Charging stations to support the EV massive introduction. A real network, located in Northern Italy, is investigated to understand under which condition significant criticalities may arise and how to manage them. The paper demonstrates that in the planning process, network reinforcement is very sensitive also to small variations in the hourly load profile for the EVs, which leads to a very cautious approach to load modeling. The impact of FCS, for a given load condition, can anyway be mitigated through dedicated connection infrastructures such as storages; however, the authors suggest that the level of uncertainty which is inherently linked to EVs and related infrastructures development, calls for probabilistic criteria in network planning.

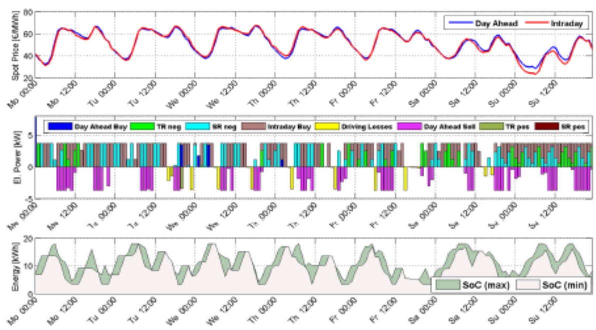

Fig. 20: An example schedule of V2G strategy "Charging with Reserve" as in Paper 0622

Paper 0622 investigates how V2G can be a crucial issue in the introduction of EV in the market. An evaluation of the market potential of V2G services (namely reserve) is performed and different strategies are analyzed from the EV owner's point of view, supposedly joining the energy market. Results show (see also figure 20 above) that participation to the Intraday Market can bring additional benefits to those already provided by EV, making the business case even more attractive.

Paper 1456 investigates the impact of EV on the distribution network of the living lab of 'Rotterdam test electric driving'. A complete study is performed, starting from load profiles of conventional customers and EV, evaluating their impact on MV/LV substations and analyzing possible criticalities. Further developments can be expected in the near future, as the project in still ongoing.

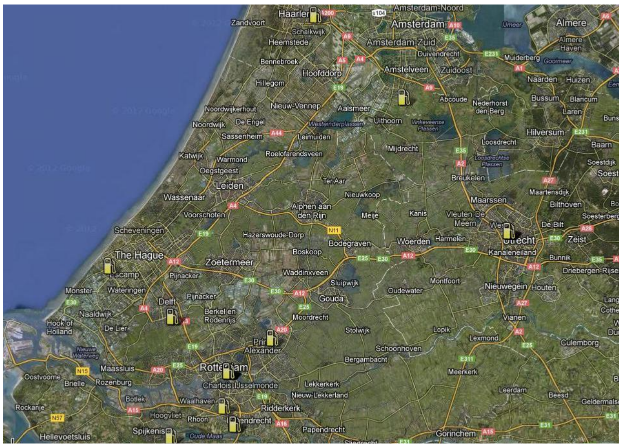

Fig. 21: Locations of the measured charging points as in Paper 1456

A comprehensive simulation model representing the whole "driving experience", including traffic, EV charging, electrical distribution and power generation, is presented in **Paper 0840**. The simulator can also take into account the effect of environmental parameters, such as temperature, on EV performance in terms of vehicle consumption and charging losses. Algorithms have been developed to allocate individual consumption to single vehicles in order to analyze the impact on the network and the power system. A case study is then described, in which the simulator is used to analyze different charging strategies for a given area.

A methodology to optimize distribution system planning in presence of PHEV is proposed in **Paper 0531**. The authors describe the problem of finding the best charging strategy for a given system by means of Artificial Immune System enhanced by incorporating tangent vector to help in the search direction. The algorithm proceeds starting from avoiding any voltage violations and, once ensure that, aims at minimizing energy losses; result show that the introduction of TV helps accelerating the computation and give better results, leading to a truly efficient process.

Paper 0861 presents a methodology for the assessment of the impact of EVs on the distribution network of two power utilities in Brazil. Firstly, a possible distribution of the EV in the network is estimated through deterministic and probabilistic algorithms; secondly, EV characteristics in terms of type of battery, state of charge, etc. are also foreseen according to probabilistic variables; thirdly, different loading profiles and strategies, also according to expected tariffs, are considered. The impact on distribution networks is then evaluated, analyzing the loading of feeders, secondary networks and distribution transformers and verifying the voltage profiles and losses.

Sub block 4: Distribution Planning in the Era of Smartgrid

The distribution planning is one of the most traditional activities in distribution companies. Recent CIGRE C6.19 papers and reports highlighted the main stages of the planning process as generally carried out in companies. Papers of this block are often aimed at describing how planning procedures and algorithms should be changed in order to make them suitable to the incoming new world. Some papers focus on the optimization techniques, some demonstrate with business cases the importance of changing planning procedure in order to capture and not be prone to uncertainties of RES generation and fast changes in load demand.

Figure 22 and 23 from **Paper 1046** clearly show the most relevant activities of planning and highlights the areas most affected by innovative distribution systems, where the high shares of RES, the novel load patterns obtained with demand side integration (DSI) and the incoming electric mobility require new tools and methodologies.

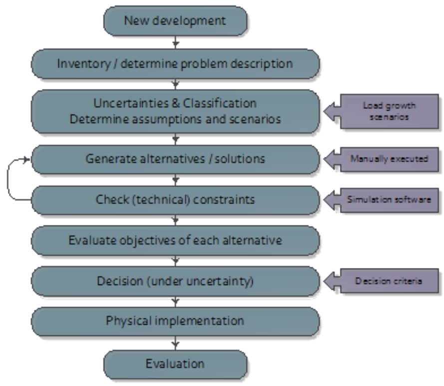

Fig. 22: Typical planning structure framework according to Paper 1046

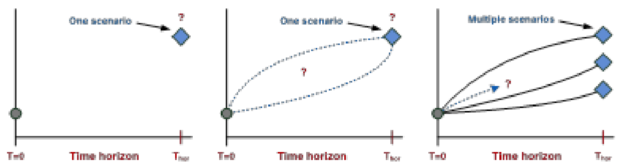

Fig. 23: Graphical impression of static, dynamic and dynamic uncertain planning (Paper 1046)

It is clear that the existing tools and planning procedures have serious shortcomings for future application. As a result DSOs require improved methods and tools for network planning in order to guarantee an affordable, sustainable, and reliable electric energy supply. These tools need automated generation of alternatives as well as optimization capabilities, since inclusion of time aspects and new (smart grid) planning options substantially increase the number of possible network expansion alternatives. Moreover, automation can reduce the effort required and improve consistency (i.e. contributes in standardizing the planning process). Applying multi-objective optimization methods will present decision makers a collection of different "trade-off" solutions. Overall, these properties require very efficient optimization techniques. Advanced decision support tools would thus greatly help DSOs to make better decisions under uncertainty, which contributes to an affordable, sustainable, and reliable electric energy supply.

Papers selected in Sub block 4 therefore deal with comprehensive methodologies and algorithms that have been studied and proposed in order to include in the planning process the already available or foreseen capabilities and/or roles, resulting in a more efficient use of the infrastructures, an increase of the expected level of performance and/or an enhanced interaction between the different sets of users.

