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.

126 papers have been selected for the Session 1 – Network Components – of CIRED 2017. 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 Research & Development of Network Components – Cables systems (28 papers):
- New materials & designs;
- Development of accelerated ageing tests and failure detection methods;
- Diagnostics methods development.

Block 2 Research & Development of Network Components – Substations (29 papers):
- SF6-alternatives & vacuum switching;
- Safety, environment & reliability considerations in the design of network components;
- Testing and numerical simulation methods for development of network components.

Block 3 Management and Architecture Evolution of the installed base of Network Components – Cables & their environment (31 papers):
- Smart Grids solutions and applications in smart metering;
- Applications of methods and tools to asset management of cables and distribution lines;
- Enabling solutions and methods for the integration of renewable energy generation.

Block 4 Solutions for managing the installed base of Network Components – Substations (38 papers):
- Condition assessment, ageing behaviour and maintenance strategy;
- Monitoring solutions for asset management and operation of Network Components;
- Diagnosis tools and methods.

6 papers per block have been selected for oral presentation in the Main Session (MS), but all the papers can be presented in the interactive Poster Session (PS).

In addition to the Main and Poster Sessions, three Round Table (RT1, RT2 and RT3) discussions and a Research and Innovation Forum (RIF) will take place within Session 1.

RT1 – “Digital solutions for network maintenance: drones and image processing, virtual and augmented reality, big data, data analytics and IoT”.

RT2 – “Smart secondary substations, technology developments and distribution system benefits”, will present the results of the CIRED WG on this subject.

RT3 – “Reduction of technical and non-technical losses in Distribution Networks” (joint RT with Session 5) will share the approach and main findings of the CIRED WG on this topic.

Finally, 8 papers, presenting various results from research activity in the field of network components, have been selected for oral presentation and exchanges with the audience during the RIF.

Block 1: "Research & Development of Network Components – Cables Systems"

The 28 papers of this block are organized into 3 sub-blocks:
- New materials & designs
- Development of accelerated ageing tests and failure detection methods
- Diagnostics methods development

New materials & designs (11 papers)

The cables & lines systems have always to answer to new requirements that drive the development of new materials and design: visual impact (107), commissioning and testing (266), health and environmental aspect (272, 430, 1108), weather conditions (279).

The Aerial Bundle Cable (ABC) are usually black, Paper 107 is presenting a technology with a "stone grey" outer sheath installed 18 years ago to reduce the visual impact while keeping a good resistance to UV. The tests of 18 years old cable are positive and the "stone grey" ABC can be further used and ideally applied to telecom cables.

As presented in paper 266, a conductive skin on top of MV underground cable allows testing of the external sheath integrity after installation and along cable lifetime. This layer may cause some difficulties during accessories fitting. A solution based on red coloured over-sheath is proposed.

Figure 4 of paper 0266: MV insulated cable sample with external conductive layer and red colored over-sheath

In order to mitigate the risk of electrocution of large bird on overhead line, Paper 272 is estimating the maximum current that can flow through the bird's body. Danger has been identified only in case of rainy weather and mitigation solutions consist in line insulation or an increase of the distance between phases.

Paper 1108 proposes a two layers model of soil to simulate accurately the earthing current and therefore to size correctly the earthing circuit to avoid safety hazard. The result shows difference in case of more resistive layer beneath a surface layer of 0.5 to 1 meter, resulting in underestimating the earthing resistance based on surface measurement.

To prevent line overweight due to ice, the paper 279 is addressing solutions based on ice-phobic agent coating on the line surface. The actual lack of maturity of the technology has decided the operator to restart from scratch a cost effective solution adapted to application and maintenance on installed lines. Lab test has been carried out and two coatings will be applied on existing lines.

Figure 1 of paper 0279: Accumulated ice on an overhead line

Another driver for materials and design innovations the increase of performances translated into more resilience (602, 414, 912, 1066) or more capacity (430, 917).

