Special Report - Session 5
POWER DISTRIBUTION SYSTEM DEVELOPMENT

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Contents

Introduction

The **scope of Session 5** has been defined as follows:
This session deals with all aspects related to the short and long term development of high, medium and low voltage distribution networks, with reference mainly to the changing requirements for electricity distribution in the new context.
The main topics are related to:
- *demand needs and forecast*
- *performance requirements, results and benchmarking*
- *network schemes, design criteria and practice*
- *investment strategies.*

The **S5 papers** will be discussed in **three events**:
- Main Session (Tuesday, May 22, 9:00-12:30 and 14.00-17.30),
- Poster Session (Wednesday, May 23, 9:00-12:30 and 14.00-17.30),
- Research & Innovation Forum (Thursday, May 24, 16:00-17:30).

Two Round Tables will be organized (Thursday, May 24, 9:00-15.30):
- Investment strategies to face rapidly increasing local demand (Tuesday)
- Future network development and architecture (smartgrids) including smart metering, energy storage, and optimisation of the load profile

The aim of this special report is:
1) to present a synthesis of the present drives in System Development according to items treated in the selected papers (S5 has 107 papers),
2) to call for prepared contributions at the plenary session, on particular points which appear in the papers or which are not covered by them,
3) to stimulate the free discussion at the plenary session.

The 2007 **plenary session** will be divided into **four blocks**:
1. Asset management and maintenance strategies,
2. Network Development,
3. Distribution Planning, and
4. Methods and Tools.

Each block will be divided in two main parts:
1) oral presentations based on papers that cover general items or can stimulate the discussion (10 minutes presentation) ,
2) discussion (prepared contributions and free discussion).

Call for prepared contributions. Prepared contributions will preferably aim at answering the questions of the Special Report.
However, other kinds of contributions will be welcome :
- fresh information on particular items which appear in the papers or which are not covered by them;
- case studies;
- comments on a particular paper (“I agree/disagree with that result/conclusion”, "My own practical experience in the same field is...");
- address questions to the authors at the plenary session.

All the prepared contributions will be published in the **Proceedings**. They will be made available to attendees at the entrance of the conference room and also on **www.cired-s5.org**. Furthermore, some of the most relevant ones will be selected for a verbal presentation (second part of each block at the plenary session).

General guidelines for authors of prepared contributions:
- the language is English;
- each contribution has to start with title, name of author(s), affiliation, country, number of the relevant

question in the special report or number of the commented paper;
- Whether a Power Point Presentation is prepared, please send the Power Point file together with the contribution (only ppt files received in advance will be available in the computer on the platform);
- **contributions should be sent by email before May 7th 2005 to the following addresses:**
  - ardito@cesi.it,
  - pilo@diee.unica.it
  - ch.lacrosse@cired2007.be

Block 1: Asset Management and Maintenance Strategies

AM&MS has gained a lot of interest in the CIRED 2007. There are 23 papers covering items related to AM&MS. The key drivers for the growing interest on AM&MS are mainly related to the need of facing challenges arising from the reliability requirements worldwide imposed by the Regulators and from the ageing of assets. Furthermore, distribution companies are concerned about budget restrictions and they are concentrated on risk management and investment priorization. **Paper 251** deals with the practises that are used in ENDESA to make compatible the scarcity of resources, a direct consequence of the current regulation, and the increasing request of high quality power delivery. The procedure is based on Risk Analysis, Reliability Behaviour and Management of Crisis. The key point is that the scarcity of resources determines a network with a certain level of risk; the quantitative approach followed allows managing an acceptable level of risk and improving the level of quality in an economic sound manner. As in Paper 251, **Paper 094** deals with the problem of identifying which are the most critical assets. Criticality of assets does not mean urgency as correctly the authors said. Criticality is crucial to identify where to put investments, urgency is related to priorization. Both aspects have to be used simultaneously for a proper asset management. Criticality depends on attributes that are related to health and safety, economic performance, environment, regulatory compliance, customer satisfaction, and branding. The authors propose and compare two methodologies to assess the asset criticality: the Euro conversion and the Failure Mode and Effects Analysis (FMEA). The first approach transforms a failure in money considering the direct costs of repair actions and the financial costs related to the unused energy. The conclusion is that the Euro conversion is less usable than the FMEA because of the assumptions necessary to convert failures in costs. **Paper 588** presents a Multi-Criteria Decision Support to **AM** that is a very complex decision making problem that has to find a good balance among risk, performance and cost. In today's AM&MS there is the need of choosing among replacing after failure, upgrading and refurbishment or total replacement. The alternatives have to be judged on the basis of different criteria some less tangible (public opinion, regulatory risk, politics) than others (costs, profits). Furthermore the Decision process is affected by many uncertainties (prices, load growth, climate change, etc.) and inevitably there is the risk of wrong decision. The Multi Criteria Decision Analysis is a powerful tool for the Decision Maker, who can take into consideration the most important, even if intangible issues, and clarify, visualize and document his preferences. The paper gives a clear example of application in a real case (the maintenance strategy for existing switchgear in an in-house MV/LV substation in Norway). Risk Management applied to AM is also dealt with in **Paper 39.** The paper presents a Condition Based Risk Management as it has been developed in recent years with distribution companies in UK. The CBRM links detailed asset information, engineering knowledge and experience to the investment planning and implementation process. The main idea of CBRM is depicted in Fig. 2.

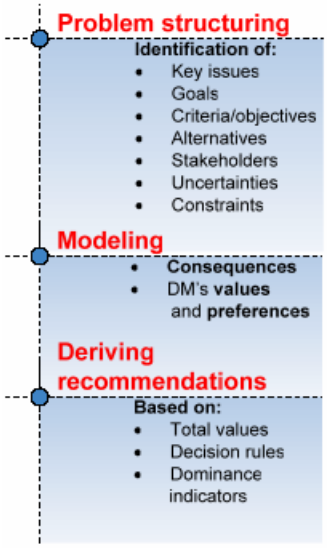

Fig. 1 - The MCDA process as presented in **Paper 588.**

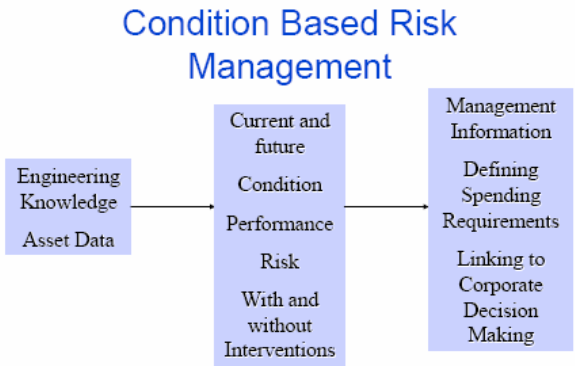

Fig. 2 - The CBRM process as presented in **Paper 39.**

The paper gives a clear definition of risk and outlines the advantage of risk analysis in AM. The application to the 11 kV cable population replacements is really interesting. The CBRM allows pointing out that the current replacement rate (0.5%) will be not able to maintain the current risk level for more than 10 years, an increase to 2% or to 3.5% will be

necessary depending on different choices. **Paper 668** deals with the concept of asset simulation. The dynamic asset management is adopted to predict the long term monetary consequences of maintenance and renewal strategies. It is a dynamic modelling approach that enables building of a formal representation of the dynamic behaviour of a business system, where the behaviour of the system is a direct result of causal relationships between different elements of the system. Fundamental to system dynamics is the idea that all dynamic behaviour is a consequence of the structure of the system, where the structure refers to how the elements of the system are put together. Dynamic asset simulation of different maintenance or renewal cycles is a fundamental approach to find the optimal investment plan. It helps strategic asset management to enhance its understanding of the long-term impacts and risks of planned measures without actually taking any risks. This enables strategic asset management to conceptualise and implement balanced and sustainable long-term asset strategies. The process is now used by RWE Energy in Germany and applied to decision support in asset strategy evaluation. The use of the model has improved the quality of RWE asset investment decisions.

Another group of papers (**Papers 415, 611, 682**) addresses the impact of reliability on AM. **Paper 611** is focused on the condition assessment, ageing models and failure probabilities since there is a lack of such information in MV networks. The authors proposed a statistical approach combined with a statistical method to evaluate the component state for several classes of components. In particular they proposed a very useful model failure model that from statistics allows assessing the probability of the components with respect to age and maintenance. **Paper 682** gives an example of a complete Reliability Centered Assed Management that has the goal to find a fair compromise between cost effectiveness and power quality. Fig. 3 gives an overview of the modular structure of the procedure.