For sure distribution planning in the new context of smart grid and active distribution networks will be based on a huge amount of information that was not necessary in passive distribution planning, as **Paper 0559** well explains. Therefore, the development of information systems for active distribution planning should closely track the development of a variety of new type electricity customers, make full use of smart meters to collect, aggregate and mining information.

Paper 1426 deals with LV and MV distribution planning in Norway and focus on the importance of considering the operation and ICT capabilities in planning. As the authors said, with ICT and operation the light will come, and new possibilities will occur to planner engineers. Conversely, data management and data security problems will arise and new possible threats will have to be faced. Anyway, the classical planning paradigm used by NTE will remain valid but more different alternatives will have to be compared and generated.

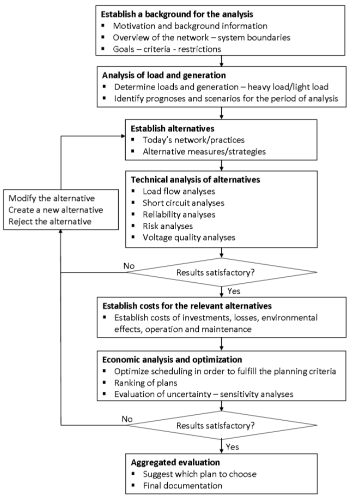

Fig. 24: Planning process as proposed by Paper 1426 and in good agreement with the Scientific literature

Paper 1370 reports some of the findings of the CIGRE WG C6.19 that deals with planning for active distribution networks. The authors show that ICT technologies are critical components in the successful deployment of active distribution networks because power delivery systems are expected to become increasingly reliant on these technologies (see Fig. 25). ICT should be considered when evaluating ADS reliability with some issues and approaches presented in the paper. Further work on the planning of ADSs is due to be disseminated by the CIGRE C6.19 WG report in 2013.

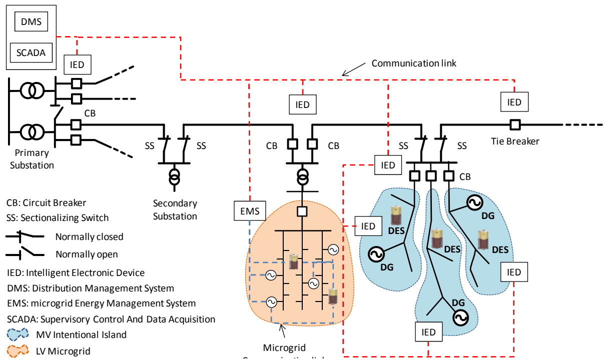

Fig. 25: Schematics of an active distribution network with self-healing functionalities from paper 1370 (the pervasive role of ICT is clearly evident)

The problem of a proper assessment of “Smarting Actions” is dealt with by **Paper 1495** where Key Performance Indicators (KPI) are proposed to comparatively assess the benefits from typical smart grid-like operation. The authors applied the proposed KPI to assess the exploitation of FACTS devices, the increasing of network rated voltage, and the centralized control of the reactive power from RES. The simulations confirmed the validity of the proposed KPI to rank the effectiveness of the examined actions.

Paper 500 deals with the new challenges faced by distribution planning. Particularly, the authors focused on the need of integration between asset management and planning. The paper proposes an integrated planning architecture whose planning rules have been defined by German DSO planning engineers.

The main features of the proposed methodology (see Fig. 26) are the integration of asset management with the expansion planning, the adoption of probabilistic models and scenario analysis, and the exploitation of financial and economic optimization techniques. The paper presents first results of the “Smart Planning” approach: contingency analysis, scenario matrix generation, and practical rule-sets for network expansion and maintenance planning. The developed “new” integrated approach will be used for an analysis of a real distribution system. The practicability will be demonstrated by end of 2013 by integrating the different modules in the asset optimization process.

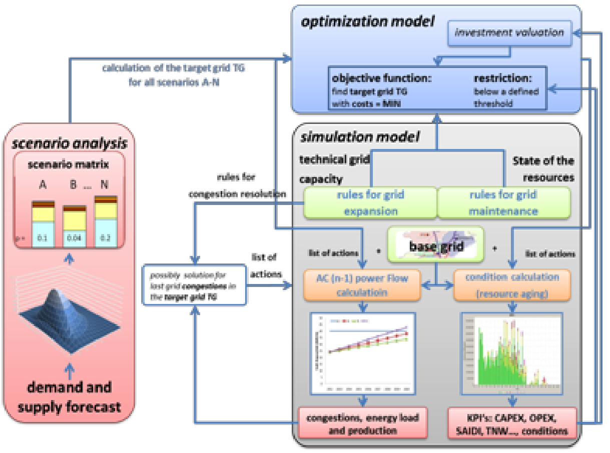

Fig. 26: Integrated architecture for Smart Planning (Paper 500)

Paper 1178 and **Paper 1356** deal with a joint research effort in France by EDF R&D and ERDF. In **Paper 1178** the expected scenarios for RES integration are deeply investigated and the investments for network reinforcement are shown. Figure 27 shows the expected cost per unit installed. It is worth noticing that the greater the RES power capacity the greater is the need for building new portions of the grid or for upgrading the existing network. Alternatives, no-network solutions, are investigated in the paper in order to avoid or minimize the financial impact of RES connection. Local reactive power control for voltage regulation is estimated to allow reducing by 30% and more the expenses caused by new MV generators. Local active power control can also reduce the economic impact of new MV connections but its worth is strongly dependent on the regulatory framework that is not really ready for active and smart distribution. From these studies the authors conclude that planning should be changed and more planning alternatives have to be considered in planning.

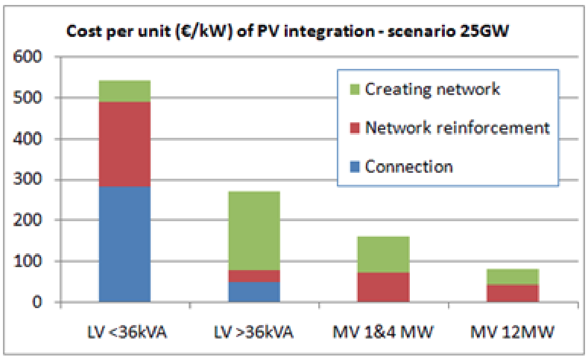

Fig. 27: Expenditures caused by the connection of PV in France (Paper 1178)

In **Paper 1356** a tool to assess the value of possible alternatives to the grid reinforcement is described and applied to some significant case studies. Particularly, grid reinforcement, the use of distribution storage, and generation curtailment are compared in a real distribution network. This is an excellent exercise since, as it has been proved by CIGRE WG C6.19 work, DSO do not take care of Smart Grid options in their planning studies and one cause is the lack of reliable, industrial sound business cases. The results showed in Fig. 28 are for this reason of the maximum importance.