Paper 602 is presenting a novel route to realize very compact and robust MV joint by in-field extruded mould process. This solution is producing seamless junction with no interface and using the same materials as plain cable.

Different approaches of self-healing materials are addressed in Paper 414. A first version has been proposed based on oil filled cable, the oil containing a curing agent reacting in case of leakage and stopping rapidly the flow of oil. A second solution based on hydrophilic thermoplastic elastomer, itself not self-healing, would delay the water ingress by filling the sheath damages.

Paper 912 proposes a new generation of nano-composite HVDC and HVAC insulator materials. Nano-silica powder has been functionalized with epoxide prior to planetary dispersion with base resin. Benefits expected are good surface discharge resistance, enhanced thermal conductivity and higher breakdown strength.

Paper 1066 is a study about the benefit in term of performance and possible drawback in term of health and environmental aspect of nano-TiO_2 for MV insulator and lightning system. The lack of clear regulation is an obstacle of the safe use of nanomaterials.

Paper 430 evaluates the cost benefit and environmental impact of up rating of existing 60 kV overhead lines with high temperature conductors. ACCC (composite core) and ACSR (Steel reinforced) conductor are compared. The ACCC environmental impact is lower but exhibits higher losses.

In order to increase maximum operating temperatures and electrical performances in cable, the paper 917 is presenting the development of thermoplastic blends and processing optimization.

Development of accelerated ageing test and defects detection methods (9 papers)

The return on experience of installed assets brings a lot of data about ageing phenomena and critical defects (114, 418).

Paper 114 investigates the relation between corrosion and insulation damage. The pierce insulation due to manufacturing defect or mechanical damage is the main enabler of conductor corrosion. A solution could be to improve detection of defect leading to piercing during production or in field.

Paper 418 is proposing an ultrasonic rotating 3D scanning for cable in order to measure continuously insulation thickness and eccentricity to insure that the insulation system is according to specification and defect free.

To transform the ageing understanding into long term reliability, performances specification and therefore new accelerated ageing test are developed, combining thermal, mechanical and electrical (200, 260) and in particular electrical wet ageing of cable (537,598, 1134) and accessories (893, 826).

Paper 200 is presenting the ageing result of High Temperature Low Sag over-head line conductors in the frame of the FP7 project “Best Paths”. Combined thermal and mechanical ageing have been applied to lines and splices. All thermal resistant aluminium technologies are passing, only pure aluminium (ACSS) show deterioration before the 2000 hours of accelerated ageing.

To avoid corona, shielded bus bar presented in Paper 260 have replaced standard air insulated systems. The study is investigating ageing criteria of the over moulded rubber. Thermo-mechanical and electrical accelerated ageing have been applied to identify the most critical ageing mode.

In Paper 537, in the context of steady increase of asset ages, 30 years old cables are inspected to detect early degradation in order to establish the level of aging and to organize preventive replacement. For this purpose, water tree and AC break down are measured on the removed cables as well as equivalent artificially accelerated aged cable at high frequency. The AC breakdown and water trees revealed that the residual lifetime is around 30 years but as the accessories are likely to be the limiting a new study will be carried out to estimate their lifespan.

Paper 598 is presenting the result of 10 years of development and test of 3 kHz accelerated wet ageing test.

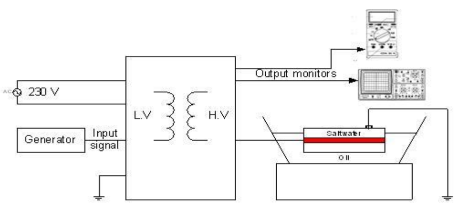

Figure 1 of paper 0598: 3 kHz test set-up

Different materials performances are compared using the evolution of breakdown level as well as water tree inspection before and after 3 kHz ageing. Global improvement of insulated system materials has been confirmed.