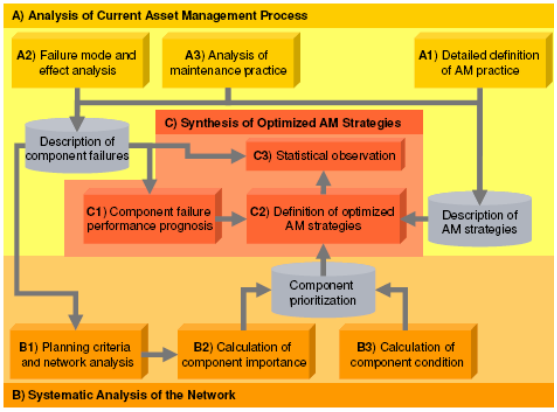

Fig. 3 – **The modular structure of the RCAM as presented in** Paper 682.

The modular structure of the proposed method offers the possibility to adapt the AM process to different situations of different network operators.

Paper 415 also deals with the role of reliability in AM. The most important feature of the process presented is that it uses data already collected by the network information systems or by national (Finnish) statistics about outages and their causes. The Tekla Xpower network information system presented in the paper has been tailored for Finnish distributions companies but it shows a very flexible structure that can be easily used by other network operators. The system proposed performs reliability calculations and also voltage dips analysis. The presented case studies prove that the simulation results and the collected data are in really good agreement. It is interesting to notice that the enhanced protection of substations with surge arresters and all MV/LV transformers protected against animals allows drastically reducing momentary interruptions (Fig. 4).

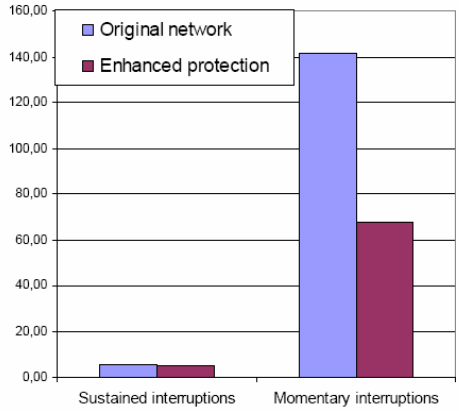

Fig. 4 – Number of interruptions MV/LV substations with enhanced protection (**Paper 415**).

Paper 14 describes how ARGL Distribution Company has implemented an ambitious program for high quality standards in very dense urban areas. The analysis method applied was supported, firstly, on an internal best practice performance evaluation and benchmarking, in order to allow the comparison of data based on measured reliability data. In a second phase, gap analysis between significant areas helped to define the most effective way to achieve the goals. The project integrates also conditioned Based Maintenance (CBM) strategies, based on diagnosis methods for different configurations and Network structures; other indicators of possible bad performances are also achieved by network information systems (overload, overvoltage, etc.). The final goal is to reach in ARGL a 50% improvement of the number of interruptions to customers.

Papers 74, 127, 184, 215, 583, and **741** are all focused on optimal maintenance planning. Efficient maintenance planning is fundamental to properly face the requirements from shareholders and management on one side and the regulatory authorities and customers on the other one. All the papers in this group propose methodologies and tools to improve the efficiency of the maintenance process. **Paper 74** deals with maintenance models based on lifetime and time-to-failure density functions. The main novelty in the models is that the effect of perfect and imperfect maintenance is properly modelled as well of inspections are considered. With such models component conditions and

irreversible system degradation (independent from maintenance activities) can be realistically simulated. By using cost functions that include maintenance and societal outage costs, the maintenance optimization can be performed. **Paper 127** deals with the monitoring the operational behaviour of the electric equipment. Such data are used to quantify the technical conditions and to improve the reliability by means of improved maintenance and operation. Figure 5 shows the whole maintenance information system used in Romania and presented in **Paper 127**.

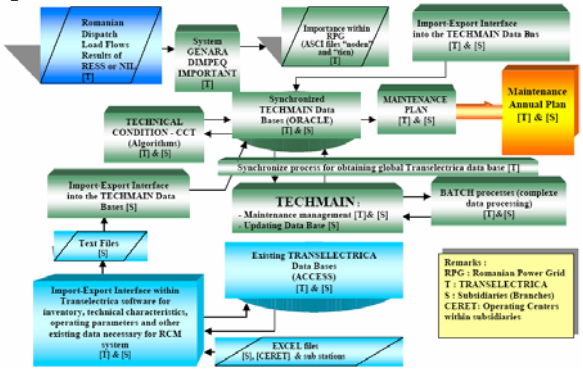

Fig. 5 – Maintenance information system presented in **Paper 127.**

Paper 184 also from Romania presents a Reliability Centered Maintenance (RCM) database of urban MV networks. The RCM is a well known method that can reduce maintenance costs without degrading the power quality. The paper presents the RCM implementation in Romanian urban MV networks. Particular attention has been paid by the authors to develop a database oriented to RCM applications. **Paper 215** presents a risk management approach for the optimal long-term maintenance schedule of distribution system used by EPS Company in Serbia. The risk management of maintenance is based on the assessment of the risk of equipment failure and of the related consequences. The main novelties in the approach proposed are the decoupling of risk factors and related preventive actions, the development of long-term strategies, and the simultaneous treatment of different components. **Paper 362** proposes a new approach for Asset Life Cycle management used by AES Eletropaulo, a Brazilian distribution company. It is also based on RCM and uses priorization criteria for substation and lines maintenance investments. The application of the ALF allows reducing the operational costs for maintenance as well as investments; in the same period the SAIFI increases by 2%. **Paper 741** proposes a multi-criteria analysis for the optimal priorization of maintenance activities. The optimal maintenance planning helps the decision maker find a good compromise among different needs. The fuzzy technique allows the identification of feeder priority for maintenance accomplishment by translating linguistic attributes of feeders.

Many distribution companies are concerned about the maintenance or the replacement of MV cables because their performances have a great impact on network reliability and costs. **Paper 115** states that the 30% of the entire networks costs are generated by MV cables and they influence reliability for about 65%. The 78% of typical faults occur in cables and 22% in joints. Finally, faults may be caused by a reduction of electrical strength or by external actions. The authors propose a very intelligent renewal strategy for MV cables that allows achieving a constant network quality with low cost. The optimal strategy in the long-term is constituted by a mix of corrective maintenance and the application of a network scheme with good reliability characteristics and low costs. **Paper 40** illustrates the optimal strategy followed by EDF for the decommissioning of fluid filled cables in the UK. The methodology proposed by the author is based on an objective risk based process for assessing the investment needs and for the long-term investment strategy. Also MV substation may be a serious concern for distribution companies because they are starting to be aged. In Germany (**Paper 453**), the 35% of MV substation was built between 1960 and 1975 and they will require a lot of investments for the replacement of components in the next year. The proposed methodology allows determining the condition of MV substation objectively and with a minimum effort.

Paper 135 deals with an action plan developed by EDF to face the impact of major failures. The plan is based on characterization of climatic phenomena, historical analysis of major events on the network, quasi exhaustive analysis of vulnerability, risk characterization and definition of techno economic criteria for priorisation of actions.

Paper 351 presents a proposal to valuate a network with a methodology created by the authors. It is based on the concept of rationality which had been successfully implemented in four utilities in Argentina. Five variables are the targets of the study: conditions of operation, use level, conservation state, level of technological obsolescence, and level of installation's functionality. A rationality factor sated with the optimal value of the electrical goods according to the referred conditions. These are value drivers which will allow to taking correct decisions at the time of demanding. Rationality had an impact of additional increment of depreciation coefficient in a range from 2% to 7 %.

Paper 631 deals with the selection of works in a distribution system that is not a trivial task because it involves a lot of variables and a great volume of works. The least square method used in the works selection together with bilevel optimization, is still being developed, but seems to be a useful tool to works evaluation in the distribution system.

Questions on Block 1

– Question 1B1: Many papers report the experiences made by Distribution Company with Risk Analysis. Risks are consequence of decision making in uncertain scenarios. How much is important in the decision process the probability of occurrence that

the decision maker assigns to each possible scenario?

- Question 2B1: Ageing is becoming a serious concern worldwide. Are the current maintenance strategies followed by distributors able to face the situation?
- Question 3B1: Are the data currently available in distribution companies reliable and detailed enough to perform asset simulations?
- Question 4B1: The ageing of assets (cables, transformers, switchgears, etc.) might require high investments for maintenance and replacement. Are the revenue mechanisms introduced by Regulator Bodies sufficient to cover such a huge investment campaign?
- Question 5B1: Papers of the block deal with the application of software tools to optimize the asset management and the maintenance process. Which is the impact of the subjective judgement of experts on the reliability of the results?
- Question 6B1: Which is the level of integration between SCADA, asset management and maintenance optimization tools?