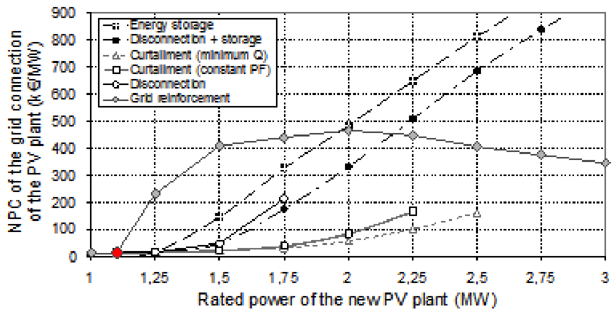

Fig. 28: Net present cost of each studied solution vs. the rated power of a new PV plant in Paper 1356

Also **Paper 0847** proposes a novel planning methodology to show the impact of new Voltage Controlled Distribution Transformer (VCDT) in German rural distribution networks. Particularly, the authors show how VCDT can be used for voltage regulation in a wide area of the distribution network. Finally, the pro and cons of VCDT are analyzed with particular attention to the deferment or the avoiding of MV reinforcements. Figure 29 shows the benefit of VCDT that will be able to handle the increasing of generation and load demand in 2025 without any problem.

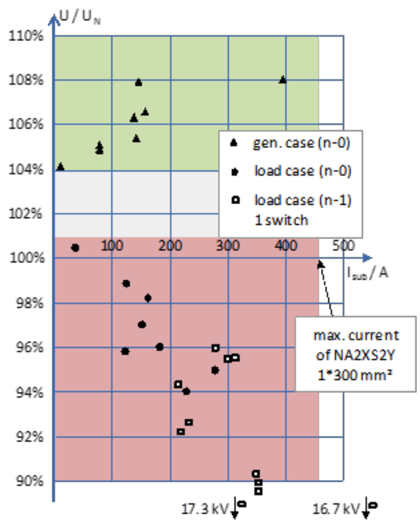

Fig. 29: Maximum voltage level and maximum feeder current related to each substation feeder at Nettlingen 2025 (Paper 0847)

Paper 0827 deals with the problem of assessing the contribution of distributed generation in network capacity planning. The paper discusses the definition of capacity value of DG arising from its ability to support additional demand without the need for new network capacity, in analogy with the definition of Effective Load Carrying Capability (ELCC) at transmission level. Understanding the quantification of the contribution of DG within relevant reliability calculations will certainly be of value in guiding discussions over standards. There is a natural desire to define a standard directly in terms of circuit capacities and capacity values of other resources rather than via a full probabilistic calculation. If no systematic way can be found to define such a standard then a natural conclusion may be that a full probabilistic standard is required. But probabilistic reliability analysis have not traditionally formed a core part of a planning engineer's skill set, and it is desirable for engineers to be able to take full ownership of the analysis which they use to take decisions.

Since many RES have been connected or are going to be connected to the LV distribution network, planning algorithms are necessary to deal with this not enough considered portion of the distribution network. **Paper 0229** and **Paper 0888** go in that direction.

Paper 0229 describes an integrated network Planning And Design Decision Support (NPADDS) tool for the integration of low carbon technologies and solutions. In order to consolidate the differing network and connectivity models expressed by DEBUT™, IPSA™, Northern Powergrid and other DSOs, a generic model for representing and communicating electrical networks is required. To meet this need, the Common Information Model (CIM) was selected for use in both the NPADDS software layer and the Oracle network database. Even though NPADDS (see figure 30 below) does not seem to be completely aligned with the most modern concepts of distribution planning, the use of solution templates provided by the software solution engine is quite interesting as well as the possibility to make calculations not only based on the worst case scenarios, but also with more complex, but more precise, Time of Use models.

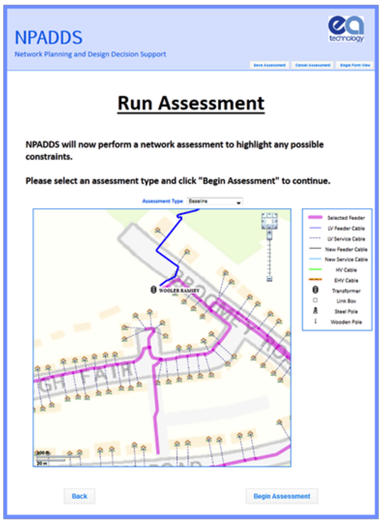

Fig. 30: The NPADDS network wizard in Paper 0229

Paper 0888 from Sweden also deals with the problem of the increasing connection of PV at LV distribution level. The paper aims at defining some practical and easy-to-use connection guidelines based on the usage of a rigorous planning study to assess the hosting capacity of distribution networks with existing high quantities of PV installed. For this purpose, the authors firstly defined an LV Swedish representative network and applied on it a simple worst case criterion to identify the maximum PV that can be hosted by system. However, it should be noted that the actual power the grid can handle is higher than what the guidelines suggest. The proposed method also can be used to identify the critical points, where reinforcement is needed. This study has shown that the locations of the PV can impact on the hosting capacity. The proposed method provides conservative results, so if a PV has higher capacity than the guideline suggests, a more detailed study is necessary.

Paper 1284 adopts a similar approach for LV analysis in a rural network in Austria with dispersed generation installed, and proposes an interesting integration of measured data and power flow simulations. The simulations of representative distribution networks under consideration of different load cases till 2020 and 2030 show the limits of network components in respect of demand growth and decentralized generation. Finally, the authors found that the influence of a reactive power feed-in is not so significant than the supply of active power into the low voltage network (as shown in figure 31). The reactive power can influence the voltage change only in a restricted way but increases the current load of network components.

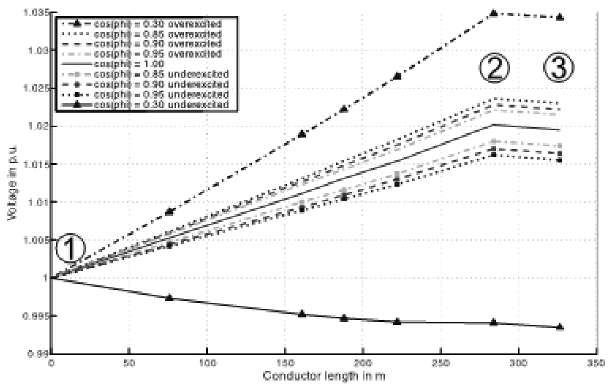

Fig. 31: Paper 1284 - Simulation results, active power P = 45 kW, variable power factor cos φ (over- and under-excited)

Paper 1361 deals with the planning of LV distribution networks, but the proposed planning methodology is probabilistic to avoid the risk of too much conservative solutions. The authors avoid the use of worst-case scenarios to estimate peak loads considering that today's grid planning needs to account for new technologies like dispersed generation and electric vehicles. A worst case approach, for example, would consider generation without any simultaneous load. However, in practical experience there is always a minimum load, which mitigates the effect of voltage rise due to generation. The paper gives interesting information about the probabilistic aggregation of load demand (see e.g. figure 32), RES generation and electric vehicles. The main idea of the paper is to explicitly use the risk of overcoming technical limits to guide the optimal choice of feeder cross section.