Paper 1134 is summarizing long term study about wet ageing of polypropylene thermoplastic using accelerated ageing at 500 Hz.

Paper 893 is addressing long term wet ageing tests of MV joints. A cylinder model is proposed to check water diffusion through silicone and full scale set up under voltage cover the risk of water ingress in the assembly and by diffusion. The results on cylinder model and on the immersed MV joint without outer protection show higher performances under permanent high voltage than under low and intermittent voltage. Thus the cylinder model is therefore validated.

The aim of paper 826 is to give recommendation and guidance to obtain long term reliable cable connections, especially screen connection, based on analysis of service failures. Moreover, discrepancies of design, testing and specification have been identified between suppliers and operators, as well as not covered aspect in the existing standards and recommendation. The reason can lie in a lack of understanding of electrical and physical phenomena and underestimated difficulties during installation. A CIRED working group has been initiated to propose a harmonized specification.

Diagnostics methods development (8 papers)

The recent evolutions in the field and sensors, electronics, software and digitalization open a new generation of systems by using actual protections or monitoring tools in extended modes in association with new hardware or data analytics enabling much more accurate identification of root causes and localization of the event (270). The phenomena understanding and methods developed for off-line diagnostic and commissioning is continuously improved (049, 291, 797) but also applied to the analysis of data from on-line monitoring system (56, 270, 813, 532, 1130).

Paper 270 addressed the evolution of components having initially mainly protective function towards smarter missions like network diagnostic. But the high accuracy required to fulfil such missions is not covered by industry standards. The authors are investigating the conditions and recommendations to reach a 0.5% class of accuracy level for a system of LPIT, a MV recloser and its control unit. Especially adequate design and construction of control cable and junction box are key to obtain the expected accuracy. Major designs changes are required to go below 0.5% of accuracy.

Paper 049 is comparing PD diagnostic methods using different type of excitation voltages (i.e. Very Low Frequency (VLF) Sinus 0.1 Hz, VLF CR 0.1 Hz and

Damped AC) to be used in particular for commissioning test. The study shows that VLF CR 0.1 Hz and DAC are very similar due to the same wave shape frequency at the polarity reversal of VLF. The former excitation voltages exhibit lower PDIV and higher PD intensity compared to VLF Sinus 0.1 Hz. This difference can be explained by higher level of dU/dt creating more interfacial discharges.

Paper 056 is presenting on line monitoring system able to detect and alert of a critical level of pollution of MV overhead lines 'insulators. The principle is the measurements of the leakage current burst and takes in account the influence of weather conditions. All the data collected are analysed using neural network algorithm to isolate the contribution and the level of the insulators' pollution. Beyond a limit the system sends an alert to the maintenance team. A wireless version will be developed.

In paper 291 the application of multisource defect diagnosis using DP allows localizing concentrations of discharges in joints. The analysis of these results combined with advanced detection procedure gives signatures of critical defects on MV joint, coming mainly most of the time from bad fitting and assembly.

Paper 797 presents a new association of 50 Hz dissipation factor with the usual 0.1 Hz test in a mobile system for improved off line diagnostic of MV Paper Insulated Lead Cover (PILC) underground cables. The components of the system need to be compatible and their dependency accurately evaluated with both frequencies. The temperature distribution along the underground cable is an issue in field conditions for 50 Hz dissipation factors. The very low frequency system is disturbed by external PD that could be eliminated by field control elements.