Table 1: Papers of Block 1 – Asset management & maintenance strategies

Paper No.	**Title**	MS a.m.	MS p.m.	RIF	PS
14	A system development promoting reliable access to Electrical Energy (Project OACis)	X			X
39	Condition Based Risk Management (CBRM), a process to link engineering knowledge and practical experience to investment planning - an update	X			X
40	Investment Strategy for Decommissioning Fluid-filled Cables				X
74	Combined maintenance and inspection models for application in condition- and reliability-centered maintenance planning	X			X
94	Criticality of Assets	X			X
115	Intelligent strategies for the renewal of cable networks in consideration of quality and economic aspects	X			X
127	Monitoring the operational behavior of electric equipment - key factor for the technical condition evaluation and maintenance policies				X
135	How to reduce the impact of major climatic events: action plan	X			X
184	The Reliability Centered Maintenance Data Base of Urban Medium Voltage Networks				X
215	Risk management approach in Distribution networks maintenance schedule				X
251	But, Can we afford the current level of risk? A new model for a new age.				X
351	Asset Management of Network Components: The Concept of Rationality on Distribution Utilities.				X
362	ALS: A New Approach to Asset Life Cycle Management				X
415	Reliability-based Asset Management for Investment Strategies and Decisions	X			X
453	Condition assessment of MV transformer substations to optimize the investment strategy	X			X
583	Utilization of grid condition data for efficient Maintenance Planning				X
588	Multi-criteria decision support in distribution system asset management	X			X
611	Statistical approach for component state evaluation implemented in asset management of distribution systems				X
631	Least Square Method Applied to the Network Distribution System Planning.				X
668	Asset simulation - an approach to predict the long term monetary consequences of maintenance and renewal strategies for electrical grids			X	X
682	Reliability Centered Asset Management in Distribution Networks – Process and Application Examples –	X			X
741	Multi-criteria analysis for establishing automatic priority levels for maintenance activities in distribution systems using fuzzy techniques				X

Block 2: Network Development

Sub block 1: Network development & reliability

The quality of the energy supply is one of the most important reasons for investments in the distribution system. DNO operators are worldwide obliged to respect quality standards that are normally measured with the number and duration of interruptions to their customers. Many different mechanisms have been implemented in different countries but the common feature is that the DNO has to pay penalties whether reliability standards are not complied with. The papers in this Sub block are all related to the network development as a consequence of reliability constraints. **Paper 326,** even if it does not deal with network development, is a good starting point because give the reader the basic definitions and methodologies concerning the quality of energy delivery. Also **Paper 479** addresses some methodological issues, since it provides a comparison of different customer outage cost models that are useful to assess the worth of reliability. Aggregated, probabilistic and fuzzy cost models are critically analysed. As the distribution business is shifting from asset-based to performance-based, the interest for tools and methodologies that compare different alternatives have become of greatest interests. **Paper 712** addresses such issues by resorting to *representative networks*, which reduce a real system into a limited and more manageable system. *Representative networks* are created by using relevant disaggregation parameters and they are useful to predict Customer Minute Lost and Customer Interruptions (i.e., SAIDI and SAIFI respectively). The association of *representative networks* to reference networks allows the planner to define targets to be reached to achieve specific level of reliability. **Paper 253** deals with a very similar object and describes how, the ENECO NetBeheer, a Dutch distribution company, determines its quality of supply targets.

In **Paper 613** some scenarios dealing with power distribution are presented and evaluated. Special attention is paid to reliability parameters, such as failure rate and outage costs. The authors propose some long-term planning studies based on reliability parameters. Such studies show a high correlation between the profitability of investments and the reliability parameters used. What is really important is that the strategic planning has to be performed by explicitly considering the different scenarios for reliability. The correlation between weather variables and reliability are considered also in **Paper 283** that describes investigations into the statistical relationships between storm weather variables and system outages. The study found a clear correlation between wind speed and the vegetation clearance. Wind speed exceeding 40 km/hr wind blown debris can begin to bridge a typical 3-4 m vegetation clearance. The main idea of the study is to define target levels (e.g. SAIDI, SAIFI) that are not influenced by the variability of storm season. **Paper 613** does not consider the positive effect of network automation to improve reliability with a relatively low level of investments because of the very severe assumptions. Anyway as the authors said, network automation is a valid option that should be deeply investigated. **Paper 334** deals with such cost-benefit analysis. The method allows optimising the feeder protection and switching devices to maximise benefits. The consideration of uncertainties reduces the overall benefits and has an impact on the rate of return of investments. Some practical examples clearly show the benefits of automation.

Paper 152 deals with ageing and reliability. The authors highlight that in order to maximise the profitability of the distribution business the cutting down of replacement costs could be an apparent good solution but it should be considered that an aged network will have an increasing number of failures. Theoretical models presented in previous works are used to analyse the critical asset formed by buried XLPE MV cables. The evolution of fault rate for both cables and joints is provided taking into account the most important analysis criteria. **Paper 478** is focused on the impact that different probability distributions of reliability have on short-term investments. In the paper a simulation method for the assessment of network reliability is used. A risk assessment is performed by considering uncertainties that are treated with fuzzy techniques. **Paper 684** deals with the Six Sigma tools for a reliability oriented design. The proposed approach is quite interesting and allows the integration of engineering design, operations management, and asset management. The methodology proposed is very interesting and innovative and may help utilities to meet long-term reliability regulations and decrease overall maintenance costs by having the ability to look over the entire device lifecycle.

A consistent group of Papers deal with network studies that aim at improving reliability by changing architectures and operational practices. **Paper 514** from Romania proposes a methodology to identify the most effective architecture in MV urban distribution. The procedure considers the cost of penalties that are going to be paid for low quality of supply. The paper proposes the network solution that is the most suited for urban MV distribution in Romania. **Paper 607** deals with the improvement of reliability in Swedish rural areas. Technical solutions suited for rural areas have to be simple, modular with a minimum number of components; also network schemes have to be simple with few components. Two pilot installations are now testing the modular components and the experience is very positive so far. The SAIDI reduced from 1400 minutes to 70 minutes. **Paper 559** deals with the impact of automation on outage costs. In particular the impact of high speed automatic reclosers and delayed reclosed is investigated on a typical Finnish network with a 20 kV hybrid open ring in urban area combined with radial networks for rural area. It results from the paper that overhead lines in rural areas cause interruption costs more than underground cables

(roughly double) Automation can improve SAIDI and SAIFI. **Paper 525** from Finland also proposes a methodology and performs a comparison of different investment strategies. **Paper 462** focuses on the 1 kV LV systems that may have a significant impact on distribution reliability in Finland and how it can be regarded in the strategic planning. It is interesting the consideration that falling down from strategic planning to implementation the advantages of 1kV systems are considerably reduced. This result is confirmed by other experience (e.g. Italy). **Paper 140** from Germany gives a methodology to restructuring the existing MV network based on the segmentation method. Cable networks can be regarded as 'under'-maintained because of the significant limitation of maintenance activities in case of cable assets. Among many significant problems, two require extra maturing: ageing and structural configuration. **Paper 426** also from Germany proposes a Genetic Algorithm to plan a novel subtransmission network (110kV) considering the reliability. The GA generates many alternatives and a special routine RAMSES simulates the reliability and calculates common indexes (SAIDI, SAIFI, CAIDI, etc.). At the end of the GA, the optimum network able to comply with reliability constraints is provided. The authors affirm that the procedure proposed is completely new but this is not correct. There many interesting novelties in the paper but there are some other papers in the Literature that approach the problem in a similar manner. **Paper 249** describes how the Essent Netwerk, a Dutch distribution company, decided on improving the quality of service in the town of Groningen. Firstly, the reliability of the existing network was calculated (base case), secondly three options were examined. Finally the most cost effective solution was adopted since all the alternatives led to similar reliability improvement. A similar approach is also followed by the ESKOM Distribution Company in South Africa (**Paper 321**). **Paper 21** describes the methodology followed by the ARGL a Portuguese distribution company that serves more 1.5 million of inhabitants. The company has been facing an increasing number of customers and simultaneously more stringent requirements on the quality of supply. The project SCAI presented in the paper allows improving the quality, reducing clients' complaints on the quality of service, preventing new claims. **Paper 268** describes the application of Sequential Montecarlo and antithetic variables to reduce the computational effort. The case study is a small low voltage network but the reduction method proposed did not give the attended results. **Paper 483** presents the results of a reliability assessment in a Chinese LV real distribution system. The idea is to displace some reliability monitoring point in the network. The data collected are then elaborated in monitoring centre for automatic computation. The results prove that the methodology gives enough accurate results. **Paper 110** from Ireland presents a novel design of HV substations to cut costs by maintaining an acceptable level of reliability. Two papers consider network development under reliability constraints considering overvoltages induced by lightning as one of the main cause of outages. **Paper 860** considers the overvoltages induced by lightning on MV networks. The methodology is based on the very sophisticated methods developed by the authors. From the paper it is clear that the most convenient solution to reduce the number of outages caused by lightning is based on 3-conductors, BIL greater than 200 kV (Fig. 6). Surge arresters or grounded wire are less convenient considering the costs involved.