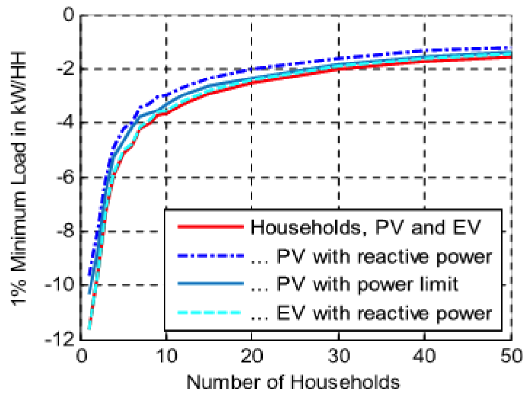

Fig. 32: Minimum active power causing voltage rise on feeder with influence of photovoltaics and electric vehicles (Paper 1361)

Paper 1453 gives an excellent analysis of the influence of generation curtailment priority on network hosting capacity (see also figure 33 below). In the transmission network, generation curtailment is an established methodology to tackle congestion. In passive distribution networks, curtailment is rarely used as the 'worst-case' conditions, typically maximum generation and minimum demand, largely determine the hosting capacity. This guarantees the network can operate without any additional control requirement but it reduces the potential energy that can be harvested from distributed generation (DG). Given the infrequent occurrence of the worst case conditions, the introduction of active network management (ANM) can provide technical and economic benefits, and facilitate DG connections. The paper compares the simple "*First In Last Out (FILO)*" curtailment scheme with other schemes based on OPF calculations.

DG	Capacity (MW)					Energy (GWh)					Curtailment (%)				
Location	Base	FILO_A	FILO_B	OPT	PROP	Base	FILO_A	FILO_B	OPT	PROP	Base	FILO_A	FILO_B	OPT	PROP
DG A	15.0	16.3	15.2	15.6	15.8	131	138	133	135	129	0%	4%	0%	1%	7%
DG B	4.2	4.7	6.1	6.4	6.2	37	41	54	51	51	0%	0%	0%	9%	7%
DG C	3.0	3.1	5.7	5.5	4.7	26	27	38	42	39	0%	0%	24%	13%	7%
DG D	2.3	4.2	3.1	3.3	3.4	20	30	27	27	27	0%	19%	0%	9%	7%
DG E	2.4	3.4	4.5	4.3	4.1	21	29	32	33	30	0%	0%	18%	12%	7%
Total	27.0	31.7	34.6	35.2	34.2	237	266	284	288	276	0%	4%	8%	9%	7%

Fig. 33: Comparison of DG capacity, production and curtailment under different curtailment priority schemes (OPT stands for the Optimal Setting Curtailment Scheme while PROP for the Proportional Curtailment scheme) in Paper 1453

All curtailment schemes, even if inappropriate, deliver benefits to passive networks and allow increasing the hosting capacity. The paper demonstrates that multi-period OPF is not only technically appropriate, but also economically beneficial. OPF is better than sensitivity analysis, particularly if DG is used for Volt/VAR regulation. The issue of fairness is important where DG has been connected on a firm connection basis and where reversion to non-firm operation would deliver substantial increases in output overall.

Paper 0292 deals with a strategic planning methodology that aims at assessing the DG optimal capacity mixture for hybrid benefits. Fig. 34 shows the proposed algorithm to evaluate the optimal mixture of dispersed generation. This paper proposes a hybrid approach to assess the DG capacity mixture taking into account network benefits and benefits external to the network. Network benefits are assessed by minimizing the cost to offer a reduced tariff to the electricity consumers. Life cycle costs of generation assets are also incorporated for assessing the DG mixture that results the minimum cost through network internal benefits. External benefits are quantified through the reduction in volumes of greenhouse-gas emissions. Both types of benefits are compiled by the application of carbon tax provision into the reduction in greenhouse-gas emission. The entire approach drives through the sequential simulation of optimized samples capturing intermittent effects of DG and demand level variations at each customer sector in an active distribution network environment.

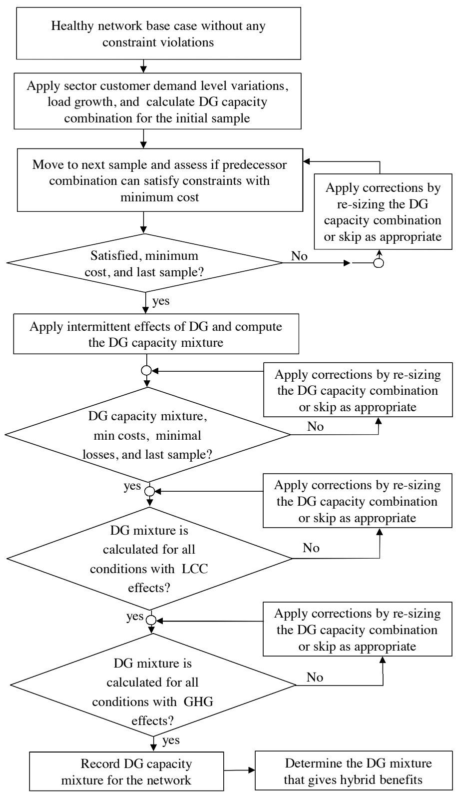

Fig. 34: Overview of DG mixture assessment used in Paper 0292

Also **Paper 851** deals with the optimal allocation of dispersed generation. A multi objective optimization is proposed to determine the optimal size and location of distributed generation in the distribution network. In this paper the cost of DG investment, maintenance and operation is considered in objective function as well as the benefits of load supply cost reduction and reliability improvement.

Two papers - **Paper 0897** and **Paper 1475** - deal with the central role of demand side integration in planning. Indeed, the flexibility of the demand can give many new opportunities to distribution planners and is one the most important features of active distribution.

Paper 1475 presents an overview of the activities of CIGRE WG C6.19. The authors describe demand side integration and electric vehicles potentialities for distribution planning. **Paper 0897** proposes a practical demand response program for industrial loads and a novel load-scheduling algorithm. Besides, customers' satisfaction is modeled with a load-shifting index. A fast algorithm is presented to solve the proposed optimization problem. The merit of the paper is to consider industrial load in demand side integration. Indeed many demonstration and research projects worldwide aim at involving residential customers DSI, but industrial loads, which can easily contribute to solve network issues, are not duly considered.

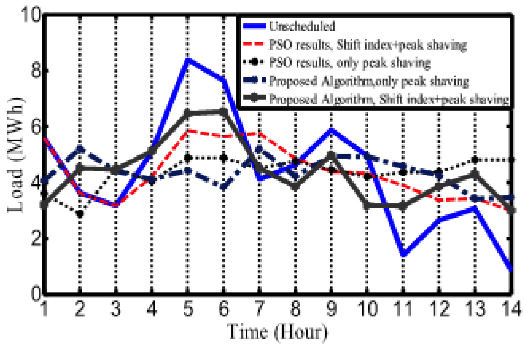

Fig. 35: Total load before and after scheduling the proposed algorithm in Paper 0897

Paper 1035 deals with the optimal operation of microgrids. Microgrids have control facilities for performing particular managements to improve reliability indices. The paper propose an algorithm for the intraday optimization of DER in the microgrid.

Finally, a block of three interesting papers deals with the impact of RES in distribution networks. The papers are not focused on planning algorithms or novel methodologies for active distribution networks. Anyway, these papers propose interesting results, which can be used for the planning of distribution under the pressure of the integrating PV and RES in LV distribution systems. **Paper 0257** deals with the expected impact of PV on the meshed LV distribution network of Eindhoven (The Netherlands) depicted in Fig. 36. The authors observed that when all the connected PV panels produce electricity at their full power, the existing network would not be able to fulfill the voltage conditions of standard EN50160. Moreover, station transformer and some of the feeding cables will also be overloaded. Besides that the modern PV panels with a built-in voltage sensor can be installed that can sense voltage condition at its terminal and accordingly switch on and off or will control the amount of PV-power to adjust generation from the panel.