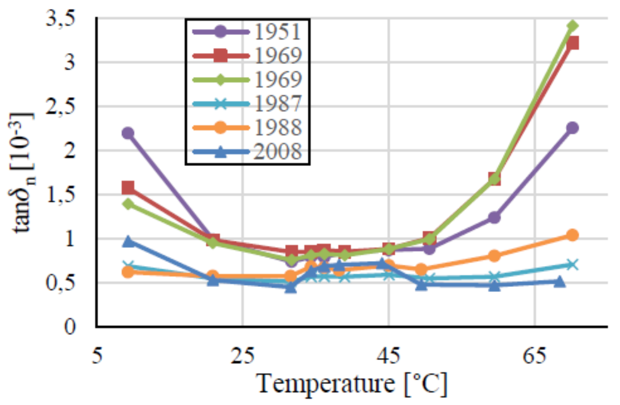

Figure 7 of paper 0797: Normalized 50 Hz dissipation factor over temperature development of differently pre-aged PILC cable samples

Paper 813 presents a system to detect and localize along MV underground cable length defects and influencing external factors. The spatially resolved diagnostic is based on attenuation of travelling waves. In presence of mixed types of cable (XLPE and PILC) a correction of wave propagation characteristics is required.

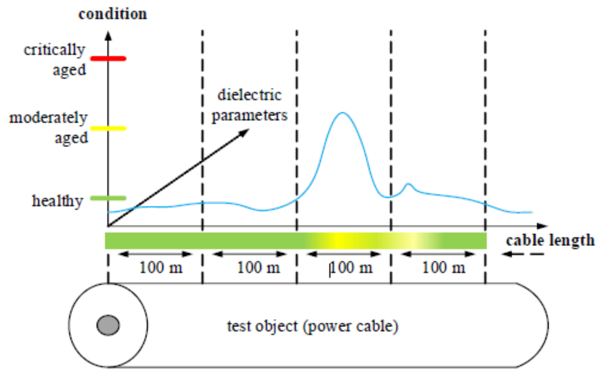

Figure 1 of paper 0813: Exemplary measurement of a cable condition with spatial resolution

Compared to standard existing system, this method can localize in laboratory environment a change of dielectric properties over few meters over a cable length of few hundreds of meters. Next step is to integrate field constraints like reflection from multiple joints.

Paper 532 is showing the effect of frequency on PD measurement. The authors showed that PD levels decrease at high frequencies due to accumulation of charges in cavity walls, moreover maximum of PD occurs for a given frequency, which is characteristic of dielectric materials and cavities' morphology.

The authors of the paper 1130 have stated that the underground cable network compared to overhead line network is much less equipped with continuous monitoring of current, temperature and voltage which can be of great benefit to manage more efficiently the operation and preventive maintenances. An Advanced Distribution Automation system is presented as the association of automated protection and relays with distributed intelligence based on electronic devices located on several nodes and more accurate sensing system. The benefit is to provide a better selectivity as well as proper and faster reaction through continuous progress in applications and hardware developments fed by the increase of sources and reliability of data. Further development would include other type of data in relation with operation, diagnostic or aging of the system.

Table 1: Papers of Block 1 assigned to the Session

Paper No. Title	MS a.m.	RIF	PS
0107: ABC cables in colour different than black			X
0266: External Conductive Layer on EDP MV Underground Cables Leads to New Oversheath Requirements			X
0272: Design of MV overhead lines to maximise bird safety			X
1108: Sensitivity Analysis of Earthing System Impedance for Single and Multilayered Soil			X
0279: Anti-ice and snow coating for EDP Distribuição's overhead lines			X
0602: An Innovative Power Cable Connection of Property Equivalence and Non-joint			X
0414: Self-healing materials for autonomous cable repair			X
0912: New HVDC Nanocomposite Electrical Insulation for Improved MV and HVAC Performance			X
1066: Using Nanomaterial to Enhance the Performance of Medium Voltage Insulators and Street lights Considering Environmental Impacts			X
0430: The use of high temperature conductors in existing lines: Economic and Environmental benefits			X
0917: High Performance Thermoplastic Cable Insulation Systems		X	X
0114: Parameters of influence on LV cable ageing	X		X
0418: Determining Cables Metrics Using 3D Ultrasonic Scanning			X
0200: Investigations on the Mechanical and Electrical Long-Term Behaviour of HTLS Conductors by Accelerated Ageing Tests			X
0260: Medium Voltage Screened Busbar Ageing Test Method	X		X
0537: Evaluation of Aging Degradation of 6kV CV Cable (Three-layer Co-extruded Structure)	X		X
0598: 10 Years of experience with 3 kHz water tree test			X
1134: Development of long-term reliability evaluation method for polypropylene insulated MV cables	X		X
0893: Long-time evaluation of cable joints in water			X
0826: Experiences with Cable Faults due to Bad Metallic Screen Connections	X		X
0270: Integration challenges of high accuracy LPIT into MV Recloser			X
0049: Offline PD diagnostics using several excitation voltages			X
0056: On Line Monitoring of Medium Voltage Overhead Distribution Lines Polluted Insulators Severity			X
0291: Sensitivity Analysis of Cable Oscillating Wave Test System on Multi-source defects Diagnostics			X
0797: Analysis and Evaluation of Dielectric Parameters and Status of Field Measured MV Cables			X
0813: Field Measurement Results of a Spatially-Resolved Diagnostic Method for Power Cables			X
0532: Investigation on Partial Discharge Frequency Dependence in Cables of Distribution Systems			X
1130: Underground and Overhead Monitoring Systems for MV Distribution Systems	X		X