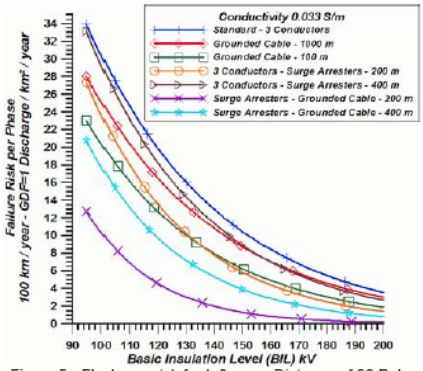

Figure 5 - Flashover risk for Influence Distance of 20 Poles, Soil Conductivity = 0.003 S/m and GDF = 1 fl/km^2/Year

Fig. 6 - Flashover risk for Influence Distance of 20 Poles, Soil Conductivity = 0.003 S/m and GDF = 1 fl/km^2/Year (**Paper 860**)

Paper 616 presents a reliability assessment that takes into consideration the effect of overvoltage protection. Three alternatives are considered: traditional protection, with surge arresters for the biggest transformers and spark gaps for the smallest ones, "full" protection with all the spark gaps substituted by Current Limiting Arresters (CLA), and a partial protection, with all the small transformers protected with CLA and the biggest ones protected with surge arresters at a certain distance from the substation. The reliability analysis shows the impact of lightning on outages and voltage dips. The use of surge arresters, even in the partial protection scheme, allows reducing the cost of lightning with a reasonable amount of investments.

	Traditional protection	Full protection	Partial protection
Permanent faults	1005.65	997.89	1002.28
Permanent faults (lightning)	22.09	14.33	18.72
Short interruptions	998.48	663.34	896.29
Short interruptions (lightning)	433.94	98.8	331.75
Voltage dips	733.7	471.77	471.77
Voltage dips (lightning)	361.78	99.85	99.85
Investments	-	103.8	45.6
Total	2737.83	2236.80	2415.94
Total (lightning)	817.81	316.78	495.92

Fig. 7 – Outage and investments costs caused by lightning with different level of protection (**Paper 616**)

Sub block 2: Innovative system development for accommodating the dispersed generation, improving the efficiency, and increasing the quality of service

The current energy efficiency of the global energy sector is only 32.5 % which globally affects the security of energy supply, the global emissions and the costs (Paper 255). The most important reasons for the low efficiency are high distribution losses, the use of outdated technologies and running at low loads. These results are presented in Paper 255 and justify the resort to high quality local electricity production and cogeneration that can allow a 20% reduction in primary energy supply. Paper 255 gives a very complete analysis of the energy situation in EU and justifies the growing attention to DG and energy efficiency. For these reasons µCHP may be a useful option to improve energy efficiency as proposed in Paper 61.

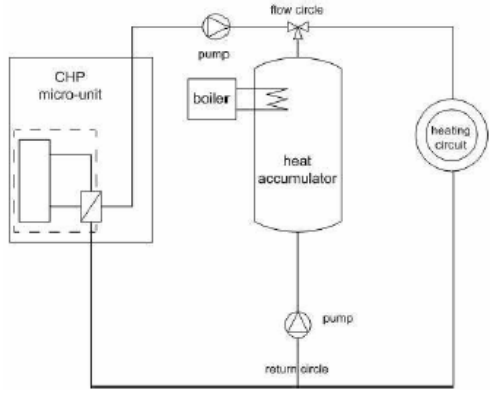

Fig. 8 – Equivalent circuit of the CHP micro-unit in the simulation tool proposed in **Paper 61**

µCHP generators are connected to the low voltage network and their integration in the system has to be carefully analysed. The current economic situation prevents a strong market penetration but the foreseen increase of energy prices will favour the widespread integration of µCHP units. Paper 61 gives an interesting method to assess the impact of µCHP on low voltage networks. It is very important the conclusion that the grid operator should participate in the market process so that the benefits of CHP micro-units cab be properly assessed and exploited. Paper 273 is also focused on the network efficiency that can be improved with DG and storage system. The paper proposes different energy scenarios in Germany. The efficiency scenario is depicted in Fig. 7. The conclusions of the paper are very interesting. Power losses may be reduced but the CHP DG has to be designed considering the local power and heat demand of the consumer. Also storage devices may contribute to reduce losses but internal losses cannot be neglected. From the environment point of view, again CHP DG has the possibility to reduce emissions but the evolution of heat demand has to be carefully considered since a reduction of heat demand may lead to a reduction in the efficiency of CHP units.

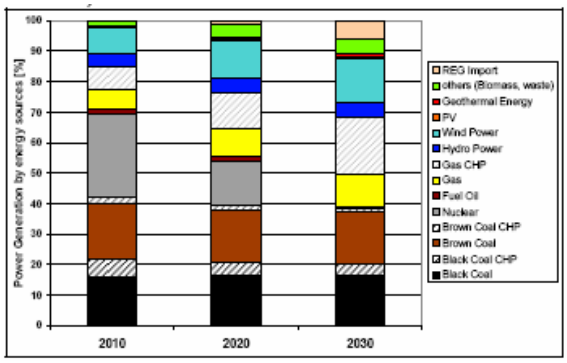

Fig. 9 - Power generation in the efficiency scenario presented in **Paper 273.**

DG is considered an interesting option to improve efficiency but it should be recognised that there non technical barriers that are still limiting its integration. **Paper 267** gives very useful information on the UK distribution price control and on the system of incentives implemented to promote RES and DER. DNO and DG owners have conflicting objectives and the authors propose the application of multi-objective programming to solve the tensions involved in connecting DG. The current UK incentive scheme does not consider the deferral of investment achieved with DG. For this reason, the optimum penetration level of DG is different for DNO and DG owners. From the DNO point of view, the direct benefits from DG connections may be covered by a possible losses increase, by limiting its willingness to integrate DG. From the developer point of view, the incentive scheme leads to connect as much capacity as possible and in the least number of units. Nevertheless such objectives are contrasting, fair trade-off solutions can be found that are reasonable for both actors. **Paper 755** deals with the Italian distribution code for the non discriminatory access to public networks. The subject is of the highest interest because the rules for network connections have a large impact on the DG market and can create unfair situations.

What emerges from all the papers is that the future will be characterised by a significant penetration of DER and RES. **Papers 567** gives the Finnish vision of the future power system (Fig. 8) and DG is one of the options for improving the distribution system. Furthermore, the authors propose the adoption of innovative solutions like microgrids to improve efficiency, increase reliability, and accommodate significant dispersed generation. Similar to Microgrids are the Autonomous Demand Area Power System (ADAPS) proposed in **Paper 368 (**Fig. 9**).** The experimental studies proposed in the paper show that the voltage regulation used in ADAPS can reduce the fluctuations caused by the load and power generation changing.

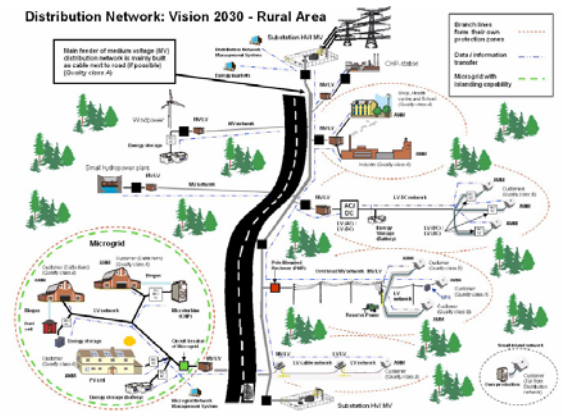

Fig. 10 – The Finnish vision of the future distribution networks (**Paper 567**).

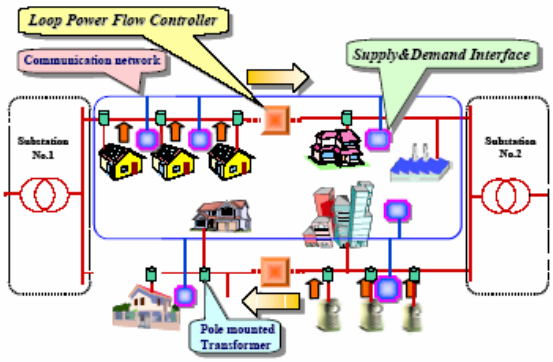

Fig. 11 – The ADAPS presented in **Paper 368**

The impact of DG in system development is often concentrated on voltage regulation and many authors have proposed voltage regulation solutions that can be regarded as implementations of the more general concept of active networks. In **Paper 806** the active network is used for voltage regulation in distribution networks autonomously controlled. The centralised controller coordinates the intelligent nodes in the network and the tap changer in the HV/MV transformer. The voltage regulation in long feeders is achieved by acting on power flows, whereas the customers supplied in the vicinity of the transformer benefits of the transformer control. The paper gives important requirements on the transformer and on the control system. Again in **Paper 35** the application of innovative voltage regulation is presented as a way to facilitate the integration of DG. The paper does not present the method used but shows the impact of voltage regulation on the maximum allowable DG penetration. **Paper 791** describes a DMS platform that enable the DNO to improve operational flexibility, to meet regulatory targets and to accommodate DG, avoiding in many cases the network reinforcement CAPEX normally required in such circumstances. The paper describes the state of the art reached and demonstrates that active control of distribution systems is going to be a practical reality.
Where some authors prefer to implement in the existing distribution scenario new control and automation systems to achieve the active management of the distribution systems, some others prefer to think about innovative solutions that require a dramatic changing from the current situation but in the long term can have important benefits. In such a context, **Paper 843** proposes to use intelligent nodes to improve voltage regulation. The idea is to defer networks investments and to facilitate DG connection by using a scheme like the one presented in Fig. 10. The intelligent node is power electronics device that has the duty to optimize the voltage in the feeder connected by modifying the active and reactive power flows. The system has interesting features but many questions on its practical applications have to be still answered.