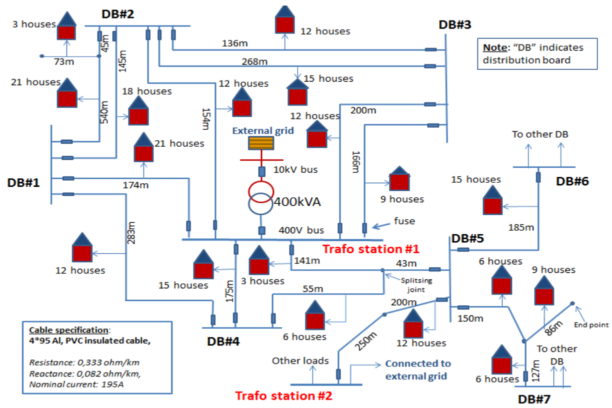

Fig. 36: LV meshed distribution network for the assessment of PV impact (Paper 0257)

Paper 1241 examines the integration of an excessive share of distributed generation into a T&D system in the southern part of Germany. Various solutions like conventional network extension; energy storage; load management; and controllable smart grid components are compared in terms of number of assets and investment costs. The analyzed scenarios are depicted in Fig. 38. The study proved that smart grid components are very effective to defer or avoid network expenses for RES integration but they require strong communication facilities. Furthermore, the smart grid and storage exploitation requires their consideration in the German regulation system.

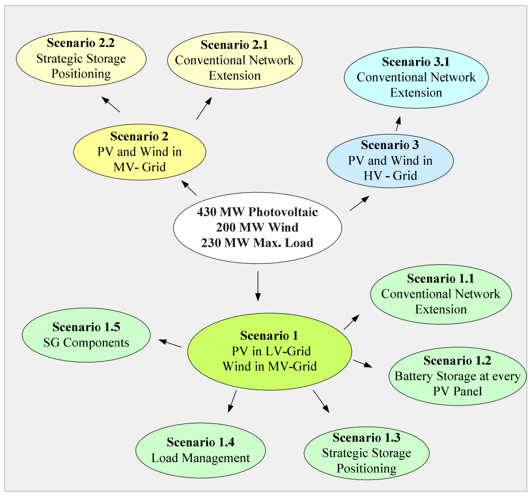

Fig. 37: The scenarios examined in Paper 1241

Paper 1419 proposes a Monte Carlo-based technique to assess the impacts of different PV penetrations on a real LV network for the North West of England, considering 5-min resolution models for domestic load and PV generation. The impacts of PV location are analyzed through two scenarios based on location: closer to and further from the distribution transformer. Voltage impacts are measured using EN50160 and the thermal capabilities are examined through a utilization factor. Additionally, the effects of higher LV busbar voltages are also investigated. Results indicate that voltage issues are more constraining than asset utilization, particularly with clusters closer to the transformer. Particularly, the most severe issues arise when PV are supposed far from the transformer (Fig. 39). In addition it was observed that longer feeders present voltage issues sooner than shorter ones. Finally, the analysis of busbars voltage showed that lines with higher tap position can pose a significant constraint for the connection of PV generation.

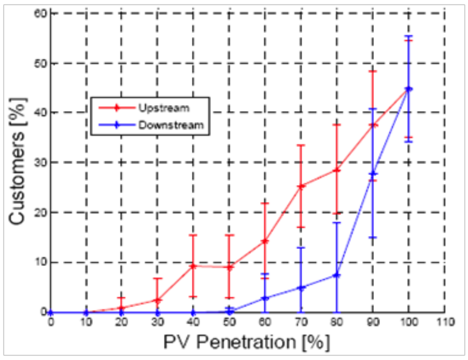

Fig. 38: Consumers with voltage issues caused by PV (Paper 1419)

Potential scope of discussion

Many authors underlined the need to change planning methodologies by abandoning the classical worst-case analysis and adopting probabilistic analysis. Are DSO ready to move from deterministic planning to a probabilistic one? Modern planning tools require the handling of a huge amount of data and the integration of sophisticated load models to simulate the modern operation of active distribution. The amount of computing resource that is necessary can easily become unfeasible making planning not really applicable in real scale data.

Table 3: Papers of Block 3 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0087: An Integrated Interval Arithmetic Approach for Reactive Power Compensation of Radial Distribution Feeders				
0124: Fault Current Limiter Optimal Placement by Harmony search algorithm				
0132: Effect of financial and technical uncertainty on distribution network reconstruction project selection				
0182: Integration of GIS Data into a PSS Sincal Electrical model				X
0186: Investigating the impacts of plug--in hybrid electric vehicles on distribution congestion				
0187: Distribution Network Expansion Planning Considering Distribution Automation System				
0227: Improved network analysis by using data from smart meters		1		
0229: A Network Planning and Design Decision Support tool for integration of Low Carbon Technologies and solutions				X
0257: Impacts of large-scale integration of PV based generations in a mesh-connected low voltage network		4		X
0292: Assessment of distributed generation capacity mixture for hybrid benefits				X
0347: Comparison between different multi-objective approaches to distribution network planning				
0351: Analyzing the effect of transformer utilization factor in distribution networks as an investment management index by using DisPlan software				
0415: Predictive assessment of power continuity indicators				X
0500: Smart planning - an integrated approach for distribution system planning to cope with its future requirements		7		X
0531: Recharging process of plug in vehicles by using artificial immune system and tangent vector				X
0548: A new method for optimal planning in extensive distribution networks despite uncertain data				
0553: Study of Fault Repair Control Mode for Distribution Network based on Automation and Information under Big-Maintenance System				X
0559: The analysis of the information needed for the planning of active distribution systems				X
0609: First use of Smart Grid data in distribution network planning				X
0622: Market potential analysis for the provision of balancing reserve with a fleet of electric vehicles				X
0624: A novel algorithm to the multi-stage grid expansion problem taking into account grid topology modifications and storage devices				X
0807: Network planning case study utilizing real-time thermal ratings and computational fluid dynamics				X
0827: Capacity value of distributed generation for network capacity planning				X
0840: A multi-agent based approach for simulating g2v and v2g charging strategies for large electric vehicle fleets		3		X
0847: Avoiding MV-network expansion by distributed voltage control		5		X
0851: DG allocation based on modified nodal price with consideration of loss and reliability using PSO				
0861: Evaluation of the Impact of Electric Vehicles on Distribution Systems Combining Deterministic and Probabilistic Approaches				X
0868: New load and infeed approaches for cost-efficient low-voltage grid design				X
0888: Short-term network planning of distribution system with photovoltaic				X
0897: Industrial load scheduling in smart power grids				

