Special Report - Session 1
NETWORK COMPONENTS

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Introduction

Session 1 deals with all aspects related to the components used in the electricity distribution networks: cables, overhead lines, primary and secondary substations, transformers, switchgear and their control, protection and monitoring systems, new active power electronics devices. It covers topics related to the life cycle optimisation of assets from design through installation, operation and maintenance to the end of life management, as well as new solutions for diagnosis and monitoring. The session also covers environmental aspects including eco-design and life cycle analysis, standardisation, ergonomics and the safety of both the operating staff and the public. It aims at providing an overview of the state-of-the-art in component design and proposals for future components, including the ones needed for smart grids and e-mobility. This session is an opportunity for DSO and manufacturers to share their objectives.

124 papers have been selected for the Session 1 – Network Components – of CIRED 2013. They have been organized in four blocks, which are the same for both this special report and the Main Session.

The structure retained for these blocks is as follows.

Block 1 Ageing of network components, diagnostic and monitoring (31 papers):
- Partial Discharges monitoring on MV networks
- Ageing of the cables both in MV and LV networks, either UG or OHL
- Ageing of other network components, i.e. transformers including OLTC, MV circuit breakers and LV switchgear

Block 2 Return from field experience, retrofit and maintenance strategies (32 papers):
- Behaviour of network components as an input for standards and improvements
- Retrofit, statistics and maintenance strategies

Block 3 Innovative network components for the Smart Grids (29 papers):
- Various experiences in Smart Grids with smart sensors
- Data treatment and communication concern associated to smart grids experiences
- Components for power control in smart grids

Block 4 Innovation in network components (32 papers):
- Modelling and simulation
- Environmental considerations and eco-design
- New designs

6 papers per block have been selected for oral presentation in the Main Session (MS), but all the papers can be presented in the Poster Session (PS). Like in the previous conferences, guided tours of the PS will be organised in order to facilitate the exchanges between the authors and participants.

In addition to the Main and Poster Sessions, three Round Table (RT1a, RT1b and RT1c) discussions and a Research and Innovation Forum (RIF) will take place within Session 1.

RT1a – "New components for voltage regulation" will consider the various possible options for regulating the voltage in grids increasingly connected to fluctuating distributed generation sources.

RT1b – "Smart secondary substations" will discuss the future functionalities of secondary substations in the smart grids, the innovative components that are needed and how to integrate these components in the most effective way.

RT1c – "Partial discharge and on-line cable monitoring" will present the technical options for this topical subject, share the experience from existing implementations and analyse possible innovative future solutions.

Finally 6 papers, presenting various highly innovative solutions resulting from the research work conducted in universities in the field of network components, have been selected for oral presentation and exchanges with the audience during the RIF.

Block 1: "Ageing of network components, diagnostic and

monitoring"

This first block is devoted to the evaluation of network components ageing, either through analysis of some specific components or thanks to precise electrical tests methods.

The 31 concerned papers were split within 3 sub-blocks:
- Partial discharges monitoring on MV networks (8p.)
- Ageing of cables and accessories (OHL and UG, LV and MV) (15 p.)
- Ageing of other network components such as transformers including OLTC, MV circuit breakers and LV switchgear (8p.)

Partial Discharges monitoring on MV networks
(8 papers)

Electrical ageing of insulators materials is not a clearly identified phenomenon as time, temperature, mechanical constraints or any other chemical attacks can have an influence on global electrical behaviour. Only a very few electrical tests – apart applying destructive impulse or high voltage tests – can help MV network stakeholders to assess the remaining level of performances of the electrical insulation, Partial Discharges (PD) measurements is one of them. This test method is known for decades, as currently applied in routine tests. The development of new technologies for signal treatment allows interference signals rejection and gives access to on line PD measurements either thanks to an installed equipments or "ready to use" mobile devices. Some field measurements experiences on MV and HV cables links with joints, or switchgear are presented in these eight papers.

Partial discharge signals originate from different sources. The ability of identifying PDs from numerous sources is the great demand and challenge. Paper **0399** proposes a method based upon the Phase Resolved Pattern (PRP) for interference signal rejection. Six different PRP are identified thanks to electrical tests performed in HV labs on a three phases MV cable with artificial defects. The results of these tests was to establish typical knowledge rules, 4 types for interference signals and 3 types of typical PD signals. Similar work has to be performed for other types of cables and for other sources.

The on-line PD detection is preferable but it is difficult to calibrate apparent charge magnitudes due to changes in real distribution network loading and topologies. For asset management and preventives purposes, the trend in PD activity over time is a key indicator. Paper **0714** introduces an on-line monitoring system with integrated calibration to determine the apparent PD activity and location in a network section. Test performed in an urban area on a 11kV link gathering XLPE cables, straight joints and transition joints (XLPE/PILC). Reference pulses are injected at a central point (switchgear), then pulses are detected on both close substations. The PD data are processed and sent to a central server. First results have shown a good detection capability of the equipment and should be a useful tool to observe medium and long term evolution of the PD activity and to predict possible failure.

The paper **0393** is devoted to on-line PD measurements on switchgear compared to spot PD measurements. OLPD shows a more complete view on PD situation as some non electric parameters, like relative humidity rather than the temperature can have a strong influence on the PD level. Such a situation minimizes the interest of PD spot measurements. Although OLPD monitoring presents quite interesting results, the cost of the single measuring device and the number of substations to be equipped makes the OLPD monitoring not suitable.

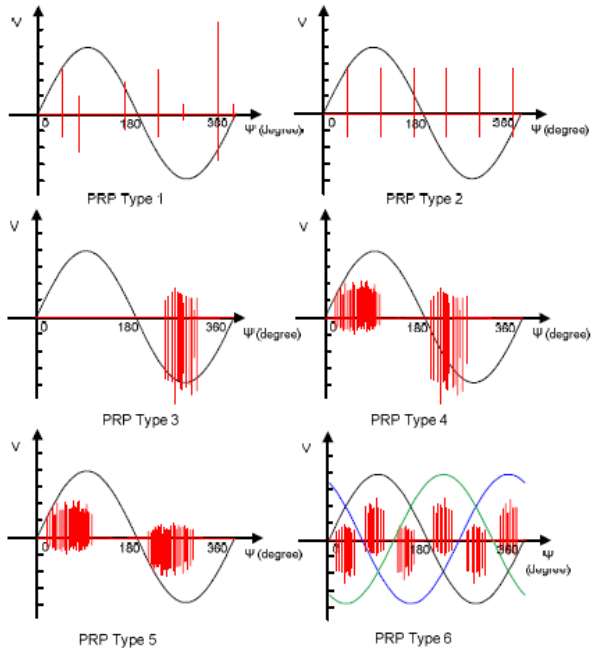

Fig. 1: from paper 0399 – Six types of Phase Resolved Pattern (PRP)

Tests equipments with smart signal rejection system are requested to perform efficient OLPD measurement. A few test devices are currently available on the market. In the frame of Condition Based Maintenance Strategy, paper **0604** presents tests conducted on new installed cables before commissioning. Two OLPD measurement test devices were considered and tests performed with both of them during six months. The analysis of signals and the associated interpretation for a future decision, even supported by such smart equipments, definitely request trained and experienced people. The cooperation of the suppliers' engineers and their expertise was fundamental to achieve good results.

Similarly to the previous one, the topic of paper **1248** is proposing PD measurement devices comparative tests. Three PD tests devices were evaluated and performances compared with Oscillating Wave Test System (OWTS) by measuring PD activities on six MV circuits, two 33kV and four 11 kV. The three findings points are the following: Field suitability assessment, Test management assessment

and Data analysis and report preparation assessment. Even one of them could be considered as the most interesting one, position is that OLPD monitoring technique is most probably not mature yet and needs many field experiences and testing data for references.

PD could be extinguished by decreasing voltage applied on the phase, paper **1339** exposes this technique of controlling neutral voltage currently applied in MV networks as a means of eliminating earth fault currents, so called Ground Fault Neutralizer (GFN). The reported experience was performed on 3 cases. A 30 kV cable sample with insufficient stress relief at the termination was connected to a spare switchgear bay, a HFCT sensor was used for PD detection. The second case was on a 20 kV network during GFN commissioning, measured PD revealed water ingress at switching bushings. A 11 kV GFN commissioning was the third case. The ability of GFN to quench PD activity was then measured.

Strong financial drivers can trigger PD monitoring when offshore renewable and Oil & Gas industries are concerned with land sea export cables and sub-sea array or platform interconnection cables Condition Based Maintenance (CBM). Paper **1334** proposes some case study where OLPD monitoring and Time Domain Reflectometry (TDR) methodologies could be associated to either identify a more accurate fault position or to predict fault in the network. In the first study case, TDR identify quite accurately the fault location on a 12,2 km 6,6 kV subsea circuit. On the second case, OLPD test performed after a joint repair highlighted an abnormal high PD signal on a phase inducing another joint replacement. For an effective Condition Based Maintenance implementation authors point out that detailed, real time diagnostic intelligence and data on both state and condition of subsea cables networks is necessary.

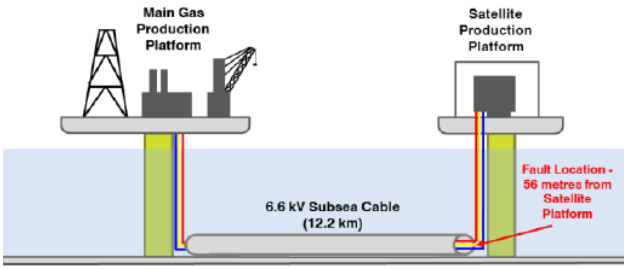

Fig. 2: from paper 1334 – Subsea circuit overview

The paper **0129** addresses PD detection and localisation in cross-bonded HV cables. It presents experimental investigations into PD pulse coupling between the centre conductor and the cable sheath and the behaviour of PD pulse propagation in cross-bonded HV cables. It also proposes optimal scheme of PD monitoring system before demonstrating the effectiveness of the procedure and algorithm in localisation of the site of origin of any PD activities.

Ageing of the cables both in MV and LV networks, either UG or OHL
(15 papers)

The OHL networks have to deal with a lot of constraints, not only electrical and thermo-mechanical but lot of faults are linked with weather and climate events. The three following papers are presenting some experiences on that topic. Paper **0281** exposes an applicable program for diagnostics and condition monitoring on 20 kV OHL located in a coastal district with a very heavy pollution level. Diagnostics techniques – online or on samples - were applied on a 50 km OH pilot line equipped with 2500 insulator of four types (2 porcelain and 2 composites). On-line leakage current monitoring, corona camera counting pulses of light emission and IR camera for hot spots are the three main methods used in this study. Gas chromatography and mass spectrum analysis were performed on composite insulators samples to collect information on materials degradation. Tests results analysis gave the opportunity to reduce cost in maintenance by selecting the insulators to be replaced in priority. This project shows that this technique is an applicable method for condition monitoring of in service insulators.

Fig. 3: from paper 0529 – SKYEYE UAV

Visual observation with the support of helicopter is a current method but expensive for OHL condition control. Paper **0529** presents OHL visual inspections experiences with MAI (Manned Air Inspection) and first experiences with UAV (Unmanned Aerial Vehicle). MAI perform track clearance (LiDAR) to detect corona activities or damaged insulators. In comparison, due to some recent development as GPS navigation, UAV can be configured to fly over a predefined set of waypoints and offer interesting safety functions. First results coming from more than one year of implementation suggest that large savings can be achieved.

Focussed on High Voltage OHL, paper **560** proposes novel techniques for automatically extracting information from OHL based on automatic image/video processing. Three application scenarios are presented: detection of ice and snow on insulators, detection swing angles of insulators and quantifying visibility of insulators at transmission lines with

typical backgrounds.

Medium voltage underground cables and associated accessories, whatever with polymeric insulation or paper impregnated, are designed for, at least four, several decades of life duration thanks to long qualification processes. Although currently produced cables are fulfilling standards requirements, the first section of this block highlights (OLPD) that main issues observed on networks are mainly caused on accessories or around them but plain cables. Paper **0466**, focussed on XLPE insulating materials for MV cables, reviews the data from initial material development to qualification testing in detail and discusses the reasons for the seeming mismatch between a moderate improvement in qualification results and a large increase in characteristic time to failure values.