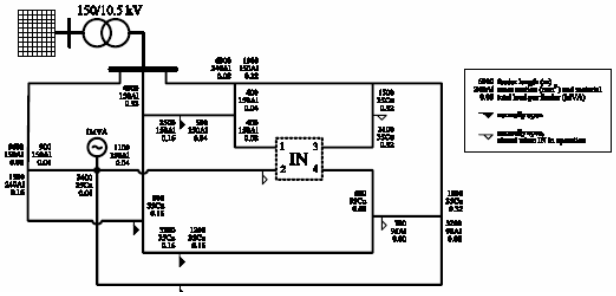

Fig. 12 – Test grid for the Intelligent Node concept (from **Paper 843**)

Paper 385 deals with the benefits of changing from AC to DC LV distribution systems. The main advantages of DC LV systems lie in the reliability improvement. The Paper clearly shows benefits and costs of the innovative system that has the important feature to easily accept DG without conversion systems (e.g. fuel cells). It is showed that SAIFI may be reduced and also the power quality increased with storage systems and IGBT AC/DC converters. Similar results are achieved in **Paper 464.** The authors highlight the main drawbacks of the LV DC distribution. In particular Power Electronics has a shorter lifetime than traditional network components.
Planning with significant amount of DG installed or going to be installed poses new challenges to distribution planners. **Paper 792** illustrates an integrated planning design and analysis environment for new DG connections. **Paper 264** propose a planning tool to define the optimal location of DG in a given network. The main novelty in the proposed approach is that it combines the optimal power flow and the genetic algorithms. It may be useful to identify the best sites and capacities to connect a predefined number of generators. Again GAs are used also in **Paper 335** to plan the optimal network expansion considering DG. The paper is interesting because the proposed methodology considers simultaneously network expansion and DG allocation. It could be useful to define reference network for the strategic planning. The application to large scale networks should be further investigated.
The use of DG is related also efficiency of the power delivery that is quite low due to the level of losses, but there other ways to improve efficiency by reducing losses.

For instance high efficiency distribution transformers may be used as **Paper 141** proposes. The paper is a useful compendium of the most important types of high efficiency transformers and gives the reader data about costs. Comparisons between traditional and innovative transformers are also presented. From the presented results it is clear that the attention of Regulators and politicians should not focus only on RES but more generally on efficiency. The reduced diffusion of high efficiency distribution transformers is mainly related of an unfair incentive mechanism that is too much unbalanced towards RES. **Papers 518** deals with efficiency and losses and compares different schemes for LV networks. **Paper 193** proposes the adoption of DSM to reduce losses. In particular the delay of the peak of domestic loads gives very useful benefits. The domestic load shifting applied in the UK would save around 160 GWh per year. The achievable scale of reduction is small in comparison to effort involved in the profile change but if a less conservative comparison is preformed more interesting considerations can be made. Finally, **Paper 43** deals with the problem of the business efficiency of distribution companies, i.e. the reduction of non technical losses. The paper focuses on the localization of non technical losses by means of the integration of all the information available in the company.

Questions on Block 2

Sub block 1 – Network development & reliability

- Question 1_B2.1: Climate change is becoming a reality. Catastrophic events are getting more frequent than in the past. Do the long-term network development studies consider the effect of severe weather condition? Is the reliability calculated properly?
- Question 2_B2.1: Network automation is a relatively economic way to achieve reliability goals. Is this correct in aged systems?
- Question 3_B2.1: Designing with the Six Sigma tools seems to give many interesting benefits. Can the authors of paper 684 give a clear explanation of the method highlighting the improvements in comparison with other techniques?
- Question 4_B2.1: Many papers show the impact of network architecture on the reliability. Normally alternatives are compared measuring their reliability calculated with different methods (analytical and simulations). Then a cost benefit analysis is performed to choose the most effective alternative. Is the robustness of the optimal choice properly considered? Which is the role of uncertainties in the choice of optimal solution? Can fuzzy logic, risk analysis help the decision maker?
- Question 5_B2.1: Distributed generation is often regarded as a possible solution to improve reliability. There are no papers in the Block that has tried to assess the benefits of DG for the reliability. Does it depend on the low penetration of DG? Does it depend on the current standards and rules for connections? Can intentional islanding be adopted in some cases?
- Question 6_B2.1: 1kV LV distribution systems have been used in Finland and in Italy with the idea to improve reliability in rural areas. Despite the favourable simulations, this solution did not find a large application. Why?
- Question 7_B2.1: Lightning phenomena are important causes of outages in distribution systems. Paper 860 proposes to increase the BIL, while Paper 616 considers as possible actions the use of surge arresters. Can the authors compare and discuss the results achieved?

Sub block 2 – Innovative system development for accommodating the dispersed generation, improving the efficiency, and increasing the quality of service

- Question 1_B2.2: Medium size CHP units can help to improve efficiency in the distribution system. Is this totally correct or there is the risk to increase network losses?
- Question 2_B2.2: Micro CHPs at the low voltage level are very promising, thanks to a better exploitation of natural gas. Can LV distribution networks accept a high penetration of DG?
- Question 3_B2.2: What about safety issues with millions of micro CHP generators in consumer premises?
- Question 4_B2.2: Can the building automation help integrate micro CHP generators?
- Question 5_B2.2: DER and RES have subsidies and incentives to favourite their integration in the system. DSO can earn money whether it accepts the connection of generators. Is it fair that the deferment of investment is not currently considered?
- Question 6_B2.2: The Italian distribution code for the non discriminatory access to public networks considers DSO and consumers responsible for the quality of supply. What about DG? Why DG are not considered in the quality of service?
- Questions 7_B2.2: Which is the main difference between the Autonomous Demand Area Power Systems and Microgrids?
- Questions 8_B2.2: Can the active management of distribution networks help integrate new DG at minimum cost? Are there any practical examples

implemented? How can the network services given by DG be remunerated?

- Questions 9_B2.2: The active network management may be regarded as a service for power producers. Is it necessary to establish a tariff for such a service?
- Questions 10_B2.2: Intelligent nodes in Paper 843 allow a better exploitation of lines and a better voltage regulation. The use of intelligent nodes allows implementing functions similar to those achievable with "traditional" active networks, which control producers and responsive loads. Considering the cost of intelligent nodes and the difficult in practical realization, which are the potential benefits in comparison with active networks?
- Questions 11_B2.2: DC LV systems have many interesting features. Which is the possible long term impact of such system considering the smaller lifetime of power electronics? What about the protection system in DC LV networks?
- Questions 12_B2.2: Is it useful to identify the best location for DG connections in a given network? How can such planning tools be used?
- Questions 13_B2.2: DER and RES, active management, and demand side response have the potential to reduce losses, whereas the high efficiency transformers certainly reduce losses. How can we promote the use of such high efficiency transformers?
- Questions 14_B2.2: Can the innovative active management of distribution networks help identify and reduce the non technical losses?