Block 2: "Research & Development of Network Components – Substations"

The 29 papers of this block have been organized in the following sub-blocks:

- SF6-alternatives & vacuum switching;
- Safety, environment & reliability considerations in the design of network components;
- Testing and numerical simulation methods for development of network components.

SF6-alternatives & vacuum switching (11 papers)

A round table was dedicated to the topic "SF6 substitution: alternative gases" at the previous CIRED conference in 2015: this is still a very active subject, with significant research and development going on to find suitable substitutes to SF6 gas as an insulating and breaking medium for HV and MV switchgear. Several papers from 4 major manufacturers are presenting their investigations and results in this direction. A short reminder first: SF6 has been identified as a potent greenhouse gas (global warming potential, GWP, in the order of 23000) since the Kyoto Protocol, and steps have been taken to limit its release in the atmosphere. It has been banned from all applications where alternative solutions were available and its present use is mainly restricted to the electrical equipment industry, where tightness requirements and end-of-life handling and recycling regulations have been enforced to limit the emissions. With the forthcoming revision of the 2014 European Regulation N° 517/2014 on fluorinated greenhouse gases, it is possible that more restrictions will apply if it is demonstrated that suitable alternatives are available. The use of low GWP natural gases alone, like air, N2 or CO2, is not sufficient to come close to the current SF6 solutions in terms of performance and cost, therefore most of the considered alternatives are based on mixtures of such gases with low GWP (i.e. short lifetime when released in the atmosphere) fluorinated compounds which can enhance the dielectric and interrupting properties to reach a level comparable to SF6.

A good introduction to the topic is given in paper 0819 from Siemens which presents a global approach for evaluating the SF6 alternative proposals with respect to the following criteria: technical performance (arc-quenching and insulation), safety and reliability, long term stability, environmental and health impacts. The overall assessment for 4 alternatives, compared to SF6, is summarized in the graph of Figure 6 below: it can be seen that the current SF6 technology is the best one for all criteria except the environmental impact, that natural gases have reduced performances but nevertheless interesting properties, and that fluorinated mixtures may raise concerns in terms of stability and/or safety, toxicity. The conclusion of this paper is that probably SF6 will have to be substituted by several different technologies, depending on the considered applications (HV or MV, CB, GIS, etc.).