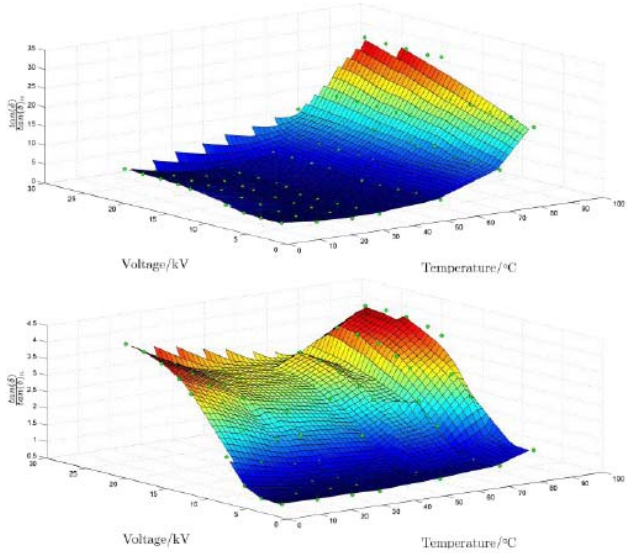

Fig. 4: from paper 1258 – Tan(δ) fingerprints of a sample that has been in operation for over 40 years (top) and of a sample that has been in operation for over 20 years (bottom)

The purpose of the second paper on MV cables, paper **0029**, is on-site AC test combined with Partial Discharge measurements on a 66 kV cable link. Tests were performed with variable frequency (20 Hz to 300 Hz) HV source up to 72 kV, and two PD measurement methods were evaluated thanks coupling capacitor and High Frequency Current Transformer sensor (HFCT). Similarly paper **0081** discusses practical experience on PD measurements by using Very Low Frequency (VLF) source but on MV underground cables. Some technical reasons are presented for using VLF (0,01 Hz up to 0,1 Hz), they are: weight and volume of test equipment, higher sensitive and precision on PD measurement, diagnostic efficiency, fault distance monitoring, effectiveness of VLF compared to DC which can also produce space charges. According to the paper, apart interest of PD measurement, the use of VLF instead of power frequency or DC is a more sensitive measurement.

Very Low Frequency source is also selected for test and diagnostic methods described in paper **1058**, even PD measurements are similarly performed (VLF-PD), the association of dielectric losses measurements (VLF-TD) could be more efficient. This Monitored Withstand Test (MWT) applied on a 11kV link (different cable types and ages) gives more valuable information on the link either based on tangent delta or PD measurements variations.

A few tan delta measurement techniques are possible for on-line diagnostics. In the study, presented in paper **1098**, four of them were selected with one dielectric spectroscopy (FDS) considered as the reference. Tests comparison were performed on both 11kV cable samples in lab and on field, three 33 kV circuits and two 11 kV circuits. The analysis of results shows that only one tan delta method among the four ones present similar results than FDS.

A lot of medium voltage distribution networks are still using PILC cables which are a major source of failures. Paper **1258** presents a research project launched with goal to determine the remaining life time of such cables by PD and tan delta measurements. Tests were performed on three 20kV circuits equipped with 48, 95 and 100% PILC cables and correlated to available PD and tan delta on samples test results. A hysteresis is shown on Tan delta measurements results on circuits with major part of PILC.

The thermal resistance change of surroundings with cable load increase has definitely an influence on cable systems operating temperature and may generate failure. The performances of the soil have to be considered as compaction process, porosity after compaction, particle sizes. Paper **0651** highlights the interest for the MV networks managers of a more detailed investigation of thermal behaviours of the soil around highly loaded MV cables.

Fig. 5: from paper 0651 – Melted cables and dry soil around

PILC cables are also present on LV networks and faults due to ageing are in certain case difficult to localize for repairing. Paper **0527** introduces the "BIDOYNG" single shot auto-recloser to understand the nature of LV intermittent faults. Data collected by this Smart Fuse facilitates the location of failure or fault source.

Extruded LV cables systems are ageing and a condition assessment is necessary. Paper **0581** describes first the symptoms observed on faulty LV cables and branching joints by means of visual examination, material and electrical measurements in labs. Second different investigations are described for controlling and improving

quality of new LV cables systems. Some recommendations are proposed regarding qualification test, i.e.: water penetration, long-term tests with buried cable, impact test; and cables design: outer sheath thickness and material nature, some requirements on sector shape conductor.

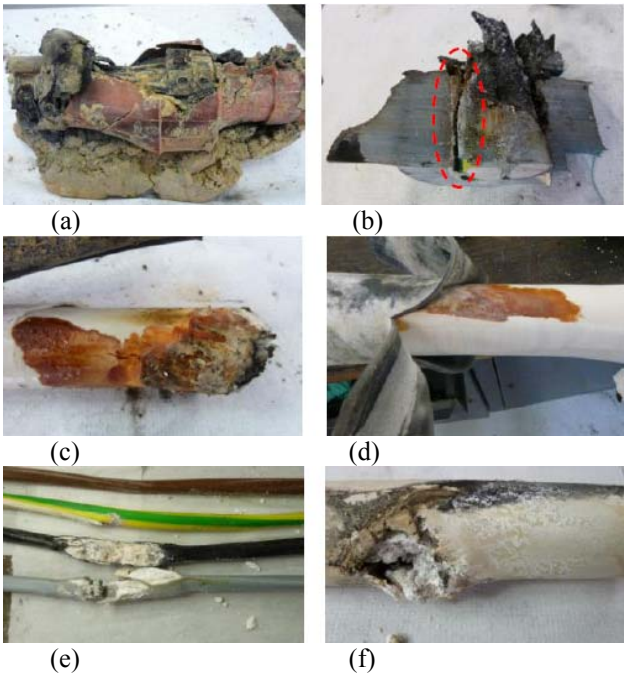

Fig. 6: from paper 0581 – (a) resin not correctly poured; (b) poor adhesion between the resin and the XLPE insulation; (c) & (d) corrosion on the PVC filler; (e) corrosion of conductors; (f) degradation due to water ingress

The three following papers are dedicated to specific components of the accessories. First paper **1017** highlights, thanks to tests performed in a lab, the importance of the crimping factors that can affect the contact resistance of MV cables ferrule and lug which should be below 50 µOhm. As hotspots can cause overheating in cable joint and then breakdown, a better connecting method is needed to ensure a good contact. A few crimping factors have been pondered in this study, i.e.: crimping pressure, number, location and shape of crimp indents. A number of samples have been analyzed with several tests: contact resistance, X-ray, tensile strength and load cycle. A correlation between crimping factors and contact resistance was established. A comparison between the best crimping method and mechanical connector was also done in order to compare both technologies.

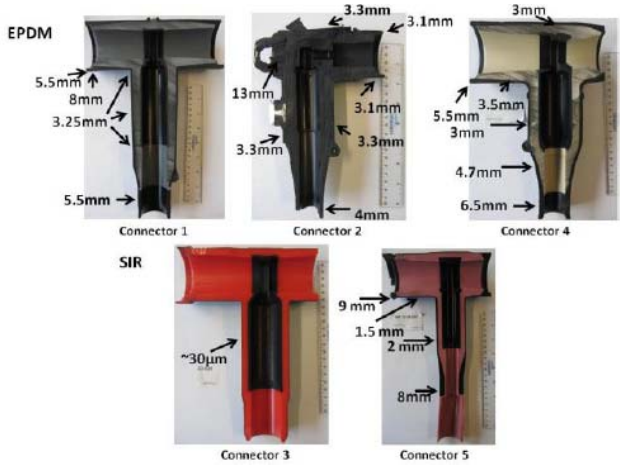

Fig. 7: from paper 1341 – Section of the connectors illustrating their design

Thermal ageing in joint is the topic of paper **1377**. European standards for MV joints for cables describe heat cycles in air and water. The connectors used in combination with the joints are tested separately in free air. Investigations on several failures occurred on qualified joints using qualified connectors pointed out the need of compatibility tests between both joint and the connector. A research program is launched for developing such a test method. Two tests method are proposed in the paper: i) simulation of heat losses by artificial connector, ii) evaluation thermal behaviour of cable system.

Paper **1341** raises the question of semi conductive material selection for the MV separable connectors face subjected to external aggression. Semi conductive layers of five separable connectors, either SiR (two) or EPDM (three) were exposed to an artificial accelerated weathering during 1000 hours and then characterized under various aspects. There is no clear advantage between SiR and EPDM. However EPDM showed the best performance followed by SiR, two separable connectors (one SiR and one EPDM) are not advised for outdoor applications.

Ageing of other network components, i.e. transformers including OLTC, MV circuit breakers and LV switchgear
(8 papers)

A few papers are dedicated to transformers, either standard ones or with On Load Tap Changer, so called OLTC. Injection of renewable energies, EV deployment, etc., should impact the thermal ageing of insulating oil in distribution transformers. The composite insulation they are made of are also submitted to ageing process, paper **0407** presents the investigations carried out on the MV/LV transformers ageing state using methanol and furfuraldehyde (2-FAL) as key indicators. In parallel, an accelerated ageing experiment of paper-oil system in sealed vials confirmed both indicators production and showed the relation between their concentrations in oil and the degree of polymerization of the paper. The study results show that

methanol in transformer oil, produced during the very first break of cellulose molecule, is a promising screening criterion.

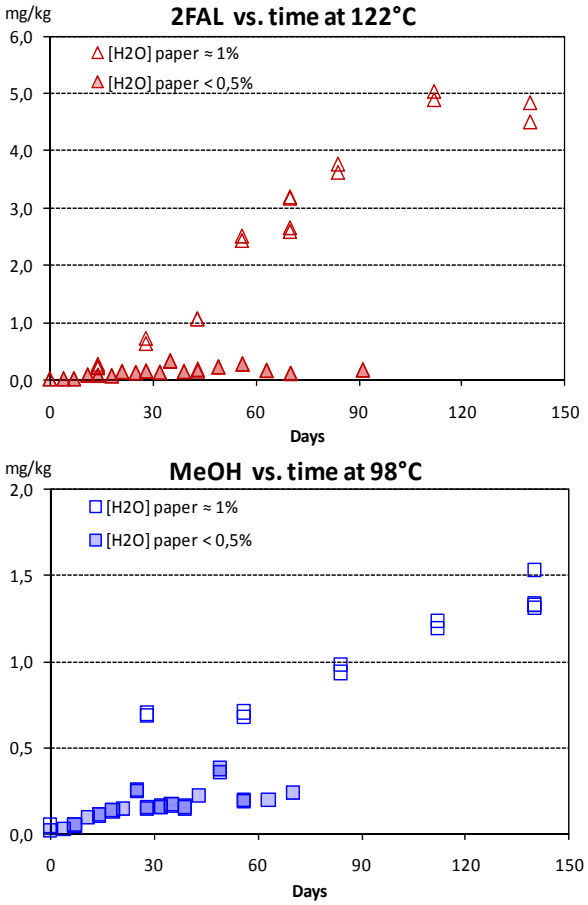

Fig. 8: from paper 0407 – Evolution of the 2-FAL at 122°C and MeOH at 98°C (in ppm) with different initial levels of water content in the paper

Similarly to the previous one, paper **1352** presents a study on timely monitoring of oil conditions. Here fluorescence spectroscopy is applied to evaluate the ageing status of oil. The fluorescence spectra were measured for the oil samples thermally aged in laboratory. It's found that the ratio between the two peaks is in line with traditional parameters as colour index and total acidity number. Preliminary results imply that it's feasible to apply the portable fibre based fluorescent probe system in online assessment of ageing status of transformer oil.

Still on transformer ageing assessment thanks to infrared temperature measurements is proposed by paper **1383**. It establishes criteria that correlate the distribution transformer tank temperature with the top-oil temperature, parameter used to compute the life expectance. Therefore, an easy reading through an infrared camera could be converted in a top-oil temperature. The results by the proposed methodology show errors lower than four degrees. Consequently this technique offers an opportunity to improve the evaluation criteria for overload distribution transformer and the management overload capability.