Table 2: Papers of Block 2 - Network Development

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Sub block 1: Network development & reliability					
326	Methodological issues concerning the quality of energy supply				X
712	Reliability Evaluation of Distribution Networks and Comparison of Performance using Representative Networks	X			X
613	Visionary development of distribution networks				X
479	Customer Outage Cost Models - Comparison	X			X
334	A Cost-Benefit Analysis of the Network Automation Programme	X			X
283	The Relationships between Weather Variables and Reliability Indices for a Distribution System in south-east Queensland				X
253	Rationale for the Quality of Supply Policy; Determination of Quality of Supply Targets				X
152	Impact of ageing on the MV underground asset reliability	X			X
684	Utility Design for Reliability – Optimization with Six Sigma Tools	X			X
478	Influence of Different Probability Distributions of Reliability Parameters on Short-Term Investment Prioritization in Distribution Networks				X
514	Choosing of the optimum type of the MV municipal distribution network when respecting the customer's standards of electricity supply continuity				X
607	Improvement of the supply quality by introduction of a new concept for modulized distribution networks in rural areas of Sweden				X
559	Outage cost comparison of different medium voltage networks				X
525	A Comparison of the Electricity Distribution Investment Strategies	X			X
462	1 kV low voltage system as a part of a distribution network reinvestment strategy	X			X
140	Restructuring Of The Existing Medium Voltage Cable Networks Using Segmentation Method - Impact On Networks Reliability	X			X
425	Quality of Supply as a Boundary Condition of Cost-Efficient Distribution Networks				X
21	Fixing network constraints as an opportunity to promote a generalised and high quality access to Electrical Energy (Project SCAI)				X
249	Advanced Reliability Assessment of a Distribution Network; Objectifying of Proposals to Improve the Quality of Supply				X
321	The application of Reliability Methodology to select and prioritise distribution networks within Developing Country (South Africa)				X

268	Antithetic Variates Technique Applied to Time Sequential Monte Carlo Simulation for Reliability Assessment of Small Isolated Distribution System with Dispersed Generation			X	X
483	Reliability assessment of low voltage consumers in Jinan Power Supply System				X
110	Cutting the costs of hv substations				X
616	Optimization of over voltage protection of distribution networks	X			X
860	Comparative Performance of Projects of Medium Voltage Overhead Distribution Line Under Induced Voltages	X			X
Sub block 2 – Innovative system development for accommodating the dispersed generation, improving the efficiency, and increasing the quality of service					
255	Local electricity generation: an evaluation of its values for the distribution of electricity		X		X
61	Grid orientated integration of combined heat and power micro-units		X		X
273	Eco-efficiency Assessment of dispersed power generation in distribution energy networks		X		X
267	Multi-objective optimal power flow to evaluate the tensions involved in connecting distributed generation		X		X
755	Distribution code set up in the liberalized environment Regulatory perspective – The Italian experience		X		X
35	An evaluation of alternative voltage control methods enabling increased distributed generation connection capacity		X		X
791	Recent Active Distribution Management System Developments		X		X
843	Intelligent Nodes in Distribution Systems - Operating Concept			X	X
806	Intelligent limiting of voltage variations in autonomously controlled networks			X	X
567	Vision of the Future Power System - Distribution Network 2030		X		X
385	Distributed Generation in DC Distribution System		X		X
464	Application of low voltage DC-distribution system – a techno-economical study				X
368	Development of Autonomous Demand Area Power System - Operation and Control for Regulation of System Voltage -		X		X
792	An integrated planning, design and analysis environment for new distributed generation connections		X		X
335	Distribution Systems Expansion Planning considering the Exploitation of Distributed Generation by a Multi-Objective Genetic Algorithm				X
264	Strategic placement of distributed generation capacity				X
141	Energy Efficient Distribution Transformers in Spain: New Trends		X		X
518	Improving the energy efficiency in electrical distribution networks through loss reduction				X
193	The impact on distribution losses of delaying some peak demand to change the domestic single-rate demand profile			X	X
43	Energy losses management				X

Block 3: Distribution planning

The term planning can be found in many papers presented in S5. Anyway the papers assigned to Block 3 cover the problem of network planning not only from the theoretical point of view but they also give interesting practical application of planning. In particular there is a growing interest not only in the medium term planning but also in the long term one. The factors that are determining such an interest in planning are mainly related to the investments that the incoming ageing of assets, the reliability requirements imposed by the Regulatory Bodies, and the impact of Distribution Generation will cause in next years. **Paper 822** suggests to modify the classical approach based on peak power and to use the energy for planning purposes. Such a change requires a small effort but can help to manage the risk of un-served energy for each planning option. The Energy Exceeding Normal (EEN) may be used in ranking planning alternatives for the risk analysis. The suggested application is particularly well suited for Distributed Resources integration because their power output is often not coincident with the demand, but it can be used also in traditional substation and feeder solution. The proposed methodology can give an important contribution to the development of traditional planning tools that are normally based on power capacity.

Long term planning has been dealt with different approaches in various papers. **Paper 440** shows the approach followed for the long-term planning in Libya, which has been experiencing a rapid economic development that is putting under pressure the power system. The main idea is the definition of a Masterplan for the strategic network development (the target year is 2020) that could be the guideline for everyday decisions like network extensions, removal of weak points and changes in the network. The main steps of the proposed procedure are data collection, load forecast, definition of planning criteria, development of standard structures, and the application load density. The principle of superimposition to develop intermediate networks is also used.

Three papers deal with the optimal planning with the multi-year optimal planning. **Paper 690** adopts the dynamic programming to find the optimal evolution of distribution systems during a given period of study. The main idea of the paper is to find the optimal evolution of the network that minimises CAPEX and OPEX. The resort to active network is considered as a planning alternative as well as the network upgrade or the building of new lines. **Paper 761** also focuses on multi stage long term planning. The main idea of the paper is to deal with the uncertainties on loads and generators related to long term planning. The procedure adopts fuzzy models and robustness criteria to find the network development that is optimal from both economic and technical perspective and is also robust to withstand unpredictable future scenarios. **Paper 205** solve the multi-stage network planning considering the uncertainty on load growth. As in **Paper 690**, the dynamic programming is used with a special strategy that allows reducing the computational burden. The load uncertainty is modelled with fuzzy models whereas the risk management is dealt with the maximum expected cost criterion. But distribution planners are not only concerned about long-term planning. Everyday decision is a very complicated activity that has to be performed in distribution companies. **Paper 637** concentrates on such a topic and shows that everyday decisions require following a superimposed strategic long-term plan. Indeed, short term solutions are often foes of global optimization. Figure11 gives an overall view of the planning process considering different time scales. The greenfield approach can be used to identify the reference optimal long term system evolution. Following the long-term planning solutions during the operational planning allows saving money and improving quality and reliability. The useful examples provided help to understand the process that has been used for more than 10 years without any investment error.

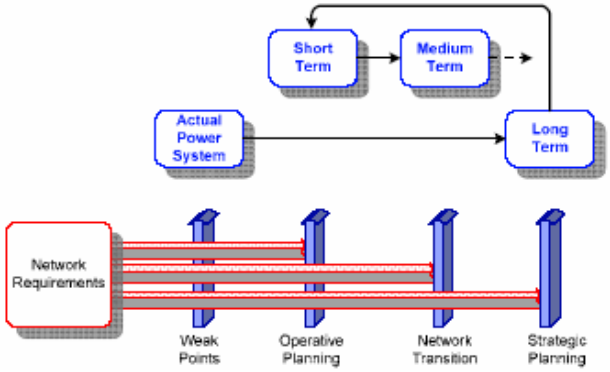

Fig. 13 – Planning loop from proposed in **Paper 637**

Paper 640 gives an interesting solution to the expansion planning problem. Network automation can be really a solution to postpone traditional network investments but the network automation is seldom considered in planning as the traditional distribution planning normally does not consider the role of automation that is generally related to system operation. The methodology proposed allows considering the different requirements of loads for reliability without increasing the reserve capacity. **Paper 392** partially disagrees with the **Paper 640.** It proposes an optimal planning tool for distribution network planning that considers the presence of network automation and with the aid of a sequential Montecarlo simulates the sequence of actions following a fault. The presence of aged elements is considered. The main result found is that, due to the growing number of components that are reaching the end of their operative life, automation will not be able to maintain the current level of reliability and without corrective maintenance and replacement customers are destined to experience an increasing level of interruptions. Also the authors of **Paper 913** are concerned about ageing, but they consider that there is in many cases enough reserve to face the current situation without the replacement of portions of the network. The methodology proposed is based on a solid database containing geo-

referenced data on the network and other technical aspects. Such data are used in a simulation tool that allows optimising planning. The application of the procedure to a German urban grid that is characterised by a low degree of utilization and a large amount of equipment showed that is quite simple to achieve a 10% reduction of the infrastructures. Finally **Paper 771** deals with distribution network planning giving an overview of different schemes that find a good compromise between reliability and costs. **Paper 412** deals with the problem of Voltage Dips (VD) in planning. The improvement of service continuity and the reduction of customer minute loss are one of the most important drives of the distribution business. Nevertheless, VD are gaining importance because the number of sensitive loads is continuously increasing. The paper proposes an optimization algorithm that explicitly considers power quality at the planning stage. Network actions and custom power devices are used to achieve an acceptable average level of VD under a prefixed threshold. The paper gives some results and consideration derived from the application to a small scale example. Useful charts are provided that correlate the desired power quality level with the level of investments that are necessary. **Paper 360** presents another planning tool based on genetic algorithms that is also focused on quality improvements intended as the reduction of SAIDI and SAIFI. The planning actions considered are not only the network refurbishment, replacement or building but also maintenance. The system called SPIN is currently used in the Rio Gran Energia, a Brazilian Distribution Company with a significant improvement of the decision making process.