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
1035: The impact of load and distributed energy resources management on microgrid reliability				X
1046: Requirements for advanced decision support tools in future distribution network planning			X	
1063: Integrated AC/DC Network Planning				X
1144: Optimum rearrangement by GA and GIS in distribution network				X
1178: Analysis of the options to reduce the integration costs of renewable generation in the distribution networks. Part 1: impact of PV development in France and global analysis of considered alternatives to reinforcement				X
1241: Impact of large share of renewable generation on investment costs at the example of AÜW distribution network				X
1243: Planning-oriented yearly simulation of energy storage operation in distribution systems for profit maximization, voltage regulation and reserve provisioning		2		
1266: The impact of EV's fast charging stations on the MV distribution grids of the Milan Metropolitan Area				X
1284: Technical analyses of network structures regarding decentralized feed-in				X
1356: Analysis of the options to reduce the integration costs of renewable generation in the distribution networks. Part 2: a step towards advanced connection studies taking into account the alternatives to grid reinforcement.		6		
1361: Probabilistic grid planning with consideration of dispersed generation and electric vehicles				X
1370: Assessing the impact of ICT on the reliability of active distribution systems				
1419: Impacts of Photovoltaics on Low Voltage Networks: A Case Study for the North West of England				
1426: Power system planning in distribution networks today and in the future with smart grids				X
1453: Influence of generator curtailment priority on network hosting capacity				X
1456: Living lab ‘Rotterdam tests electric driving'				X
1475: Demand side integration aspects in active distribution planning				
1495: Definition and validation of key performance indicators to assess the effectiveness of "smarting actions" on a distribution network				
1500: Distribution network planning in presence of fast charging stations for EV				X

Block 4: Methods and Tools

Sub block 1: Load Modelling and Profiling

Load forecast is a planning activity that has been conducted since last years starting from elementary data drawn from historical experience or based on given 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 evaluate the "atomic" components of consumptions.

At the same time, technological evolution of domestic and/or industrial equipment enables "smart" functionalities leading to rules of combination of atomic loads which may significantly differ from purely statistical ones.

Sub block 1 deals with methodologies to make use of available individual data and of new logics of elementary load management to build models which may accurately represent the complexity of "smart" loads.

Paper 0563 demonstrates possibilities of public geographic, building and meteorological data, in spatiotemporal modeling of controllable heating loads, starting from AMR data (as shown in figure 39 below). In the paper, the computational approach based on fixed spatial units forming a grid is proposed. The benefit of the approach is on enhanced computational performance and integrity to public sector region level data, related scenarios, analyses and models. In the next stage, the approach can be linked with small-scale generation and local energy storage models in order to obtain overall power demands.

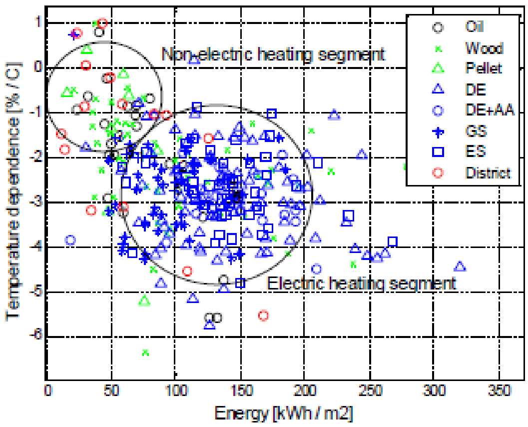

Fig. 39: Specific energy consumption based on temperature dependence of target customers, according to Paper 0563

Paper 0787 shows how AMR (Automatic meter reading) measurements can be used to create new load profiles and how these new load profiles can be applied to improve distribution network analysis accuracy. In this paper, hourly electricity consumption data is used to update existing load profiles, cluster customers and create new cluster profiles, and specify individual profiles for selected customers, all of which are then used in distribution network analysis. The results between existing and new load profiling methods are compared. Comparisons are also made between different methods of AMR-based load profiling.

Paper 1175 deals with the correlation between electricity consumption and temperature in the City of Zurich (as reported in figure 40below). The motivation is the significant increase of peak load during the summer months since the record summer of 2003. Therefore it's important for energy suppliers as well as distribution grid operators to analyze how and to what extent these high temperatures are affecting consumer behaviour. This contribution also gives valuable indications regarding the evolution of peak load in the future and the dimensioning of the distribution grid.

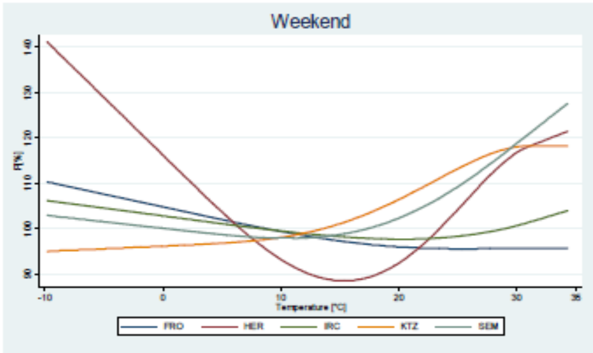

Fig. 40: Percentage load of five substations of Zurich against the temperature at weekends (in relation to the respective average load)

Paper 1254 describes the analytical and graphical techniques being used to classify and define secondary substation load profiles and identify when changes occur. The visualization techniques being developed to assist Planning Engineers with network assessment of load growth and changing load type are illustrated (see also figure 41 below). The paper also details the projects findings in respect of DG connected at low voltage (LV) and the masking of load.

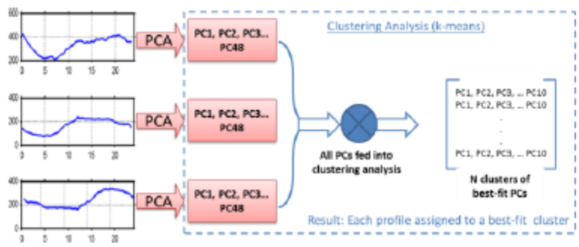

Fig. 41: Principal Components Analysis through k-means clustering as exposed in Paper 1254

Paper 1392 implements a method for the generation of individual stochastic load profiles, to gain synthetic three-phase load profiles which take account of unbalance. The stochastic load profiles generated with the presented method offer a possibility for the examination of distribution grids with unbalanced loading. The stochastic load model takes account of load peaks as well as reactive power consumption and different types of households. An individual profile is created for each house connection within the grid so that the different consumption behavior in the domestic homes is considered.

Sub block 2: Load Forecasting

The combined effect of non-conventional behaviors as in DMS and of new grid users such as EVs and RES-generation makes load forecasting a more complicated activity than in the past; at the same time, the access to large amounts of data may support the verification and validation of forecasting methodologies, allowing the adoption of wider sets of possible algorithms and eventually leading to an increase of the level of accuracy in the forecasts.

Sub block 2 deals with the development of innovative or the refinement of established load forecasting criteria in order to grant the best possible inputs to the planning process; forecasts may be defined at a disaggregated level (e.g. for a specific category of users, such as EVs or DGs) or may represent a complex entity (e.g. a substation).

Paper 0018 describes a load forecasting method for HV/MV-transformers to incorporate the influence of distributed generation. This new method involves the making of separate forecasts for demand and generation and determining the resulting transformer loading, based on the known correlation between demand and generation.

Paper 0421 presents a methodology for developing probabilistic daily demand curves for different categories of customers. Demand data for different end-users in different load sectors are collected and converted to demand data for different load categories (see also figure 42) in order to develop deterministic Decomposed Daily Loading Curves (DDLC) for different load sectors.