Paper **1466** presents a power transformer winding deformation fault diagnosis method which is based on the analysis of the vibration signal spectrum and the relationship between characteristic frequencies: it has been shown to be suitable for detecting failures in the transformer windings and also for determining the type of fault.

The two following papers are dedicated to Dynamic Resistance Measurement (DRM), a diagnostic technique that has recently been attracting a lot of attention due to its capability to detect On-Load-Tap-Changers (OLTC) problems. In paper **0338**, specific features in the current trace are explained. In addition there is a discussion of principles and DRM features as well as presentation of defect cases for reactance type of tap-changers tested using DRM technology. Paper **0473** gives an overview on the correlation between the three phase and the single phase DRM results. The measurement of OLTC synchronisation is also explained. In addition the demagnetization, which is necessary after any DC test on a transformer, is also described.

Active networks components, as circuit breakers, presents their own ageing process, paper **0184** gives a methodology to investigate the behaviour of mechanism for high current LV and MV circuit breakers in so-called "sleeping mode" which means that an apparatus performs a few or absolutely no operations during several years. This methodology consists in four steps: physical model, experimental model, accelerated ageing tests, conclusions and perspectives.

Paper **0019** presents the defect detection and preventive maintenance prioritization of distribution cubicles by infrared statistical image processing.

Potential scope of discussion

-Need of the expertise deployment for OLPD monitoring on the DNO's side when used as preventive tool

-Importance of PD level compared to voltage levels for PD inception and extinction

-OLPD technologies and standardization

-Use of new solutions for OHL visual inspections, including the use of Unmaned Arial Véhicles

-New testing methods to evaluate new cables life duration and assess existing cables actual condition

-Conditions for a wider use of diagnosis technologies for network components

Table 1: Papers of Block 1 assigned to the Session

Paper No. Title	MS a.m.	RIF	PS
0399: Knowledge based interference signal rejection and partial discharge identification from multi-PD sources for condition monitoring of cable systems			X
0714: Continuous on-line monitoring of PD activity in the medium voltage distribution network			X
0393: Partial discharge monitoring on MV switchgear	X		X
0604: Partial discharge on-line monitoring in MV underground power cables as part of condition based maintenance strategy			X
1248: Assessment of on-line diagnostic using partial discharge mapping systems in MVUG cable			X
1339: On-line partial discharge detection and control on MV cable networks with ground fault neutraliser			X
1334: Combined power quality and condition monitoring of offshore networks			X
0129: PD detection and localisation in cross-bonded cable systems			X
0281: Composite insulator diagnostics in service and condition monitoring in very harsh coastal environment of Iran			X
0529: Disruptive solutions to mitigate risk and increase efficiency in EDP Distribuçao overhead lines inspections	X		X
0560: Practical applications of automatic image analysis for overhead lines			X
0466: Correlation of accelerated ageing phenomena and LT cable performance			X
0029: Experience with on-site AC test combined with PD measurements			X
0081: Diagnostics of medium voltage cable systems using very low frequency			X
1058: Practical experiences of a new way on cable condition assessment	X		X
1098: Desktop and field evaluation of dielectric response diagnostic measurement system for medium voltage underground cable			X
1258: Experiences of in-field measured dissipation factor on MV PILC at 50 Hz			X
0651: Influence of the surroundings and mainly the soil on MV cable systems	X		X
0527: Management of Scottish and Southern Energy's low voltage distribution cable network using smart fuses with online fault detection			X
0581: Ageing of the LV underground cables and accessories			X
1017: Study of cable crimping factors affecting contact resistance of medium voltage cable ferrule and lug			X
1377: Thermal behavior of connectors in joints			X
1341: Conductivity and quality of ½ conductive materials in MV accessories			X
0407: Investigation in practice of chemical indicators on the diagnostic of MV/LV transformer ageing	X		X
1352: Portable fiber-based fluorescence sensor for online assessment of transformer oil aging	X		X
1383: A prediction of distribution transformers aging based on tank infrared temperature measurements			X
1466: Improved power transformer winding deformation fault diagnosis method			X
0338: Dynamic tap changer testing, reactors and reactance			X
0473: Comparative analysis of three-phase and single-phase dynamic resistance measurements results			X
0184: Ageing of mechanisms of circuit breakers			X
0019: Defect detection and preventive maintenance prioritization of distribution cubicles by infrared statistical image processing			X

Block 2: "Return from field experience, retrofit and maintenance strategies"

This second block related to asset management of network components (NC) is focussed mainly on the return from field experience, as an input to improvement, even innovation, in the standardisation, design and application of these components. This represents about two thirds of the papers presented in this block.

The last third is made of papers addressing the topics of retrofit or upgrading of NC, statistics on the behaviour and failure rates of NC, and maintenance strategies.

Behaviour of network components as an input for standards and improvements
(22 papers)

A good general introduction to this sub-block can be found in paper **0541** from Belgium. The authors observe that there is a lack of standardisation for the interfaces between different types of NC each covered by their own set of standards.

Some examples are given in the paper:
- Cable connection to switchgear;
- Service conditions for switchgear and substation environment;
- Extension of existing switchgear by a more recent type;
- Compatibility between fuse-links and load-break switches in switch-fuse combinations.

This can lead to serious issues affecting the operation of the network. It is recommended that joint working groups be established across the different technical committees in order to deal with these interfaces, and that the DNOs' experts be more involved in the standardisation activity, as they are those who have the global view of the solutions needed for reliable network operation.

The next five papers are dealing with the behaviour of the underground cables in the network.

SmartLife is a European initiative which aims at fostering coordination between operators in the asset management of distribution and transmission networks. Paper **0584** reports about the findings of the SmartLife cable user group which has worked in the 2011-2013 period on the improvement of cable specifications. Differences in cables and joints specifications and type testing have been examined and areas for improvement or additions have been identified, for example in the following matters:
- Specification of semi-conducting materials;
- Mechanical and thermo-mechanical testing of joints.

Fig. 9: from paper 0584 – Joint failure caused by thermo-mechanical forces

Regarding this last subject, it is reminded that the thermal behaviour of connectors in joints is the topic of paper 1377 previously presented in block 1. It is also further discussed in paper **0128** which reports on experimental measurements made to characterise the forces applied to joint connectors by the thermal expansion of cable conductors under high current loading. Although the measured forces do not exceed the static force applied during the mechanical test according to the present standard, it is recommended that an additional mechanical cycling test should be considered to take into account the highly dynamic load currents for cables used for the connection of wind farms to the grid.

Paper **1018** reports on the on-going work launched for the revision of the French national standard relative to the screen plates used for connection to the aluminium screens of MV cables. This revision has been found necessary to take into account new types of cables as well as the increase in nominal current required for the connection to the grid of distributed generation from independent producers. Improvements in the design of plates and installation procedures have been found effective to ensure good ageing under these new conditions, but more testing is still required before finalisation of the revision.

Paper **1411** reports on temperature measurements made along cable links buried at great depths by directional drilling, in order to check the values given by theoretical models. Temperatures have been measured by means of an additional optical fibre cable attached to the MV cable, as presently only HV cables are available with integrated optical fibre cable. The results are consistent with models' previsions but show also that some favourable factors at great depth can reduce the expected decrease in current carrying capacity.

Finally paper **1288** presents innovative cable connection accessories resulting from the desire of DNO Alliander , in The Netherlands, to keep the same testing, earthing and safety procedures as in their present 12 kV switchgear while upgrading part of their network to the 24 kV level. For this purpose, instead of using the screened separable connectors commonly used with gas-insulated distribution switchgear at this voltage level, a new unscreened separable connector with integral testing and earthing facilities has been developed. In this matter the preference has been given to keeping the same working procedures for the operators, over insensitivity to the environment conditions.

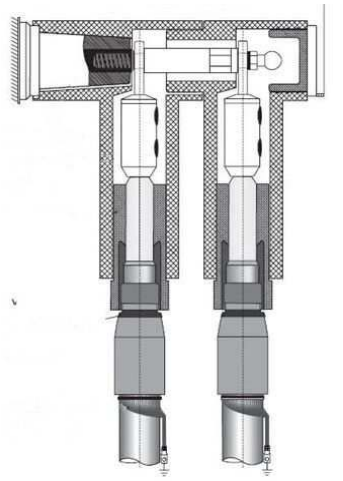

Fig. 10: from paper 1288 – Cross-section of two stacked, unscreened connectors with integrated earthing bolt

The next seven papers address various aspects of the behaviour of overhead lines components.

A general perspective is given in paper **0623** which reports on a R&D project launched to take into account the increasing frequency of severe climatic events due to the climate change in Brazil. The work is in progress, with the target of identifying the steps to be taken in the specification and installation of overhead lines in order to reduce the disruptions caused in the networks by these events, and improve the availability indexes.

Paper **1393** reports on an experience in using composite poles instead of conventional wooden poles for new 132 kV lines in Norway. Composite poles have advantages in terms of weight, strength and environment protection. Although more expensive at purchase, the total cost of ownership over the considered lifetime of 50 years is estimated to be lower, thanks to the absence of maintenance.

Fig. 11: from paper 1393 – Helicopter used for transport and placing of pre-assembled poles

The next two papers from Iran are dealing with the matter of earthquake withstand of overhead lines systems.

Paper **0406** presents the Seismic Capacity Curve (SCC) method applied for assessment of the vulnerability of concrete poles to earthquake vibrations, depending on the location and type of soil. SCC is an efficient tool for preliminary screening and identification of poles that may be vulnerable and require more in-depth and accurate analysis.

In the same line, paper **0821** explains the lessons learnt from severe earthquake events in Iran and their adverse effect on the distribution lines and pole-mounted structures. Among recommended solutions are the use of round poles instead of rectangular profile ones, and the use of pole-mounted distribution transformers of lower ratings.

The pole-top fire risk for wooden poles is discussed in paper **0240** from South Africa. A comprehensive review of possible mitigation measures against leakage currents in wood is presented, as well as feedback from pollution tests and field experience. Proposals are made for the most suitable configurations, depending on the local conditions (risks of fire, lightning, protection of large birds).

Paper **0464** from Australia discusses various types of dampers that can be used on distribution lines. It is shown that the Stockbridge type of vibration dampers generally used for transmission lines can also be used for distribution lines, with higher efficiency than the helical type vibration dampers.

Finally paper **0150** proposes a simplified analytical method for determining the lowest point in an inclined span of overhead line, for given maximum sag. This method based on the parabola curve equation instead of the catenary one is sufficiently precise and easier to use.

The six following papers are related to the behaviour of switchgear in the network.

Paper **1415** reports on a study conducted by TNB Research in Malaysia to evaluate different types of circuit-breakers for 11 kV air-insulated switchgear. The first part of the study has been focussed on the installation conditions of the circuit-breaker in the switchgear: withdrawable (roll-on-floor or cassette type) or fixed. The second part has compared two types of drive mechanisms: spring-operated mechanisms and magnetic actuators. Magnetically actuated circuit-breakers have shown good stability through ageing and mechanical endurance tests. Their mechanisms are simpler, require no (or less) maintenance and seem unaffected by the grease ageing which can lead to failure to trip after long periods of inactivity for spring-operated mechanisms. However their reliability depends on their electronic controller and storage capacitors: more tests and field trials are planned to check whether these components can provide good service in real life operation.

The next three papers are concerned with the switching overvoltages that can be generated by vacuum circuit-

breakers in specific conditions.

In the wake of the recent publication of Edition 3 of IEC 62271-110, paper **1231** provides a good review of the overvoltage generating phenomena when inductive loads are switched. The phenomena, test requirements and protection measures are described and discussed. A specific focus is made on the dry-type (cast-resin) transformers, where resonance effects may be triggered by switching phenomena (like multiple reignitions) or possibly new types of loads (switched electronic power supplies), as there seems to be an increase in the failure rates of these components. It is questioned whether transformer standard should be revised to introduce more stringent dielectric tests on the windings insulation than those presently required.