The **Papers 113**, **709**, and **880** deal with the integration of GIS in the planning process. **Paper 880** is focused on the use of spatial data for long-term planning of medium voltage distribution networks considering feeder costs and routing. The planning tool is formed by a core program that performs optimizations and several GIS modules for the GIS data treatment. With this useful tool, the planning of MV distribution networks can, for instance, properly consider the cost of routing in different terrains. **Paper 709** describes the steps and major concerns of adopting architecture for GIS and DPlan integration, reporting the results of a project in a Portuguese company, EDP. Business requirements, the adopted technical solutions and final results are presented. **Paper 113** deals with the optimal planning of the urban distribution network of Shanghai. The overhead urban distribution network in Shanghai is going to be replaced by 10kV buried cables and this change may give planners the opportunities of locating some 10kV switching stations. Both papers highlight the opportunities deriving from the application of spatial data and GIS in planning.

Questions on Block 3

- Question 1_B3: Why can the energy calculation be helpful in planning with DER? What about probabilistic calculations?
- Question 2_B3: Long-term planning is affected by uncertainties and risk. How can be managed in an objective and quantitative manner?
- Question 3_B3: The implementation of active networks is a long step-by-step procedure that requires multi–year programming. Can the consideration of active management in planning be useful to find a more convenient network development?
- Question 4_B3: The greenfield approach is a useful way gives the guideline for the everyday decisions. Many planning tools are able to develop the optimal network development (not only the final solution but also the intermediate ones) considering the existing assets. Why the greenfield approach should be preferable to the brownfield one?
- Question 5.B3: The ageing of network components will increase the number of outages. Paper 640 states the automation will not be able to maintain the current level of quality of supply. Can these results be modified whether preventive and corrective maintenance is considered?
- Question 6.B3: Which are the main advantages of Sequential MonteCarlo in reliability studies?
- Question 7.B3: Which is the impact of the reliability functions for aged components?
- Question 8.B3: Paper 913 states that distribution systems have now reached so much capacity that in many cases new investments might be avoided. Is it really a normal situation in Europe?
- Question 9.B3: Paper 412 shows that it is possible planning a network with a prefixed level of power quality (frequency of Voltage Dips) by acting on network reliability and network topology. Which is the role of voltage conditioners (e.g. DVR)?
- Question 10.B3: Planning under quality constraints is becoming almost mandatory. Some authors consider the cost of outages in the objective function, some others the penalties to be paid or, finally, the limits imposed by regulators. Which is the impact of such different choices in the final results?
- Question 11.B3: Spatial data and GIS are fundamental for planning. May GIS be useful in planning with RES to automatically identify the optimum mix of energy sources?
- Question 12.B3: Which are the most important challenges in planning the development of

distribution system in countries with a very high rate of economic growth?

Table 3: Papers of Block 3 – Distribution planning

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
822	Using Energy as a Measure of Risk in Distribution Planning		X		X
440	Network development in a fast changing society - Example Tripoli in Libya		X		X
690	Multi-year optimal planning of active distribution networks				X
761	Implications of Using Uncertainties in Multi-Stage Long-Term Distribution Planning		X		X
205	Risk Management Based Procedure for Multi-Stage Expansion Planning of Distribution Networks Under Uncertainty		X		X
637	Everyday decisions concerning network development can be optimized		X		X
709	An architecture for Flexible GIS Integration of Distribution Planning and Analysis Systems				X
880	Exploitation of Diverse GIS Data Models for Routing and Other Planning Purposes				X
771	Study on practical typical single line connection in distribution network				X
360	Integrating Maintenance and Expansion Planning for Improved Quality of Supply				X
392	Distribution system reliability assessment considering equipment aging		X		X
412	Distribution network investments to improve Power Quality		X		X
640	Automation as a Resource for Distribution System Planning				X
913	Planning of projected medium-voltage power grids A tool that meets the requirement of today's regulated market		X		X
113	The automatic routing of 10kv switching station in urban distribution network based on spatial gis				X

Block 4 : Methods and tools

Sub block 1 – Load demand evolution and forecast

Load forecast is essential for distribution planning and operation. An accurate estimate of consumption can improve long-term strategies and reduce the uncertainties of the planning process. **Papers 8** and **9** deal with a methodology for the peak load forecast in Serbia where a new tariff system has been recently applied. The methodology proposed is able to capture the trend imposed by the new regime with high precision. Climate changes and global warming are becoming a serious concern. **Papers 722** correlates load peak demand with temperature and gives interesting results. Long term load forecast is dealt with in **Paper 823** as it is the source for a proper long-term planning. The paper is based on a three steps procedure. Step 1 describes how all loads are modelled to get a base for load forecast. Step 2 is definition of load increases/decreases in networks which are split into structural groups/classes and Step 3 is the simulation and evaluation of these network developments. The described process gives a detailed and reliable picture of the future network and is therefore the source for the strategic network planning.

Paper 866 proposes a new method based on Functional Analysis, applied as a sequential procedure to model under the lack of data. This situation is what happens in Brazil after the energy crises of 2000/01. The case study shows that the load dynamic of Elektro, a Brazilian distribution company, is almost entirely explained by the Brazilian GIP, temperature mean value and a reduced seasonal component. The synthesis stage was tested for a nine month period with almost negligible errors. It is interesting to observe that, although the functional approach is common to the solution process, the employed explanation variables differ from utility to utility, according to their operational regions. The basis vectors do depend on the nature of the load, but the algorithm is general. **Paper 472** deals with the estimation of load consumption for the optimal power transformer utilization.

Sub block 2 – Methods and tools

Papers in this block are mainly devoted to methods and tools to solve some specific problems of the distribution business. **Paper 145** deals with a new methodology used to elaborate the investment process (Fig. 11). The idea behind the model is to correlate the stochastic model of each component to the feeder to whom it belongs. The model gives the attended network performance and the investments that are necessary to comply with reliability drivers.

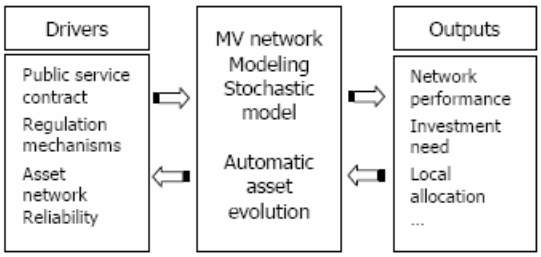

Fig. 14 – Overview of the methodology proposed in **Paper 145**

Paper 163 describes a tool to assess the theoretical performance of an electric substation during peak demand for planned and unplanned outage conditions. Indeed, the peak annual demand is in summer and, as a consequence, the high temperatures will significantly reduce the cyclic capability of transformers at the time when the demand is highest. In particular the thermal transformer analysis tool is implemented in the procedure described in Fig. 12.

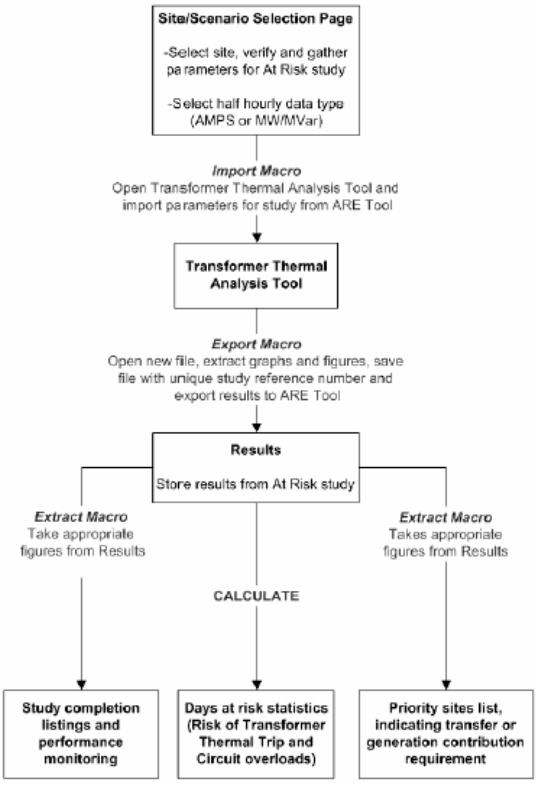

Fig. 15 – Tool for the assessment of at risk stations (**Paper 163**)

Paper 458 gives a useful model of non linear loads to be used in load flow calculation. The paper considers the most common load models used in load flow analysis (constant impedance, constant power, constant current and the general ZIP model). The models developed by authors and implemented in PSPICE allowed demonstrating that both the ZIP and the exponential model are not suited for non linear electronic loads, like rectifiers and dc-dc converters, when these devices use passive power factor compensators. The error is due to strong influence of source inductance

(which is network specific), and internal circuit inductance and capacitance. This influence is better modelled with the general Polynomial load model. When an active power factor compensator is used, Exponential and Zip load models are sufficient.