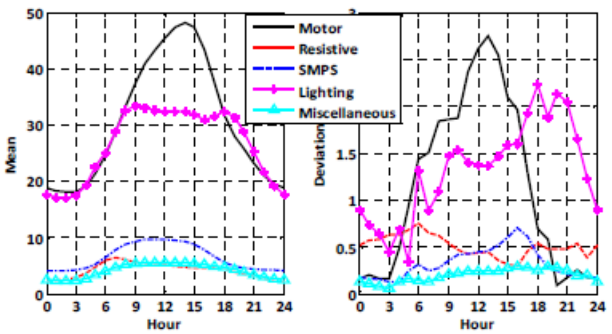

Fig. 42: Mean and standard deviation of demand for different load categories in commercial load sector, according to paper 0421

The target of **Paper 0058** is impacting Demand Side Management (DSM) when it is applied at different sectors; residential, commercial, public, government, agriculture, industrial and the total load of these sectors on national network of power system in Egypt for year (2009-2010) and estimating load forecast for these sectors by Adaptive Network Fuzzy Inference System (ANFIS) techniques during the period from year (2010-2011) to year (2020-2021).

Paper 0857 underlines some mathematical techniques which will play a key role in better understanding the customer's behavior and create solutions for supporting the network at the LV substation level. Possible mathematical approaches that are available in better understanding customer's energy behavior through categorization are exposed, anticipating changes in behavior by forecasting and helping to support the network with smart control algorithms. Results, as in figure 42, show that a "smart" management of a set of customers together with a storage may significantly reduce aggregated peak demand.

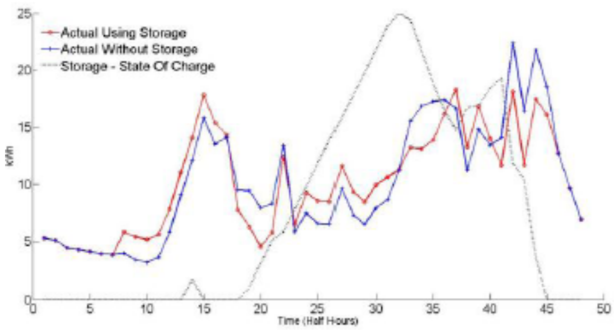

Fig. 43: Simulation results showing hourly aggregated demand with and without storage and the SOC of the storage device as in Paper 0857

Paper 0333 develops a multivariate probabilistic framework for PEV load modeling to be embedded in system planning problems. In order to successfully integrate the uncertainty attributes of the PEVs in the probabilistic planning issues, relevant vehicular load scenarios is provided through appropriate synthetic data. A student's t copula distribution function is utilized to capture the correlation characteristics among the included datasets namely home departure time, daily travelled distances and home arrival time of the vehicles during weekdays. Then, a Monte Carlo based stochastic simulation is provided to derive hourly load distribution functions of the PEVs. Extraction of the demand profile of the individual PEVs is fulfilled in order to estimate the demand profile of the fleet.

Paper 0249 proposes a forecast system for DGs with uncertainties in the primary energy source. The power generation uncertainty is reduced through a multi-objective optimization algorithm in multiple probabilistic scenarios that combines the Monte Carlo method and the Markov models.

Paper 0512 proposes a novel algorithm, which can be employed in multiple regression-based techniques in such conditions. This algorithm recognizes the redevelopment event in the small areas and shifts the shaped load growth curve to a suitable lower level using a decision making engine. The results show that employing this algorithm can significantly improve the accuracy of regression-based load forecasting methods under redevelopment conditions.

Paper 0664 analyzes three techniques for load allocation and compares to the case with actual AMI (advanced metering infrastructure) data for all customers. It describes how the used method for estimating the customer load can have a significant impact on distribution system analysis.

The main objective of **Paper 0929** is to present the results of a new model aimed at the load forecast of a region divided by grids, using a methodology based on Gaussian filter and image dilation algorithms, which provides the load growth of each cell in the studied area, separated by their consumer classes (see figure 44 below). For that matter, the history of each grid's energy and power and the global growing rate for each substation are available.

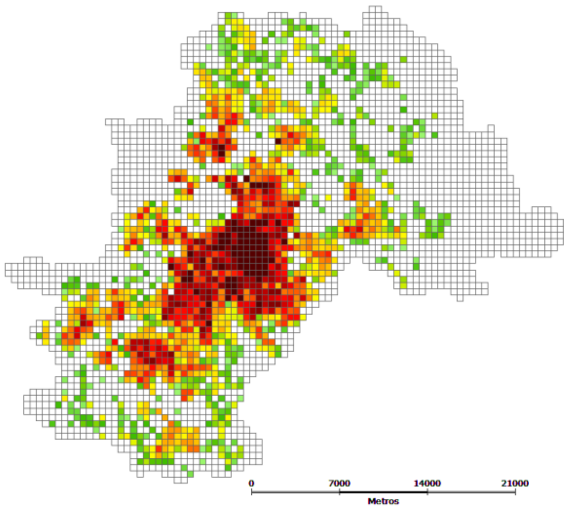

Fig. 44: An example of forecast of spatial load distribution according to the methodology exposed in paper 0929

Paper 0925 shows on a proof of concept model that focuses on simulating electric vehicle EV movements in urban environments, which serve to forecast EV loads in the networks. Having performed this analysis for a test urban environment, this paper details a case study for London using an activity-based model to make predictions of EV movements that can be validated against measured transport data. Transport data highlights the load flexibility a fleet of EVs can have on a daily basis, while an optimal power flow manages the best times of the day to charge the EVs.

Paper 1205 shows the performance of a traditional autoregressive model, a wavelet-based model, an Echo State Network, and a variation of Case-Based Reasoning (CBR) at the sub-transmission (~10000 customers), distribution substation (~150 customers) and single-meter level. For all the four prediction methods, it was employed an evolutionary algorithm as a meta-learner to automatically optimize the free parameters for each model-dataset combination.

Sub block 3: Load Flow and Short Circuit Calculations

Sub block 3 deals with specific electrical calculations widely used in network planning or in components' sizing. Some of the paper 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.

Paper 0698 analyses the advantages and drawbacks in modifying the voltage margins to LV consumers. The aim is to quantify the physical impact on grid length, number of substations and losses. The analysis is based on a geometric model with proposed parameters supposed to be representative of four typical dwelling configurations. Main conclusion is that when density is high enough, building strong grids is fine, because it reduces losses for low costs. But when density is lower, it is not worth making too long grids with too many substations. To do so, sufficient voltage margins have to be dedicated to LV grid development.

Paper 0724 presents a method for power systems size reduction when there are aggregations of generators. This is applied to obtain dynamic equivalents of distribution power systems with DG units, as in scheme represented in figure 45 below. This method is validated showing how it preserves, in presence of a fault, the original system response.

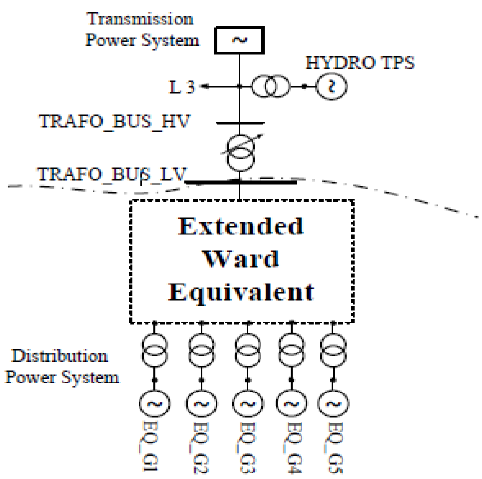

Fig. 45: Representation of extended Ward equivalent of distribution power system according to Paper 0724

Paper 0911 introduces a three phase load flow method that can handle both passive and active unbalanced radial distribution networks. The proposed method combines the direct-ZBR method (Forward-Backward based method) and Modified Lambda iteration. The direct ZBR load flow is known as a fast and accurate method for solving passive radial three phase distribution systems. The Modified Lambda approach can be combined with direct ZBR method in handling DG's which are operated as voltage controlled (PV) buses.