This topic is also the subject of paper **0412** which reports on laboratory testing performed in order to better understand the interaction between dry-type transformers and vacuum circuit-breakers in MV cables systems. No dangerous overvoltages are generated in normal switching operations (no-load energizing and disconnection of transformer). In severe conditions (switching-off during the inrush current period, or when the transformer is supplying inductive loads) successive reignitions can lead to series of steep-fronted voltage surges. The rise time of the voltage steps applied to the windings, and the voltage distribution between the turns, have not been found more severe than those applied during lightning impulse tests. But the repetition frequency is high and can lead to premature ageing of the inter-turns insulation. It is therefore recommended to apply surge protection, like surge arresters, at the terminals of transformers if the occurrence of interruptions in these conditions is significant.

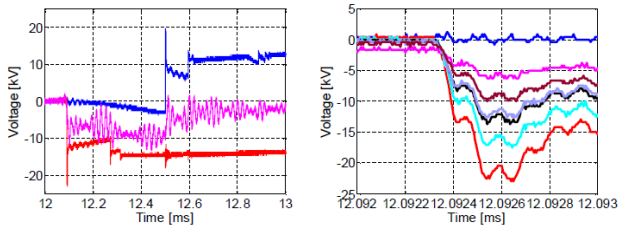

Fig. 12: from paper 0412 – Energising of a transformer under no-load: voltage traces at the terminals of winding (red and blue), mid-point (pink) and 4 end disks, showing internal resonance and capacitive voltage distribution between the turns

Paper **0488** discusses the possible influence of the overvoltages caused by vacuum circuit-breakers on the failure rates in cable networks. This is an issue which has been raised in Russia as a possible explanation of the increasing failure rates of MV cables and accessories. The authors discuss the frequency of occurrence of the different types of switching overvoltages generated by vacuum circuit-breakers and their propagation in the network. They show that this factor cannot explain the increased failures in the cables system, which are probably related to material and installation issues affecting the ageing of XLPE cables and accessories. This seems consistent with the experience in other parts of the world where vacuum circuit-breakers are widely used without adverse effect on the reliability of cables system.

The last two papers in this switchgear section are dealing with the switching conditions applicable to generator circuit-breakers.

Paper **0420** discusses specific applications of generator circuit-breakers (GCB) associated with small size generators. It is shown that in some cases the constraints (transient recovery voltage rate of rise, delayed current zeros) can be more severe than those specified in the IEEE standard C37.013. However protection means (like RC snubbers) can lower the constraints and allow application of standard GCB without any further testing. This study shows the benefits of applying electromagnetic transients (e.g. EMTP) simulation to such cases.

Paper **0065** presents another application of EMTP modelling and simulation to generator circuit-breakers. The GCB model in the software is explained and mitigation measures (RC snubbers across the circuit-breaker terminals) are proposed to reduce the transient recovery voltage constraints.

The last three papers in this sub-block are dealing with lightning overvoltages.

Paper **0194** explains how EMTP simulation can be used to evaluate the failure rate of a substation connected to lines affected by lightning phenomena, depending on the topology, protection means and the probability of lightning strokes in the area. This is useful to check whether the overvoltage protection scheme applied to the substation is sufficient or not.

Paper **1484** presents a simulation method to estimate the probability of failure of distribution transformers connected to overhead lines subjected to direct and indirect lightning strokes, on the basis of the actual lightning impulse voltage withstand data obtained from experimental tests on a batch of new and repaired distribution transformers. It is found that adequate protection by surge arresters is necessary to obtain acceptable failure rates.

Paper **0967** describes a small scale experimental set-up devised for studying the induced overvoltage caused by indirect lightning strokes in the vicinity of the overhead line. Measured values have been found to be in accordance with simulation results for the initial part of the overvoltage waveform.

Retrofit, statistics and maintenance strategies
(10 papers)

The first four papers in this sub-block are dealing with various aspects of retrofitting or upgrading network components.

Paper **0086** reports on a large scale retrofit program applied

to some 11 kV circuit-breaker switchgear in the UK. It highlights the conditions to be met, and the complementary work to be undertaken, for the retrofit solution to be an interesting and cost-effective alternative to the replacement of the switchgear.

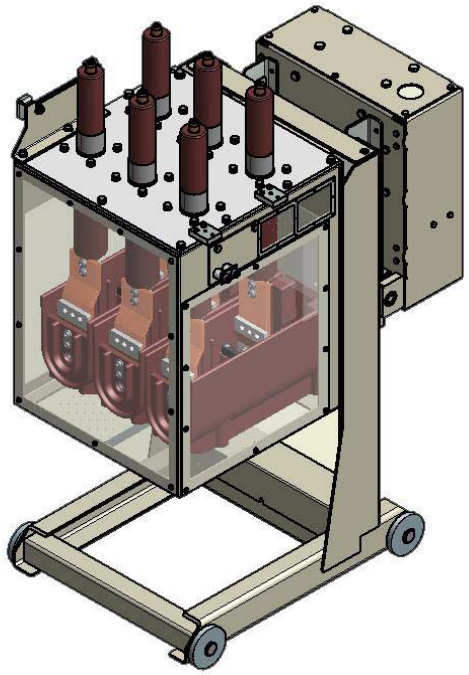

Fig. 13: from paper 0086 – Bespoke retrofit solution for 11 kV bulk oil circuit-breaker

Paper **0694** describes the different solutions implemented by EDP Distribuição in Portugal to improve the condition of its secondary distribution substations, and decrease the number of interruptions caused by surface insulation failures in these substations. Short-term and long-term solutions have been considered. In the first category, of particular interest is the reduction of ventilation apertures to adapt them to the actual load of the transformer and limit occurrence of condensation on the insulating surfaces. For the long-term solutions, the high cost ones are of course the most efficient (rehabilitation of the structure, replacement of air-insulated switchgear by gas-insulated switchgear and connections with integral screening) but a lower cost one has been found effective: it is the spraying of RTV silicone rubber on the insulating surfaces of the switchgear (see following figure).

Fig. 14: from paper 0694 – RTV silicone application on insulating surfaces

Paper **0294** reports on the experience gained in the design and construction of a compact 110 kV overhead line with steel poles and post insulators, which has been installed in a corridor previously used by a 35 kV overhead line. The target of minimising the environmental impact has been achieved satisfactorily. To obtain an optimal design it has been necessary to reconsider the conventional design rules and standards which tend to be too conservative for this type of compact construction.

Fig. 15: from paper 0294 – Line before and after uprating from 35 kV to 110 kV

Finally paper **0823** reports on some experimental and modelling investigations on the dynamic ampacity rating of busbars of outdoor HV/MV substations, as an alternative to retrofit or upgrading of the installation. Good agreement has been found between measured and calculated values and the dynamic ampacity rating has been found to be in excess of 150%. However other factors (such as stability of the network and capacity of other components) will probably limit the overloading to lower values.

The next three papers present failure statistics of network components from Denmark (first two papers) and Germany.

Paper **1090** presents the recent evolution in the ELFAS (fault and outage) statistics reported by the Danish DNOs. In order to provide data for better asset management and

more detailed information on customer interruptions, it has been agreed that more detailed information will be registered in the ELFAS database by the participating DNOs. There are no results yet to report as the new statistics system is being put in place in 2013.

Paper **1152** presents an analysis of the Danish statistics specifically centred on the failures of XLPE cables, for which relatively detailed information has been registered since the 80ies. In contrast with the early XLPE cables installed in the 70ies which had a bad record of early failures, caused by water-treeing related to the steam-cured process used at that time, the dry-cured XLPE cables installed since the 80ies have a low failure rate and show no sign of approaching the end of life after 30 years in service. It will be interesting to follow closely the evolution of failure statistics for this population of cables in the coming years. It has been noted also that about half of all ageing-related failures occur while the system is operated under earth fault condition (most of these failures occur within 2 hours after the initiation of fault condition).

Finally paper **1321** reports on a research program launched in Germany to establish a detailed damage statistics database and develop models applied to the collected data. Some available results from data analysis are presented, in terms of damage and failure statistics, determination of reliability (bathtub) curve for some components, and evaluation of the impact on interruption indexes of changes in the frequency of the maintenance cycles. This approach can provide valuable inputs for an improved asset management policy, with reduced investments compared to individual condition assessment and monitoring systems.

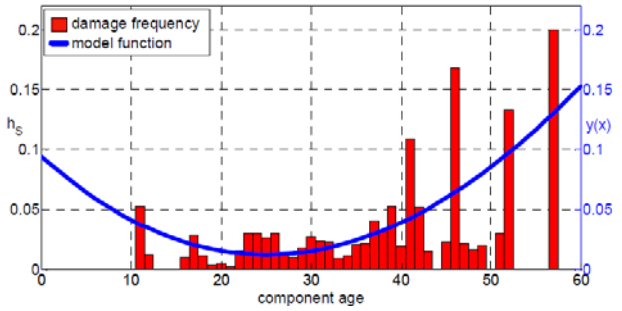

Fig. 16: from paper 1321 – Age-related damage frequency per year and model function (bathtub curve) of low-oil-content circuit-breakers

The last three papers of this block are addressing the topic of maintenance strategies.

Paper **1179** proposes a conceptual approach for a Network Condition Based Monitoring (NetCBM) system. The NetCBM architecture described in Figure 17 is based on widely distributed wireless sensor networks connected through gateways and internet to the Enterprise CBM applications where advanced analytics process and interpret the data collected from the sensor networks. These applications would provide optimisation in asset management and maintenance strategy, reduction of failures, assistance in location of faults (no concrete implementation of the concept is presented for the time being).

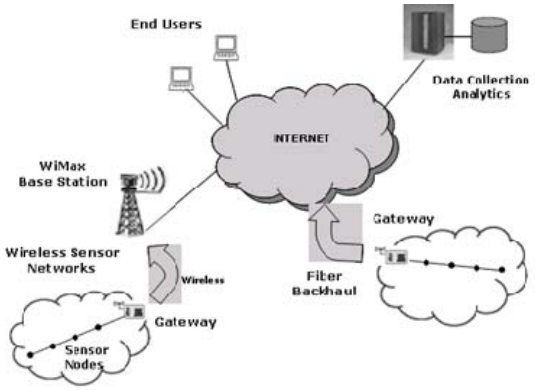

Fig. 17: from paper 1179 – NetCBM architecture

Paper **1215** proposes a multi-objective optimisation method applied to maintenance activities. The theoretical aspects are introduced and practical application to prioritisation and selection between several maintenance activities under a global budget constraint is presented.

Finally paper **0064** presents an update of the data management model developed by Edenor in Argentina to optimise the maintenance of its power transformers (previously introduced at CIRED 2011, see paper 0024). This model is based on systematic oil analysis activity, database software to exploit the collected data, algorithms to determine the health indices of transformers, and finally a risk assessment to allow prioritisation of maintenance activities. This method, applied by a highly skilled team, has proved successful in reducing planned and unplanned outages, as well as maintenance costs.