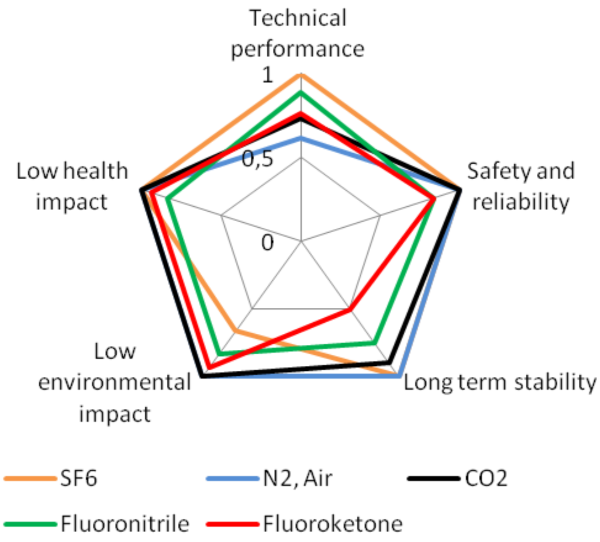

Figure 6 from paper 0819: Holistic comparison of the evaluation criteria for SF6 alternatives under consideration

The next paper 0795 presents the results of investigations performed on the g^3 (green gas for grid) developed jointly by GE Grid Solutions and 3M as a low GWP alternative to SF6 for HV switchgear. The g^3 mixture is made of CO2 with about 5% of Novec™ 4170 (C4F7N fluoronitrile, FN) fluid: with this typical composition for HV application, the GWP per kg is reduced by a factor of about 50 versus SF6, and the dielectric insulation level is about 80% of that of SF6 at same pressure. Interruption tests have been performed in a 145 kV 40 kA live tank circuit-breaker filled with g^3, representing the maximum electrical wear expected during the life of this CB: the decomposition of the g^3 mixture by arcing has been very limited, with about 2.5% of CO being observed as the main decomposition product. The LC50-4 h toxicity of arced g^3 has been tested on mice and found to be quite low, at more than 60000 ppm. It is therefore concluded that handling of arced g^3 mixture can be performed with no more precautions than for the handling of arced SF6.

Paper 0658 reports the first results of a 3 years field experience started in November 2015 on four 20 kV ring main units (RMU) filled with AirPlus™ gas mixture installed in the network of Liander in the Netherlands. AirPlus™ is a low GWP (< 1) alternative to SF6 as an insulating medium developed by ABB: its typical composition for such MV RMU application is 1.3 bar of dry air plus 0.1 bar (total 1.4 bar) of Novec™ 5110 (C5F10O fluoroketone, FK) fluid. The insulating properties of AirPlus™ are sufficient to achieve 24 kV rating in same RMU dimensions as for rating 12 kV filled with dry air (i.e. with an improved dielectric design versus standard SF6 RMU). The C5 FK is not as stable as SF6 gas and may be decomposed when in contact with incompatible materials. Therefore, the primary target of this 3 years field experience is to confirm that materials compatibility issues have been solved satisfactorily: the first results after 1 year in service show that no significant decomposition of the AirPlus™ mixture has occurred, hence give good indication that life expectation similar to that of SF6 RMU can be achieved.

Paper 0389 reports on investigations performed by manufacturer Schneider Electric to validate HFO1234zeE as a low GWP (= 6) alternative to SF6 for MV insulation purpose in GIS. HFO1234zeE is already widely used in the industry (as a propellant for spray, cooling agent for refrigeration systems, foaming agent), it can be used pure (low boiling temperature) and has the advantage over the previously mentioned fluorinated compounds to be less toxic (similar to SF6 in this respect). Its dielectric properties are sufficiently close to those of SF6 to allow keeping the compact dimensions of existing SF6 GIS with careful design. Tests have been performed to confirm its good behaviour in terms of stability, materials compatibility, ageing and internal arc testing. As it cannot be used as an arc-quenching medium it is proposed to use it as an insulating medium in GIS where current interruption is made in vacuum.