There is a group of papers dealing with the problem of the optimal location of capacitors. Each paper proposes a different methodology and has different objectives. **Paper 180** proposes the use of particle swarm optimization algorithms to optimize size and position of capacitors in networks with a high level of harmonic distortion. The objective function to be minimised is related to losses as it considers the net savings resulting from peak load and energy reduction taking into consideration the cost of capacitors. Requirements on maximum allowable THD and on maximum and minimum voltage are the constraints to be complied with. The comparison between the proposed methodology and the exhaustive search shows the effectiveness of the PSO. **Paper 15** also deals with optimal location of capacitor banks in unbalanced multiconverter distribution systems. In this case the authors propose and compare different algorithms for the optimal placement with the main purpose to reduce the computational burden that can reach intolerable levels in real scale applications. Microgenetic algorithms and two reduction techniques have been applied and compared. The reduction technique developed by the authors, the Inherent Structure Theory of Networks, allows reducing the number of candidates and gives the best results. **Paper 88** presents an enhanced particle swarm optimization (E-PSO) technique to approach the problem of reactive power compensation in distribution systems. The optimization problem uses a multiobjective formulation based on mimization of energy losses and voltage deviations, subject to voltage and compensation restrictions. The performance of the new approach was demonstrated using simulations on a 36 nodes radial test system. **Paper 768** deals with reactive power compensation in Serbia. Performed analyses indicated the need to reduce reactive loads of 110/X kV substations. The selection of the substation where it is necessary to reduce reactive loads in predetermined total amount is made by an index method presented in the paper. The index is based on the application of the optimal load flow to assess the marginal cost maximal values (for peak load). The marginal costs are used to rank the candidate substations. Technical and economical effects of proposed measures for reactive loads reduction are analyzed. **Paper 274** also deals with the impact of capacitor banks. The paper is based on the observation that the use of capacitor banks installed on the MV bus of substation did not give completely positive results. Capacitors helped to improve voltages and power factor upstream but they worsened the situation downstream. The main conclusion that can be derived from the study is that the capacitor position has to be carefully optimised as suggested by the aforementioned papers. **Paper 577** presents an innovative optimal VOLT/VAR control strategy for voltage regulation. The optimal management strategy allows setting the status of tie-switches and ULTC considering the typical daily load pattern in the area of Palermo, Italy. The economic benefits achieved with application of the proposed methodology are also given in the paper. The methodology is of the multi-objective type; the objectives are the power losses minimization and the voltage regulation. Some results are depicted in Fig. 12.

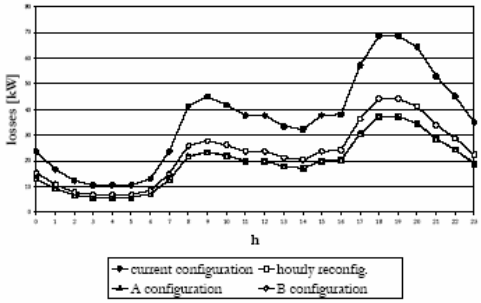

Fig. 16 – Reduction of losses with the methodology proposed in Paper 577

Papers 907 deals with load flow calculation in distribution networks and gives some data on the use of a specific software. **Paper 606** compares the well known Forward/Backward Sweep (FBS) algorithm with the current injection three phase load flow algorithm (TCIM). The authors demonstrate that many of the most positive features of FBS disappear when the dimension of the network increases, voltage regulation is considered and meshed systems are considered. In these cases, the TCIM may lead to good results with less computational effort. **Paper 562** deals with the short circuit calculation methodologies as they are proposed by different standards. Very useful comparisons are proposed.

Paper 363 describes a methodology to automate the elaboration of constructive distribution network projects. The case studies presented showed that the tool can be easily applied at the design of overhead distribution lines. The main advantages of the tool are the reduction of the dispersion in design solutions, the reduction of design errors, the reduction of costs and smaller design time.

Paper 710 proposes a methodology for the operational planning (optimal load flow) in sub-transmission systems. The optimization tools developed by the authors allow defining the optimal network configuration through the definition of the state of the breakers and the position of the tap changer according to the load pattern. The tool is based on GA and Evolutionary algorithms used for active and reactive power optimization. The methodology in this article assists the daily planning studies carried out in Brazilian Control Operational Centers.

Paper 650 presents a methodology for modelling, analyzing, and selecting suitable single line configurations for distribution substations based on different criteria, such as reliability requirements, load flow, cost of interruption, initial investments, operation and maintenance. These criteria are combined in Life Cycle Costs (LCC) with

associated interest rates and substation life cycle period. The paper also gives useful examples of application.

Paper 865 proposes an innovative and realistic approach to the problem of the Optimum Energy Portfolio Contract. The model corresponds to a mixed-integer nonlinear, stochastic programming problem, and solved by a specialized optimizing program within a couple of minutes in a standard notebook. The most important feature of the procedure is that the risk level may be kept below a prefixed threshold at any instant of the horizon of study.

Paper 704 applies a Data Envelopment Analysis (DEA) methodology for the efficiency measurement in a regulatory context by the construction of an efficiency frontier. From the results obtained, it appears that DEA is appropriately for the estimation of the relative efficiency and at the same time it allows increasing the information that a regulator has, which contributes to alleviate the problem of imperfect information.

EDF ERD has been buying its network losses on electricity market since 2004 July 1st. **Paper 323** presents this experience on two main points: measuring the losses and buying the energy. ERD's electricity losses cost around 1 billion euros every year recouped through regulated tariff mechanism. The volumes of electricity and money involved are such that they raise issues of availability, liquidity and financial risks.

Paper 389 presents a methodology for the assessment of distribution networks in Egypt. The study allows concluding that some investments are necessary considering the exploitation of the equipment and the level of energy losses.

Questions on Block 4

Sub block 1 – Load demand evolution and forecast

- Question 1_B4.1: How much are reliable load forecasts in a liberalised energy market?
- Question 2_B4.1: The global climate is rapidly changing. Is it necessary to review the load estimation models considering the correlation between temperature and peak load?

Sub block 2 – Methods and tools

- Question 1_B4.2: Reactive power compensation is very attractive because it improves voltage regulation and reduces the energy losses. Can load variability be considered in the optimization algorithm proposed for the optimal capacity allocation?
- Question 2_B4.2: Can the optimal capacitor location be a part of an optimal voltage regulation program? Is it possible to optimize the site and size of capacitors bank with the optimal site and size of DG?
- Questions 3_B4.2: Network reconfiguration integrated with the OLTC operation in the substation can improve voltage regulation. Can the existing network be managed in such a way or do they have to be modified?
- Questions 4_B4.2: Short circuit calculations are fundamentals to power engineers. There are significant differences between standard indications for short circuit calculations. Which standard should be considered more conservative?

Table 4: Papers of Block 4 - Methods and tools

Paper No.	Title	MS a.m.	MS p.m.	RIF	PS
Sub block 1 – Load demand evolution and forecast					X
8	An Alternative Methodology for Peak Load Forecast in an Assigned Area Regarding the Effects of New Tariff System				X
9	Consumption Area of "Elektrodistribucija Beograd" Peak Load Forecast Regarding the Effects of New Tariff System				X
472	The Estimation of Consumption Evolution as a Determinant Factor in Optimal Power Transformers Utilization				X
722	Weather Normalized Load Demand Forecasting for Distribution Planning				X
823	Long Term Load Forecast – The Source for Network Planning				X
866	A new approach for load forecasting: predicting the causes, foreseeing the consequences				X
Sub block 2 – Methods and tools					
145	Investment strategy studies based on a stochastic model of MV feeder quality of supply				X
163	The development of a tool to help prioritise major infrastructure reinforcement based on assessment of network demand, transfer capability and permissible DG contributions				X

458	Modelling of Non-linear Electronic Loads for Power System Studies: A Qualitative Approach				X
180	Optimal Capacitor Placement on Radial Distribution Feeders in Presence of Nonlinear Loads Using Binary Particle Swarm Optimization			X	X
15	Optimal Allocation of Capacitors in Unbalanced Multiconverter Distribution Systems Using Genetic Algorithm			X	X
274	The impact of capacitor bank installation on the performance of distribution systems - a case study -				X
88	Enhanced Particle Swarm Optimization method for power loss reduction in distribution systems			X	X
363	Decision Support System to Design Distribution Networks				X
389	Evaluation of the Electricity Distribution Networks in terms of the Investment cost of the network Components				X
577	Application to an Italian Distribution System of a Multiobjective Optimal Volt/VAR Control Strategy: Improvements and Management Problems			X	X
606	A Study on the Performance of TCIM Full Newton Power Flow for Large Distribution Systems				X
768	Reactive Power Audit in Serbian Transmission Network and Effects of Improving Measures			X	X
907	Estimation of current's flow, loss of power and voltage fall down in distributive networks by using PDM KMp,q program				X
650	Reliability and economic analysis for selecting cost efficient distribution substations				X
323	Buying network losses on the energy markets				X
865	An innovative approach for the optimum portfolio risk control instead of risk evaluation			X	X
704	Performance Evaluation and Returns to Scale in Distribution of Electricity. An Application to Argentine firms				X
710	Operational planning optimisation in subtransmission systems using evolutionary algorithms				X
562	A comparison of short circuit calculation methods and Guidelines for distribution networks				X