Potential scope of discussion

-Standardisation of interfaces between network components

-Specific duty of cables used for connection of windfarm generators

-Access to conductors for operating procedures versus insensitivity to environment

-Vulnerability of overhead lines to climatic or seismic events

-Vacuum switchgear and surge protection of sensitive loads

-Retrofit versus switchgear replacement

-Ageing of air insulated switchgear in secondary substations

-Operational reliability of network components

-Maintenance strategies

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	RIF	PS
0541: Lack of standardization concerning interfaces between network equipments			X
0584: Smartlife2: improving cable system specifications	X		X
0128: Measurement of the force induced by thermal expansion of conductor of MV cables and impact on MV joints			X
1018: Connection to MV cable aluminium screen			X
1411: Thermal behaviour of cables installed via directional drilling			X
1288: Innovative and safe cable connection in medium voltage switchgear with integrated earthing and testing facilities			X
0623: Climate change in Brazil and its reflections in the reliability of Celesc distribution overhead lines			X
1393: Experiences from a test project in Norway using composite poles in 132 kV overhead lines	X		X
0406: Development of seismic capacity curve (S.C.C.) for power distribution concrete poles			X
0821: Reducing the unforeseen incidents damages (earthquake) by using round poles and reducing the pole mounted distribution transformers power			X
0240: Pole-top fires risk assessment: a South African perspective			X
0464: Vibration dampers for AAC and AAAC conductors			X
0150: Determination of the lowest point of the conductor in inclined spans based on a known maximal sag of the parabola			X
1415: Evaluation of magnetic actuator driven switchgears in TNB			X
1231: Control of inductive load switching transients	X		X
0412: Vacuum circuit breaker and transformer interaction in a cable system	X		X
0488: Vacuum Circuit Breakers in Cable Networks			X
0420: Specific short-circuit conditions in power plants with small generator units			X
0065: New Technique for Transient Recovery Voltage Suppression on Generator Circuit Breaker for Generator Fed Faults			X
0194: Calculation of lightning overvoltage failure rates for a gas insulated substation			X
1484: A proposal to evaluate the risk of failure of distribution transformers insulation submitted to lightning induced voltages		X	X
0967: The Simulation Experiment of Lightning Induced Overvoltage on the Distribution Line			X
0086: Retrofitting 11kV Circuit Breakers in Primary Substations			X
0694: MV/LV substations - solutions to improve the technical quality of service	X		X
0294: Experience with refurbishment and upgrading of 35 kV overhead line to 110 kV operation level using post line insulation			X
0823: Dynamic ampacity rating of conductor bars in highly loaded substations			X
1090: Detailed component data and customer information as a basis for more detailed fault and outage statistics			X
1152: Results from Danish failure statistics for medium voltage XLPE cables			X
1321: Type-specific evaluation of component reliability for predicting the quality of supply in distribution systems	X		X
1179: NetCBM - Condition Based Monitoring of Power Distribution Networks			X
1215: Multi-objective maintenance optimization			X
0064: Data management model for the optimized maintenance of power transformers			X

Block 3: "Innovative network components for the Smart Grids"

This third block presents Smart Grids experiences and points out in a first part (8 papers) the need of some specific components making smart grids efficient as specific sensors. A second part (7 papers) addresses the impact on communication networks and systems to make such grids efficient and reactive on time.

The third section (14 papers) will present various devices for voltage network regulation, or new types of networks components including FCL.

Various experiences in Smart Grids with smart sensors (8 papers)

The development in renewable energies and their insertion in the LV or MV grid induce some challenges in keeping the power balance between generation and consumption, and impact the network voltage. Paper **1332** from Germany presents a good view on smart grids incentive and explains how to deal with large scale introduction of volatile renewable energy sources. This paper presents the German concept to answer to the year 2050 challenge which is 80% of power generation should be from renewable energy sources. It points out that integration of the production sources imposes to have full control of the 2 following activities: keep balance between production and consumption with versatile sources and second to connect RE sources to the consumption sites on distribution networks. The idea of "smart markets" is introduced alongside those of "smart meters" and "Smart Grids". The paper introduces the newly developed iNES system which reacts automatically in case of voltage problems or overload. An experimentation of such iNES system was successfully implemented in two Frankfurt grids areas both rural and urban.

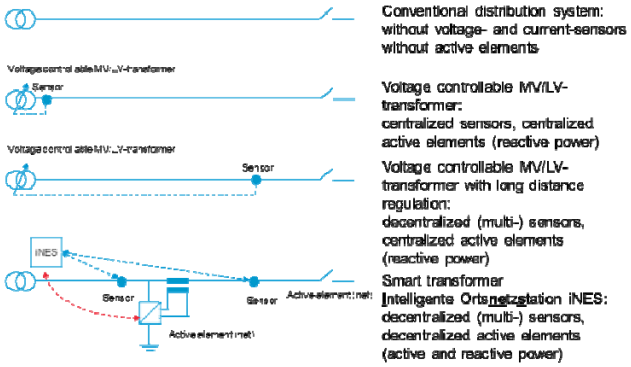

Fig 18: from paper 1332 – Systematic of smart grid concept

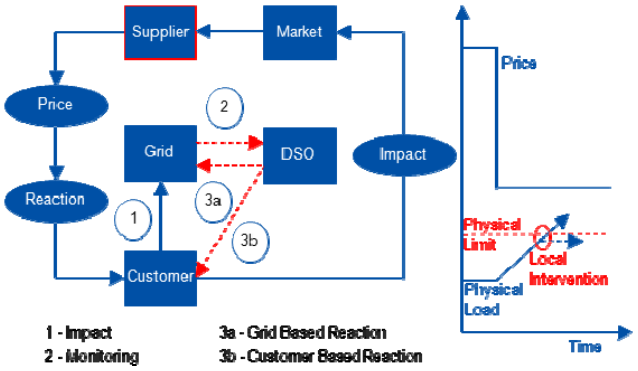

Fig. 19: from paper 1332 – Interaction of smart market and smart grids

Contrarily to the previous paper the two following ones are presenting smart grids architecture where information from networks are produced by specifics sensors and sent to the central control of the network.

Paper **0589** presents an experiment giving information on key components behaviours as vibrations signature, temperature, in transformers, circuit breakers or switches thanks to specific and smart sensors. Once these data collected thanks to hybrid communications network and treated in real time, the installed system provided gains in people effectiveness, flexibility, capital cost and maintenance costs.

Similarly to the previous one, paper **0986** proposes a cost efficient and easy step-wise approach in improved automation and remote controlled sub stations. Voltage and current smart sensors were inserted – instead of conventional and voluminous CT's or VT's – in the existing cables connectors (retrofit) or in the bushings. On top of that, the public communication network, like 2G mobile with a secure VPN, was elected avoiding huge investments in a private network.

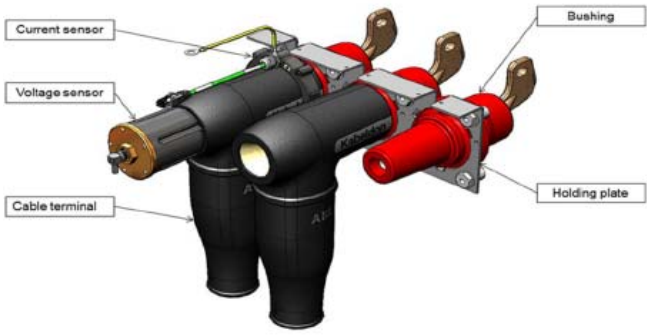

Fig. 20: from paper 0986 – Retrofitting the Current and the Voltage sensors

Smart Grids implementation incentive may change according to country which is concerned with. In the paper **0902**, the main objective with the implementation of Advanced Metering Infrastructure is, part to inform the subscriber about its energy consumption in real time, to

identify and then decrease electricity losses in the distribution network. More than 2000 smart meters, either single or three phases, were installed in a pilot network. The real time information – as energy consumption, voltage, current, and others – are transmitted from the smart meters to the concentrator by PLC communication system and then sent to the control station by GPRS or any other telecommunication system. For this test, the selected pilot area presents low levels of harmonics in the network and low radio noise.

As mentioned in a previous paper, the four following papers are describing some specific voltage and current sensors which have quite good performances in measurement accuracy and more interesting smaller size and lower costs than previous components used.

Paper **0103** points out the use in air insulated switchgear of new types of sensors associated to intelligent electronic devices (IEDs) and IEC 61850-9-2 standard can replace with a few advantages CTs and VTs used up to now. Such sensors insertion has a very positive impact on measurement dynamics and accuracy, energy consumption and volume occupancy.

After sensors insertion in switchgear – bushings or connectors – the paper **0598** proposes a smart termination for MV cable. The installation process of this cable accessory is similar to the current ones, but voltage and current sensors are inserted in the termination. This component is suitable for the most commonly used MV cables. Then the additional functions are available for the smart grid implementation without interfering on the MV switchboard structure. This component was qualified according to CENELEC tests standards for the termination and IEC standards for the sensors.

Fig. 21: from paper 0598 – Sensored termination

Lack of accuracy in voltage measurements may induce issues in Smart Distribution Management System (SDMS), the paper **0451** presents a portable assessment system prototype. The voltage sensor looks like a live stick and can be hung on any OHL conductors. Then the directly obtained value can be compared to the one transmitted to the Feeder Remote Termination Unit (FRTU) through the system and error in measurement appreciated and corrected.

Finally the paper **0869**, as applied to MV applications, proposes the replacement of the heavy and voluminous CTs and VTs by specific sensors but for HV applications. This concept delivers substantial benefits, especially financial as the cost of such device is much cheaper than CTs, spatial thanks to smaller and lighter equipment and in safety with insulating oil disappearance.

Fig. 22: from paper 0519 – Overview of a smart secondary substation

Data treatment and communication concern associated to smart grids experiences
(7 papers)

Smart grids implementation means data production with sensors, data concentration and treatment but also data transmission from distribution network to control desk and vice versa. The objectives of the smart grids stakeholders should take all these aspects in consideration before selection of the appropriate transmission technology and network, private or public or thanks to a dedicated cable. The seven following papers address data concentration, and data transportation matters thanks to different ways but answering to the user's needs and constraints.

The data emitted by sensors have to be treated to make them "understandable" and efficient for substation or widely the network control. Paper **0519** presents a "Smart secondary substation" which is a current MV substation upgraded to a key smart grid component thanks to the integration of the "Modular Substation Manager" (MSM) device newly developed. This device facilitates some tasks for the Network Operation Centre in real time as MV or LV monitoring, faults detection etc., or off line analysis as quality of supply, asset management, distributed generation impact, etc. Tasks for metering systems are also integrated in the MSM. Meters and MSM exchange data thanks to PLC, the communication between MSM and Central system

uses Ethernet.

The selection of communication technology to be applied is definitely in line with expected data flow rate, paper **1448** exposes all the available communication technologies (GSM, GPRS, Broadband PLC, Narrowband PLC) applicable for monitoring small hydroelectric plants from the Operational Control Centre. Pros and cons of each solution are proposed and discussed. As the expected flow rate was not too high and for global cost reasons – networks availability, no need for bridges – PLC narrow band on medium voltage line (13,8 kV) technology was finally selected.

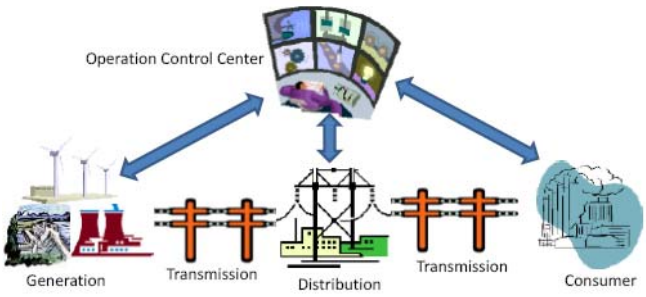

Fig. 23: from paper 1448 – Evaluated scenario

After covering all communication technologies, paper **1350** details PLC variants characteristics and introduce the key components of the PLC network as: PLC modem, PLC Bridge, PLC Access point and PLC repeater. As a conclusion it proposes an assessment tool for the deployment costs taking in consideration: purchasing prices, installation costs, maintenance costs, technology system, project management, data communication, accessories and inventory costs to be compared to GPRS technology.

When high data rate low latency are requested, Long Term Evolution Technologies (LTE) could be a solution, it's the topic presented in paper **1242** when LTE is applied to microgrids. Microgrid is a small scale grid which can behave differently than a larger one due to the presence of distribution resources units, power quality constraints and market participation positions. The control and operational strategies of a microgrid can be totally different compared to a conventional one. Four control levels are identified either inside the microgrid (level 0 & 1) or between the microgrid and the grid (level 2 & 3). Regarding data exchange – flow rate and latency – tests performed in labs confirmed the interest of LTE for microgrids management.

In the same chapter, paper **0805** compares licensed UHF and SHF RF mesh communications in support of the distribution automation. The study points out the interest of the Super High Frequency waves (SHF) versus the Ultra High Frequency waves. Although SHF network requires additional equipment like repeaters and associated costs (+17%), there is definitely some advantages with a 40 times increase in throughput and a 30 times decrease in latency.

Contrary to the previous publications the paper **0951** focus on the use of fixed transmission line thanks to developed composite cables, associating both energy MV conductors and Optical Fibres. Roles expected from OF are multiple. A few and important functions are expected from the OF inserted in the composite cable, first as data transmission from the grid to the central control system, and second as a support for power MV link monitoring (distributed temperature sensor, conductor temperature, Partial Discharge diagnosis and dynamic current rating). Two cable designs are proposed for OF protection, either with micro ducts or stainless steel loose tube (SSLT).