This drawback is considered in paper 0614 which reports on experiments performed to evaluate the feasibility of low current interruption (MV switch application) in SF6 alternative mixtures. It is shown that an improved design of puffer switch is able to interrupt mainly active load current at 24 kV 630 A for class E3 (100 interruptions) in a mixture of air and C5 FK. This could be an intermediate approach between the knife type switch (typical of SF6 switches, low cost but insufficient interrupting performance with SF6 alternative mixtures) and vacuum switches to provide a cost effective solution for secondary GIS (RMU) application. Very limited amount of decomposition products of C5 FK have been found in the tank gas after the series of 100 interruptions, probably because most of them have been adsorbed by the bag of molecular sieve used as drying agent.

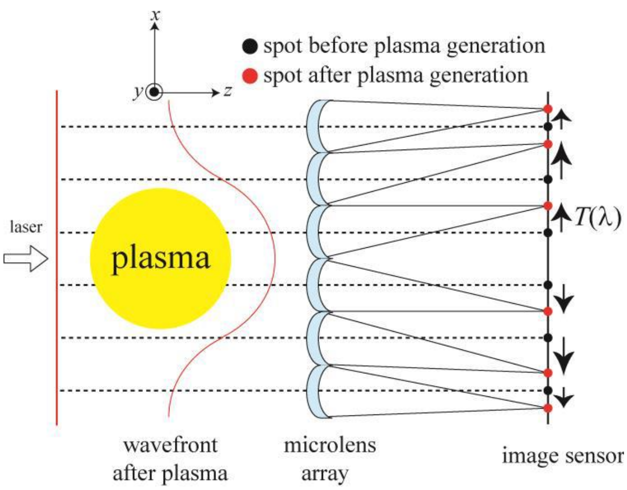

Figure 1 from paper 0604: Shack-Hartmann type laser wavefront sensor

Along the same line paper 0604 illustrates how new imaging techniques can be used to improve the understanding of arc plasma and to compare experimentally the arc quenching properties of different gases. For the first time electrons density visualization by means of Shack-Hartmann type laser wave front sensors (cf. Figure 1 above) has been applied to 50 mm long arc discharges in a nozzle (representative of HV applications) at time of current zero in order to compare the arc behaviour with different gases: air, CO2 and SF6. The superiority of SF6 over air or CO2 is confirmed by these experiments but a better understanding of phenomena will help in developing improved interrupting chambers with alternative gases, such as CO2.

The last two papers on SF6 alternatives are dealing with the safety aspects.

Paper 0230 is focussed on the case of the AirPlus™ gas mixture (air + C5 FK) considered as an alternative to SF6 for MV GIS. It is shown that in the case of normal or accidental leakage of AirPlus™ mixture in a switchgear room, the concentration levels for C5 FK and its decomposition products do not exceed the occupational exposure limits (OEL). In the worst case of an internal arc inside a GIS tank filled with AirPlus™ mixture toxic by-products are released in the switchgear room (which cannot be accessed without protective equipment until fully ventilated) but not much more than with air insulation and significantly less than for SF6 GIS.

Like the previous one, paper 0385 evaluates the safety risks in case of accidental release of SF6 alternative gas in a switchgear room, but with somewhat different conclusions. It explains that it is recommended to determine the LC50-4 h acute toxicity levels for decomposed gas from actual tests on animals instead of gas analyses which may not detect some by-products. The short term exposure limits (TLV-STEL) are estimated, in a preliminary approach, as 30 times lower than the LC50-4 h. It is then possible to define, in the event of accidental leakage, safety perimeters around the leakage point in order not to exceed the STEL. The conclusions are that in case of C4 FN mixture suitable for MV insulation, or C5 FK mixture used for current switching, safety perimeters of 4 to 10 m should be considered around the switchgear, while none is needed for SF6 or HFO1234zeE insulation gases.

The last 3 papers of this sub-block are related to a known alternative of SF6 for a part of its applications: vacuum switching is already the dominant technology for MV circuit-breakers and contactors, but it cannot compete in cost with SF6 for MV switches and physics limits its application to the lower part of the HV range. Finally, vacuum is not a practical insulating medium for volumes exceeding the small dimensions of vacuum interrupters, so air or other gases still need to be used for insulation purposes (putting aside solid insulation that is restricted to fixed parts, and liquid insulation no longer used in switchgear for safety reasons).