Finally, an analysis of the effectiveness of shunt resistance in reducing the fault current in single-phase events is exposed in **Paper 1086**. The authors describe a methodology for steady-state calculations through a simplified scheme, in order to define the optimal sizing of the component and its effects in case of phase-to-earth fault. As expected, the most critical events are zero-impedance faults located close to the transformer.

Sub block 4: Energy Losses Minimization

The maximization of profits creates the tendency to postpone investments in the network infrastructure, with negative effects on losses; in order to oppose this tendency, several countries adopt regulation directives that reward the distributors if losses are reduced and penalize them if losses increase. At the same time the increased degree of observability of MV and LV network enables more accurate and reliable losses estimation and/or calculation in the planning phase.

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

Paper 0078 proposes a selective particle swarm optimization (SPSO) to solve capacitor placement and distribution network reconfiguration in reducing the power losses of distribution networks. The algorithm has been implemented and tested on two test systems and the results has been compared with different methods given in literature.

Paper 1413 presents a new methodology for reconfiguration in distribution systems for power loss reduction: particle swarm optimization (PSO) and Nelder-Mid (NM) optimization. This methodology is compared against Genetic Algorithm methods.

Paper 1238 describes a three stage optimal distribution network planning program and applied it for surveying the effectiveness of different defined categories of load densities and dispersions on the optimal ranges of distribution substation capacities in various regions of large cities in Iran (see also figure 46 below).

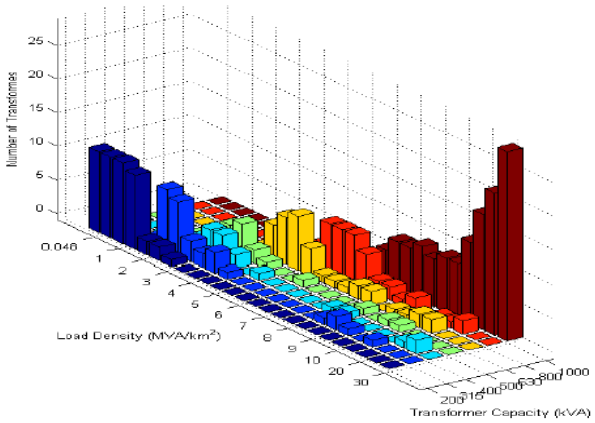

Fig. 46: Optimal number and capacity of MV/LV substations for each load density according to Paper 1238

Paper 0176 contains a genetic algorithm strategy to minimize energy losses in an electrical distribution network. In order to develop the strategy, different parameters were included that help in estimation of technical losses in medium voltage (MV) distribution network. The main objective of this paper is to minimize technical and non-technical losses in power systems.

Paper 1428 describes the methodology adopted and the main results obtained in the project allowing to EDP Distribuição of Portugal the best prioritization of their investment in loss reduction, taking into account the voltage level of the distribution network and the geographical identification of "hot spots" to be eliminated. In order to choose the best investments in HV and MV network lines, considering the trade-off between benefits and costs, a simplified computational scheme for energy losses is proposed and a sample of MV network is examined in detail, leading to results sampled in figure 47 below. The ideal scenario would be, of course, to analyze all HV and MV networks and simulate possible reinforcement alternatives.

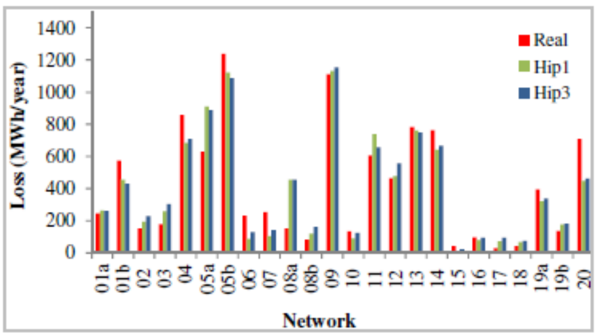

Fig. 47: Estimation of annual energy loss – real values and the best two regression alternatives - according to Paper 1428 for a given sample of MV networks

Potential scope of discussion

Energy efficiency is one of the key priorities in any political agenda. While efficiency of individual electrical components is well ahead in the process of delivering, it seems that system efficiency (e.g. through reduction of system losses) is not sharing the same level of attention; this is also proved by the relatively low number of papers about loss minimization in

CIRED. Is it because margins in system efficiency are perceived as being smaller than in components' efficiency or because system efficiency is more difficult to approach?

Automatic Reading Metering is offering to planning information for planning with a new accurate load forecasting. The behavior of load will be perfectly known and a huge amount will be available. Are we ready to use that huge amount of information?

Table 4: Papers of Block 4 assigned to the Session

Paper No. Title	MS a.m.	MS p.m.	RIF	PS
0018: Changes in forecasting of HV/MV-transformer loading due to distributed generation				X
0058: Electrical load forecasts in long –term and impact on load management application				X
0078: Combination of capacitor placement and reconfiguration for loss reduction in distribution systems Using Selective PSO				X
0176: Reduction of Energy Losses in Electrical Distribution Systems				X
0249: Efficient forecasting system for distributed generators with uncertainties in the primary energy source				
0333: Copula-based multivariate stochastic modeling of load demand due to plug-in electric vehicles in order to be integrated in distribution system planning				
0421: Development of probabilistic daily demand curves for different categories of customers				X
0512: A novel algorithm for long-term load forecasting of distribution networks under redevelopment conditions				
0563: Computational approach for spatiotemporal modeling of heating loads using AMR and other external data				X
0664: Comparing load estimation methods for distribution system analysis				X
0698: Correlation between load density and voltage drop		12		X
0724: Dynamic Equivalents of Active Distribution Power Systems for Investigation of Transient Stability			X	
0787: Improving distribution network analysis with new AMR-based load profiles		8		X
0857: Mathematical solutions for electricity networks in a low carbon future		9		
0911: Real-time unbalanced load flow development using direct-ZBR method and modified lambda iteration for on-line monitoring and control			X	X
0925: Spatial and temporal electric vehicle demand forecasting in central London		10		X
0929: A Gaussian Mask Model For Spatial Load Growth				X
1086: The analysis of efficiency of shunt resistor during a single-phase earth fault using the two-port network theory				X
1175: On the temperature dependence of the load curve of the city of Zurich				X
1205: Effects of scale on load prediction algorithms		11		
1238: Design Philosophy Revision in Metropolises Distribution System by Comparative Chromosome Genetic Algorithm				
1254: Secondary substation load profiling - identification and visualization of changes				X
1392: Synthetic three-phase load profiles				X
1413: A novel hybrid algorithm for reconfiguration problem of the distribution networks				
1428: Assessment of the investment effort in HV and MV networks to reduce energy losses		13		