Jointing operations of such a cable should not be an obstacle for deployment; a composite joint was developed and tested.

Fig. 24: from paper 0951 – Composite cables design and configuration of cable joint

Reliability of transmitted data could be an important issue for smart grids control, a design of a reliable high performance IEC61850 substation communication networks based on PRP and HSR technologies is presented in the paper **0611**. To fulfil such an objective, redundancy in circuits is mandatory. Two protocols have been developed for Ethernet applications: PRP (Parallel Redundancy Protocol) and HSR (High availability Seamless Redundancy). Both combined architectures reduce weakness of each protocol and offer a well structured network.

Components for power control in smart grids
(14 papers)

Smart grid incentives are mainly by the renewable energy generation injection on the distribution network. Sensors associated to a communication network will definitely support the controller, but some key advices are more than useful when placed at critical points in the network for voltage control or fault current limitation. The selected papers address the voltage regulation issue, then various FCL technologies are proposed, lastly some new components for network control are presented.

A few technologies are available for voltage regulation of the network with the objective to maintain voltage level at nominal value +/- 10%. The paper **0188** presents advantages and disadvantages of three possible technologies, i.e.: variation of inductance, electric contactors and thyristors in separate circuit. A pilot installation, currently under evaluation and using the variation of inductance is then

described.

The on-load-tap-changer (OLTC) combined to vacuum interrupter integrated in a vacuum bottle is the basement of the design of the Integrated Vacuum Tapping Interrupter (IVTI). Paper **0580** presents the simulation study performed with the support of the ANSYS software for arcing simulation and temperature calculation during operations. Main interest of this novel concept when coupled to a MV transformer lies in reducing the volume of the complete system.

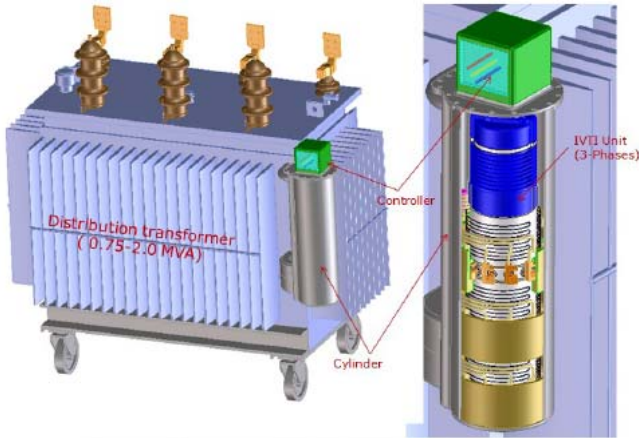

Fig 25: from paper 0580 – Example IVTI mounted on distribution transformer

For voltage regulation of MV distribution networks, injection of reactive power is the solution presented in paper **0984**. A 400kVAr D-SVC system (Static VAr Compensator) was installed on the network close to a wind farm. Three modes were tested with the D-SVC: Automatic Voltage Regulation (AVR), Short-term Fluctuation of Voltage (SFV) and Average Reference Voltage (AVR). A central server calculates and sends the optimal reference voltage to each D-SVC. Experimentation points out the interest of the AVR compared to the others.

In LV networks, voltage regulation may be improved with a portable and smart device, it's the experience presented in paper **0831**. This device (PVRLVN), for single, two or three phases can easily be installed on the critical points of the LV network where out of the limits voltage levels are registered. The power control allows three basic actions in output voltage: add voltage when too low, subtract voltage when it is too high, no reaction when voltage is on the right range. The PVRLVN have output measurement data which allows monitoring via GPRS.

Fault current limiters (FCL) can play an important role in networks design. Similarly to voltage regulation, a few technologies are available. The two next papers are supported by superconducting technology as the following one will rely on ceramic magnets. Paper **0284** proposes a 12kV-200A superconductor based FCL, YBCO is the selected superconducting material operating at 77K. The interest of such a design is shown with preliminary development tests performed on a LV coil.

Superconductor's characteristics, and especially the critical current Ic, is the basement of the FCL design previously presented. In paper **0285**, similar concept is used in a first design but using BSCCO bulk components (11kV – 400A), but another concept (resistive SFCL) is proposed using HTS magnets (MgB_2 technology) acting as pre-saturated core face a standard copper solenoid. Two FCL pilots (resistive SFCL-11kV/400A & 11kV/1250A), were installed and successfully tested on the network; an evolution in design by replacing HTS magnets with copper ones is presented as a future prospect.

In line with the previous paper, p**aper 0505** proposes FCL design without superconductors. The technology has been achieved with low costs ferrite magnets which offer some benefits to the customer which could be summarized by "Fit and Forget". The FEM modelling based study proposes the adequate geometry, main challenge lies in the substantial scaling up in the size of the magnet. An 11kv 20 MVA FCL specification was studied.

Back to superconductivity with the p**aper 0742**: a superconducting MV cable with an innovative design with the concentric three phases. After a feasibility study performed in 2009, the project AmpaCity was launched with the objective to replace an existing 110 kV link by an HTS 10 kV cable with the same power rating. The advantages of such a design - concentric conductors- associated to HTS technology are HTS MV cable compactness compared to the 110 kV link, good electromagnetic compatibility and thermally independent from the environment. A cable prototype with a specific designed joint is currently under evaluation. After qualification tests completion, a one kilometre underground link will be installed.

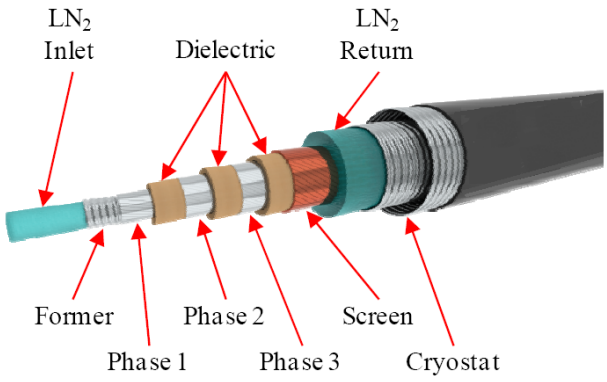

Fig. 26: from paper 0742 – HTS cable design for the AmpaCity project

Interesting experience with DC applied in LV distribution network is the content of paper **0776**. Directly connected to a 20kV AC transformer, a 100kVA rectifying substation supplies three 16kV customer-end inverters through a 1,7 km long underground bipolar DC cable (+/- 750V). Due to a quite long distance from the operation centre, a web portal was developed making possible the full remote

control and all data acquisition. After 5000 hours, the first implementation of LVDC distribution system has been successful.

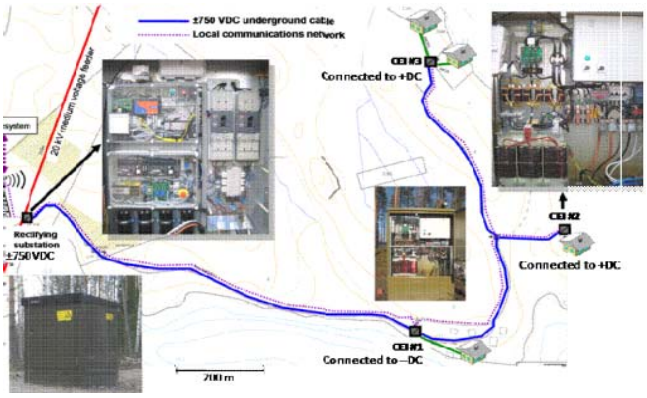

Fig. 27: from paper 0776 – The LVDC research setup components located on the map

Renewable but versatile energies deployment should be consolidated with a fundamental part of the smart grid: the energy storage device. It's the topic of paper **0781**. The Electric Storage System (ESS), key component of the "Isernia Project" is a 1MVA-500kWh Li-ion device associated to a control system. The "Black Start" tests, important to assess the impact of stored energy injection on the network voltage, were performed on field with selected MPBS (Mechanical Parallel Black Start) mode. Work is still in progress to implement also the VRBS (Voltage Ramp Black Start) mode to improve energy injection system.

Balance between MV feeders issue is the topic proposed in the paper **0789** with Quadrature Booster trial at 33kV. Such a controllable device was preferred to solve unbalanced network instead of series reactor - installed on the lower impedance line- or series capacitors to lower the impedance of the highest impedance line, or even the line reinforcement with either OHL or UG cables. The 33kV-30MVA Quadrature Boosters or Phase Shifting Transformers (PST) will be installed on the network in the current year.

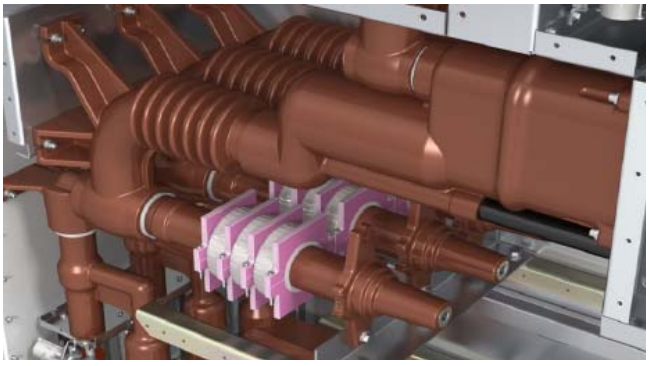

Fig. 28: from paper 0689 – Environmental friendly design, cast resin in combination with air as insulation medium instead of SF6

Energy security supply for Data Center is exposed in paper **0689**. Data centers are requiring high energy needs all the time. The fully automated DRUPS (Diesel Rotary Uninterruptable Power Supply) replaces the batteries in the secured electrical power system. This equipment is associated to high performances switchgear using cast resin in combination with air as insulation medium instead of SF_6.

Paper **0997** presents detailed modelling and design of a PV generator which is capable of working in grid connected mode and islanding mode using Simscape, a MATLAB based software.

Paper **059**1 describes the test platform for Electric Vehicle Battery Swapping Stations. These charging stations need to be fully tested before commercial service and a dedicated mobile test platform was developed. The structure and the equipment of the vehicle include: power supply, charging, battery dispatching, q-station monitor and metering systems.

Potential scope of discussions

-Drivers for implementing new sensors (voltage control, condition monitoring, others); integration of sensors in network components

-Synergies between AMIs and operation and control infrastructures in the field of telecommunication

-Best options for voltage control

-How close from market are solutions based on superconducting components

-LVDC network as smart grid component

-Smart grids deployment and investments for power quality improvement

Table 3: Papers of Block 3 assigned to the Session

Paper No. Title	MS p.m.	RIF	PS
1332: Integrated Smart Grid concept – Experience in a German distribution grid			X
0589: Smart grids, assets management in primary distribution substations, with smart sensors networks	X		X
0986: A novel retrofit concept for enabling smart secondary substations			X
0902: Experiences from a pilot project in implementing smart meters			X
0103: Application of IEC 61850-9-2 in MV switchgear with sensors use			X
0598: The smart termination : an innovative component to enable smart grids development	X		X
0451: A voltage measurement accuracy assessment system for smart distribution equipment			X
0869: Electronic high voltage combined measuring transformer			X
0519: Smart secondary substation management device			X
1448: Evaluation of communication components for monitoring small hydroelectric plants	X		X
1350: Building utility communications through development of Power Line Communication			X
1242: Channel requirements for LTE due to microgrid management system implementation			X
0805: Model comparison of licensed UHF and SHF RF mesh communications in support of distribution automation			X
0951: Medium voltage optical fiber composite power cable system for smart grid			X
0611: Designing reliable high-performance IEC61850 substation communication networks based on PRP and HSR technologies			X
0188: Voltage control in smart distribution grids – Use cases for voltage regulators and in-phase controllers			X
0580: A novel integrated vacuum tapping interrupter		X	X
0984: Effectiveness of D-VSC on rural networks			X
0831: Portable regulator , an industrial solution for voltage regulation at LV networks			X
0284: High temperature superconductor based fault current limiter for distribution systems			X
0285: Superconducting fault current limiters – UK network trials live and limiting			X
0505: Fault current limiters surge protection device for the power grid based upon zero power consumption ceramic ferrite permanent magnets		X	X
0742: Ampacity project – Worldwide first superconducting cable and fault current limiter installation in a German city center	X		X
0776: Experiences from use of an LVDC system in public electricity distribution	X		X
0781: Performances of the first electric storage system of ENEL Distribuzione	X		X
0789: Flexible Plug and Play low carbon networks (FPP) Quadrature Booster trials at 33 kV			X
0689: An integrated data center solution on medium voltage level			X
0997: Simscape based modelling and simulation of a PV generator in microgrid scenario		X	X
0591: A test platform for electric vehicle battery swapping stations			X

Block 4: "Innovation in network components"

This fourth block is gathering papers which present tools and methods used in the innovation process as well as new designs of network components not specifically related to the Smart Grids topics as in the previous block.

It has been divided in the following three sub-blocks:
- Modelling and simulation (11 papers);
- Environmental considerations and eco-design (4 papers);
- New designs (17 papers).

Modelling and simulation
(11 papers)

Numerical simulation tools and models are continuously improving and their use is increasing in the design of network components, in order to reduce the development time and testing costs while getting closer to optimal results.

The first four papers are presenting the advantages of modern simulation tools in the domain of the thermal management of network components.

Paper **0570** shows how the thermal management of high current rating gas-insulated switchgear (for primary distribution substations) can be taken into account since the early stages of the design process. The thermal network method (TNM) is very useful for preliminary assessment of the feasibility. It can be later completed and supported by other simulation tools, like finite element method (FEM) and computational fluid dynamics (CFD), to provide a more accurate model of the actual design.

Paper **0483** is also focussing on TNM for the same field of application as the previous paper. It presents the work in progress to develop a method for automatic thermal network model generation from the results of FEM and CFD analyses. The generated network can then be used for parameter studies, as it requires much less computation time than these methods. Promising results have been achieved for the simulation of conduction and convection heat exchanges. More developments are needed to improve the accuracy with respect to the radiation exchange and the influence of the temperature distribution in fluids.

The next two papers are presenting the application of CFD, or derived methods, to thermal simulation of prefabricated substations.

Paper **0625** describes how thermal simulation tools have been used to optimize the cooling system of a shore connection substation used for providing power supply to ships at port. CFD modelling of the dry-type transformer and its compartment has been implemented in this study, in order to characterize the requirements for both air forced and air natural cooling systems.

Fig. 29: from paper 0625 – Radial ventilation system at the bottom of a dry-type transformer

Paper**1055** presents a customized simulation tool that has been developed over several years for thermal simulation of transformer substations. Compared to the full CFD simulation which is very powerful but also consuming a lot of computation time, the chosen approach is to use an intermediate level model, called zonal modelling. After correlation with CFD results for a given configuration the zonal thermal model implemented in a spreadsheet can be used for comparison and selection of design choices in a fast and efficient manner.

The following two papers are not strictly centred on the thermal domain and give other examples of the application of FEM and CFD.

Paper **0463** shows how modern simulation tools can help in solving the problems raised by the design of a new type of SF6-free ring main unit (RMU) switchgear. If for instance dry air is used as an insulating medium instead of SF6 gas, it is very challenging to keep similar compact dimensions from the dielectric and thermal points of view. Examples are given of known solutions which can be used for improving the dielectric performance and how CFD simulation can help for the thermal aspects.

Paper **0410** presents a numerical model used to simulate the gas flow inside SF6 load-break switch puffer interrupters during the breaking operation. Cold gas simulation using CFD software allows better understanding of the factors which influence the pressure build-up, such as nozzle geometry and leakage rates. It is thus possible to select between design options in order to optimize the breaking performance. An arc model used for HV circuit-breakers has been implemented in the CFD software to simulate the actual current interruption, but it needs to be improved and adapted for the conditions of low current breaking in load-break switches.

The last five papers in this sub-block are all related to the

internal arc fault protection: in this domain the testing is time consuming and costly, so a lot of efforts are made to accurately simulate the internal arc phenomena and predict the behaviour of the installation.

Paper **1001** presents the simplified mathematical model developed by the CIGRE A3.24 working group for predicting the pressure rise due to internal arc in the switchgear compartments and the substation room. Good consistency between the calculated results and the measurements can be obtained when the arc energy input is well known, by adjusting the model parameters k_p (fraction of the electrical energy contributing to the pressure rise) and α (discharge coefficient determining the gas flow through the exhaust area). The simplified model can be used to predict the pressure rise values in case of design modifications when reference tests are available, thus allowing a reduction in the number of actual internal arc tests.

Paper **1301** shows how a simplified calculation method, similar to the one described in the previous paper, can be applied to determine the pressure rise in a switchgear room subjected to an internal arc event in the switchgear. The average value of pressure obtained can be used to determine the area of relief openings in a room of a given volume in order to limit the pressure stress applied to the walls. However it is shown that for large openings (with respect to the arc power) the pressure can no longer be considered uniform in the room and CFD simulation must be used to determine the pressure peaks in localized areas of the walls.

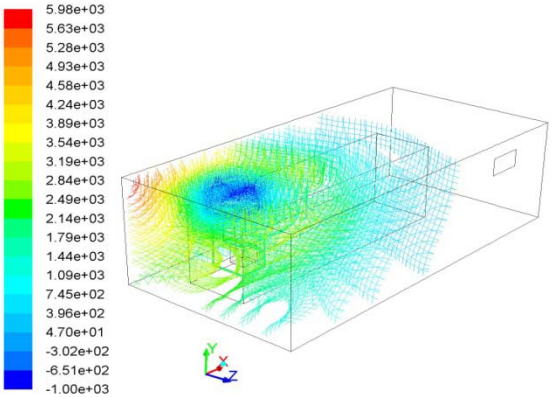

Fig. 30: from paper 1301 – CFD simulation showing a pressure peak in the corner of the switchgear room 17 ms after the fault initiation

Paper **1057** explains how the internal arc performance can be taken into account from start as a basic requirement in the design of a new type of primary gas-insulated switchgear (GIS). In order to reduce the number of internal arc tests, a common internal arc tested core assembly has been used as the basis for different variants of the switchgear. Several innovations developed in order to ensure internal arc performance without adversely affecting thermal performance and other requirements are presented, like the anti-arc ventilation system (also mentioned in paper 0570 at the beginning of this sub-block).

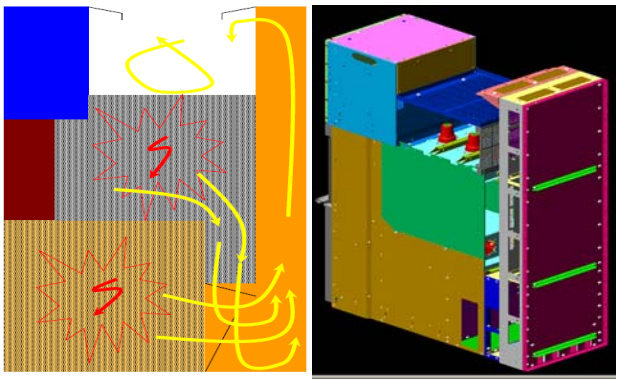

Fig. 31: from paper 1057 – Example of introverted release in case of internal arc fault

Paper **0572** presents the results of experimental investigations on different types of cooling installations and materials for absorbing the energy released by internal arc faults. Some effective combinations of absorbers and energy absorbing (by phase change) materials have been identified. A distribution of the total energy generated by the internal arc between the different compartments, absorbers and surroundings is given.

Finally paper **0562** reports on investigations about the feasibility of small scale arc fault testing. The scaling factors are discussed for volume, current, electrode gap: this last parameter must be carefully selected in order to achieve similar thermal transfer coefficient (k_p) for small scale tests as for the real ones. It is shown also that scaling must be considered as well for the position of temperature sensors and ignition indicators in order to compare the test results in a valid way.

Environmental considerations and eco-design
(4 papers)

A variety of subjects related to environment friendliness are addressed in the four papers of this sub-block.

Paper **0138** presents the PEP ecopassport collaborative program launched by several electrical industry stakeholders in order to define common sets of rules for making and declaring the Product Environmental Profile (PEP) according to ISO 14025. These rules allow the realisation of the Life Cycle Assessment (LCA) and the PEP declaration to be based on principles of accountability and transparency. More information can be found on the website at the following URL http://www.pep-ecopassport.org/.

Paper **0725** reports on a comparative life cycle impact assessment (LCIA) analysis performed on three different technologies used for windfarm step-up transformers: dry-type cast resin transformers and two types of liquid-immersed transformers (standard and high temperature compact type). The results show more impact on the environment for the dry-type technology, the two liquid-

immersed technologies being equivalent from the LCIA point of view.

Paper **0467** presents the results of life cycle assessments (LCA) and measurements of energization inrush currents performed in a comparative study of amorphous metal distribution transformers (AMDT) and standard grain oriented silicon steel (GOSS) transformers. Thanks to no-load losses reduced by a factor of almost 4 in the use phase, the LCA is clearly in favour of AMDT (about half of the CO2 emission of the standard transformer). Another aspect is the level of energization inrush current which can reach up to 25 times the rated load current in the case of AMDT, versus about 10 times for the standard transformers: compatibility of these high values of inrush current with the differential relays presently used in the system must be studied.

Finally paper **0784** describes the various steps taken to minimize the environmental impact of a new HV/MV substation built by EDP Distribuição in Portugal. In particular the landscape integration has been studied carefully as the substation is located close to a National Park protected area. Use of hybrid compact HV switchgear has allowed a significant reduction in the footprint and visual impact of the new substation.

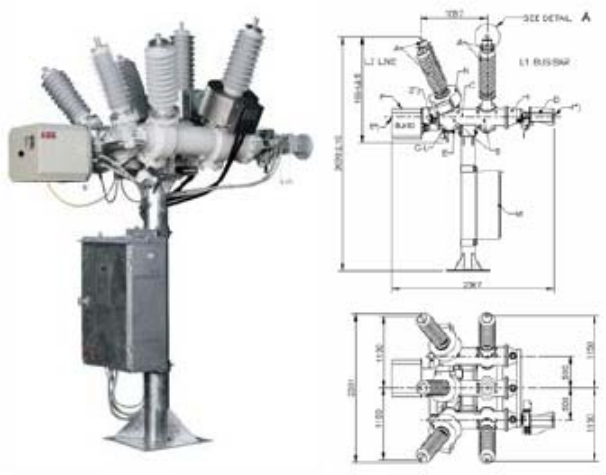

Fig. 32: from paper 0784 – Hybrid compact HV switchgear

New designs
(17 papers)

The 17 papers of this sub-block are organized in three groups: MV switchgear (8 papers), transformers and substations (3 papers) and miscellaneous components (6 papers).

Paper **0555** presents the last results of the ENEL experimentation with new types of MV switchgear according to the specification DY 900 (introduced at CIRED 2011 in paper 0468). This gas-insulated compact switchgear is fitted with circuit-breakers instead of load-break switches for the line circuits and is installed in MV/LV substations. The splitting of the ring circuit in several sections and the automated detection and separation of the faulty section allowed by the use of fast switching and high endurance switchgear has proved effective in reducing the duration of customers' interruptions. The new switchgear is also less sensitive to the service conditions than the previous air-insulated switchgear (DY 800 specification).

Paper **0274** proposes an innovative concept for a ring main unit (RMU) switchgear adapted to the "smart grid" requirements. A single loop (or ring) vacuum circuit-breaker associated with a three-position selector switch for the transformer connection (plus disconnecting and earthing devices for the ring cables) is presented as an alternative providing the same functionalities as a three circuit-breakers RMU for a fraction of the cost.

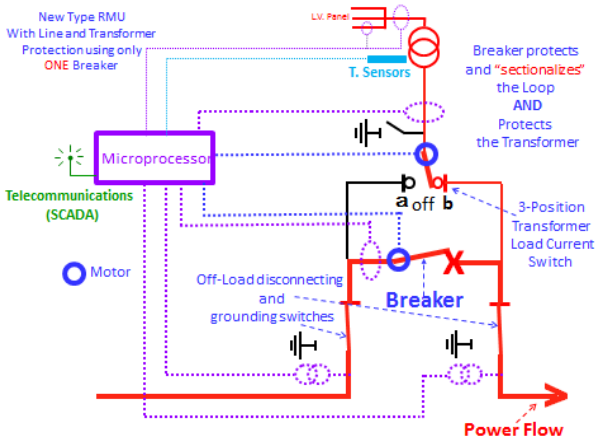

Fig. 33: from paper 0274 – Single line diagram of "smarter RMU"

Another innovative association of existing devices is presented in paper **0095**: a combination of a vacuum circuit-breaker and a SF6 load-break switch is proposed as an alternative to the conventional circuit-breaker and disconnector configuration. Depending on the current and voltage conditions, the control system is able to decide which device will operate, in order to use the SF6 switch when more appropriate (e.g. switching of small capacitive or inductive currents) and also to combine the mechanical and electrical endurances of both apparatus. Interlocks are also simplified because the load-break switch can be operated when the circuit-breaker is closed. This new type of single-line diagram for a functional unit however requires an adaptation of the current operating procedures: the necessary adaptation of specifications to take full benefit of innovative solutions is the topic discussed in the next paper.

Paper **1115** presents recent evolutions in the design of MV switchgear for MV/LV substations and MV customers' delivery substations. The new switchgear technologies, gas-insulated switchgear (GIS) or screened solid-insulation switchgear (2SIS), allow high insensitivity to the environment conditions and the realisation of compact switchgear with cost-effective circuit-breaker functional

units, together with readiness for advanced control, automation and monitoring solutions. The specificities of these technologies impact the architectures and single-line diagrams of the products, which are adapted to take full benefit of them. It is recommended that some present specifications, which are based on the older air-insulated technology, be revised in order to take into account the potentialities of the new solutions, e.g. in the field of single-line diagrams, voltage transformers protection, current transformers and protection relays testing, cable testing procedures.

Paper **1201** presents a good example of the potentialities of new technologies applied to MV switchgear, as discussed in the previous paper. The C-VIS (cubicle type vacuum-insulated switchgear) developed by Hitachi in Japan is characterized by many innovative features, namely: composite insulation (vacuum, air and epoxy resin instead of SF6 gas); vacuum used for circuit-breaker, disconnection and earthing functions; magnetic actuator drive mechanism with solid lubrication; vacuum monitoring system; screened solid insulation for the busbars, cable connections and the switching device. The resulting C-VIS 24 kV switchgear is more compact than the previous C-GIS (gas-insulated) switchgear with improved environmental friendliness.

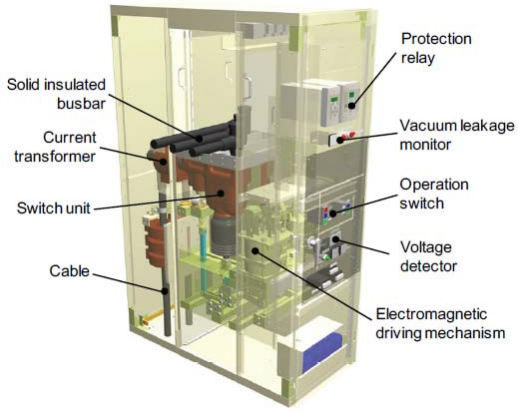

Fig. 34: from paper 1201 – Overall configuration of 24 kV C-VIS

Paper **1150** presents a new technical approach chosen by Vattenfal in Sweden to replace existing 52 kV rated switchgear in their 46 kV network by new switchgear with reduced BIL (basic impulse insulation level) corresponding to the 40.5 kV rating. This has been made possible by improvements in the overvoltage protection of the substations, with adapted use of surge arresters. The existing 40.5 kV switchgear and circuit-breakers have been tested successfully for breaking and switching operations at the 46 kV level, with some de-rating in the breaking capacity. The new solution has allowed a reduction by 30% of the total cost of the substation (excluding transformers).

Paper **0975** presents testing and approach used for selecting some materials suitable for outdoor surface insulation, equivalent or better than the often used cycloaliphatic epoxy resin (CEP). Eventually BMC (bulk molding compound) thermoset polyester with UV stabilisation has been selected for encapsulation of vacuum interrupters and conductor/current sensors, together with a modular approach (assembly of several components, versus one piece overmoulding by CEP). The new design is presently undergoing ageing tests in severe outdoor conditions at the KIPTS in South Africa.

Finally paper **0608** presents some advanced studies performed to confirm the feasibility of obtaining a MV circuit-breaker and over-current protection relay with a 1-cycle or 1.5-cycle interrupting time. The new digital relay has a tripping time of 0.5 cycle instead of typically 2 cycles. Fast acting mechanism with Thomson coil associated with magnetic actuator has been used to achieve 1-cycle interrupting time successfully. A more economical solution using a fast acting trip release with spring drive mechanism has been sufficient for 1.5-cycle interrupting time. This study will be used in the development of special types of switchgear, like DC high speed circuit-breaker or very fast transfer switch.

The first two papers from the transformers and substations group are focussed on the dry-type transformer technology, which tends to expand its field of application.

Paper **1140** reports on the progress since the presentation at CIRED 2011 of the new dry-type transformers for sub-transmission (72.5 kV class). First references and examples of installation are given. These dry-type transformers can be used more easily for indoor or underground installation than oil-filled transformers.

Paper **0521** provides an update on the testing and field experience of new dry-type pole-mounted distribution transformers, also presented at the previous CIRED conference in 2011. As these transformers are not protected by an enclosure special focus has been given to the climatic withstand of the MV insulation to the outdoor environment factors, both in natural and artificial testing facilities. The results obtained are satisfactory and it is proposed that the test procedure applied for validation of these transformers be used as the basis for the development of a new standard that is needed to cover this new type of application for dry-type transformers.

Fig. 35: from paper 0521 – Installation of a pole-mounted dry-type distribution transformer

The third and last paper in this group, paper **0437**, reviews the topic of prefabricated substations and housings from the point of view of standards and functional specifications.

While HV/LV prefabricated substations for distribution networks are well covered by the IEC 62271-202 standard, the requirements and type tests of this standard may be insufficient for other applications. In these cases detailed specification based on a thorough functional analysis is needed to establish an exhaustive list of check points and validations. Some examples are given of such cases where existing standard must be supplemented, like ventilation and corrosion resistance of substations for offshore windfarm applications, or deformations of power houses used in the oil & gas or mining activities, during transport or earthquake events.

The last group of papers in this sub-block is addressing a variety of topics: materials for transformers and cables, components for overhead lines and transformer bushings.

Paper **0382** reports on the development project of a low viscosity natural ester fluid for distribution transformers. A composition has been found that has similar characteristics of viscosity and heat transfer as mineral oil: so it can be used in existing distribution transformers without requiring any change in the design. On the other hand it has the same excellent biodegradability and low cost as vegetable oils. Laboratory test results and return from 5 years field trials confirm the suitability of this fluid for MV/LV distribution transformers. Expanding its use to the higher rating power transformers will however require more research and validation.

Paper **1224** presents results from a tests campaign carried out to evaluate different compounds of halogen-free flame retardant polymers for HV cable outer sheath (jacket). It is shown that although the compounds from different suppliers are made of similar polymers and fillers, large differences in mechanical and ageing characteristics can be found, depending on the additives used, the crystallinity of the polymer, or the copolymer ratio. The best compound has been retained as material for a HV cable jacket and passed successfully the fire test according to IEC 60332-3-24.

Paper **0737** reports on the development of a new type of porcelain insulator for 25 kV overhead lines in Brazil. Results of mechanical and electrical simulations are presented, as well as testing of prototypes. The new design is approved for field testing in an area selected for its severe environmental conditions.

Paper **1315** describes the development and mass production steps which have lead to the local manufacturing of the first MV spacers for overhead spacer cable distribution lines in Iran. Further study is being considered for using spacer system adapted for bundle configuration with 2 conductors per phase in order to reduce the reactance of lines.

Paper **0791** presents a new technology (RIS: resin impregnated synthetics) developed for dry-type HV condenser bushings. In comparison with the current RIP (resin impregnated paper) technology, RIS is characterized by the paper being replaced by a fabric of polymer fibres which allows impregnation by resin of much higher viscosity, like epoxy resin with filler. This fabric presents also the advantage of not absorbing humidity, which simplifies the manufacturing process. Test results are presented and first field trials have been launched in 2011 for a new family of RIS air-oil bushings from 24 kV to 170 kV.

Finally paper **1219** presents a similar technology (combined epoxy resin and silicone rubber insulation) applied to the simpler non-condenser dry-type transformer bushings of the lower voltage range (from 24 kV to 72.5 kV). Compared to the conventional porcelain-oil bushing technology, the new CRS (combined resin and silicone) family of bushings presents the advantages of better safety in case of failure and improved tracking performance.

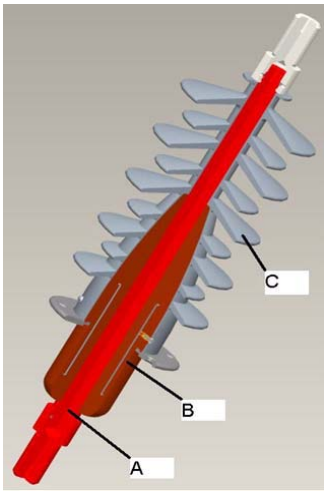

Fig. 36: from paper 1219 – Combined insulation bushing

Potential scope of discussion

-Internal arc simulation as an alternative to testing

-Standardized internal arc test conditions and reality

-Environment friendliness versus economic constraints

-Extended use of circuit-breakers in the distribution networks

-Acceptability of innovative solutions in public distribution networks

-Respective fields of application of dry-type and oil-filled transformers

Table 4: Papers of Block 4 assigned to the Session

Paper No. Title	MS p.m.	RIF	PS
0570: Thermal management in the design process of MV GIS			X
0483: Automatic generation of thermal network models for MV GIS		X	X
0625: Cooling modes and lifespan of MV dry-type transformers inside a shore connection substation			X
1055: Towards the efficient refrigeration of transformer substations by means of computational fluid dynamics			X
0463: Dielectric and thermal challenges for next generation Ring Main Units (RMU)			X
0410: Gas flow analysis in low energy arc puffer interrupters			X
1001: Application of simplified model for the calculation of the pressure rise in MV switchgear due to internal arc fault	X		X
1301: Pressure rise in switch rooms in case of internal arc in AIS MV switchboards : importance of room design and simplified calculation method			X
1057: Internal arc based innovation for medium voltage switchgear			X
0572: Energy based evaluation of gas cooling related to arc faults in medium voltage switchgear		X	X
0562: An experimental study of small scale arc fault testing of medium voltage switchgear			X
0138: Environmental Declaration in compliance with ISO 14025 thanks to a collaborative program of electrical and electronic industry : the PEP ecopassport program			X
0725: Comparative eco-study of various technologies used for distribution transformers			X
0467: Life cycle assessment and inrush currents measurement of amorphous transformers	X		X
0784: Eco-design and limitation of visual impact - Design and construction of an HV electrical infrastructure			X
0555: A low-cost high performance MV RMU with circuit breakers for use in remote controlled MV-LV substations: first results of Enel Distribuzione experimentation			X
0274: The Smarter Single Breaker RMU. A Fuse-less, Single Breaker, Auto-Loop-Sectionalizing RMU			X
0095: New medium voltage circuit-breaker switchgear with advanced functionality	X		X
1115: Impact of medium voltage technology on operating modes in the network	X		X
1201: Features of cubicle type vacuum-insulated switchgear (C-VIS)	X		X
1150: Switchgear with advanced surge protection in 40 kV network			X
0975: Material selection redefines solid dielectric medium voltage switchgear			X
0608: High-speed AC circuit breaker and high-speed OCR			X
1140: Dry-type transformers for subtransmission	X		X
0521: Polemount dry-type transformer- testing and experience			X
0437: HV/LV prefabricated substation products and HV installations in a prefabricated housing			X
0382: Development and experimentation of a low-viscosity insulating liquid based on natural esters			X
1224: Evaluation of flame retardant jacket materials for high voltage cables			X
0737: Development of a new porcelain insulator design applied to distribution networks in Brazil			X
1315: Design and Mass Production of Medium Voltage Spacers			
0791: New paper-free insulation technology for dry high voltage condenser bushing			X
1219: New combined insulation transformer bushing			X