Paper 0250 reviews the characteristic values to be used for assessing the interrupting capability of vacuum interrupters: the critical transferred charge (related to the maximum breaking capacity) and the maximum cumulative charge (related to the electrical endurance, i.e. the maximum number of short-circuit interruptions). Knowing these characteristics allows to evaluate the breaking performance of vacuum circuit-breakers in conditions differing from those tested according to the standards (e.g. different time constant or frequency) and for instance to determine the de-rating factors for special applications. An in-depth review of the possible cases of maximum transferred charges for asymmetrical short-circuit currents leads to discussion of the criteria defined by the latest draft amendment of IEC 62271-100 standard regarding the T100a test duty: it is shown that the values specified do not correspond to the maximum possible under worst conditions, even if they are considered sufficient for application in practice.

Paper 0872 addresses the case of application of vacuum circuit-breaker as a generator circuit-breaker, which can now be considered for generators up to 450 MVA, as an alternative to the current SF6 technology. The authors explain that there is no need to be concerned about overvoltages when switching generators with vacuum circuit-breakers, as this duty is different from the switching of motors in the starting phase or in the condition of locked rotor, where overvoltages can occur and surge protection devices may be necessary. In the case of vacuum generator circuit-breaker, which have the ability to interrupt fault currents with very fast rate of rise of recovery voltage (RRRV), it is also not necessary to use surge capacitors on both sides of the circuit-breaker, like for SF6 circuit-breakers which do not have the same capability of dealing with fast RRRV. Still it may be necessary to install capacitors on the transformer side, to protect from overvoltages transferred from HV through the step-up transformer.

Finally, the authors of paper 0229 introduce the physics of DC short-circuit interruption by means of a MV circuit-breaker working on the principle of counter-current pulse injection to create a current zero in the interrupter. Such a concept of MV DC circuit-breaker based on existing single-pole operated MV AC circuit-breaker, completed by auxiliary circuits for current injection and voltage surge protection, is presented in Figure 6 below. It is explained that the most important parameters for designing and dimensioning such a MV DC circuit-breaker are the rate of rise of the DC short-circuit current (can be reduced by limiting inductors) and the operating times and speeds of the circuit-breaker (very fast actuators of the Thomson coil type may be needed to avoid having to use powerful and costly interrupters). The purpose of this paper is to show that a reflexion should be started on the protection concept of MV DC networks, in order to evaluate the related costs and to compare the respective merits of DC and AC links in MV systems.

Figure 6 from paper 0229: Vacuum DC circuit breaker with current injection

Safety, environment & reliability considerations in the design of network components (10 papers)

The first 3 papers of this sub-block explain how environment and safety requirements are taken into account in the development of new MV switchgear.

Paper 0244 presents new features or functionalities which can contribute to improving the safety of MV switchgear. Motorized and remote operation is a way of avoiding the presence of an operator in front of the switchgear: it starts to be considered, not only for switching, but also for the disconnecting and earthing operations. Preventing human mistakes can be achieved by better design of the man-machine interface and interlocks. Finally, remote monitoring or measurements by means of connected sensors can avoid accessing to compartments of live switchgear for routine inspection purposes.

Paper 0220 illustrates some of the new features introduced by the previous paper. It reports on the recent development of a new MV vacuum circuit-breaker and describes the solutions implemented to achieve motorized operation of the racking truck, safe and robust human machine interface and interlocks, as well as motorized earthing switch operation in the cables compartment of the cubicle.

Paper 0372 presents the testing procedures recommended to verify that a MV switchgear is suitable for application in severe environment conditions, which tend to become more frequent with the climate change. Metals' corrosion can be addressed through accelerated ageing tests defined in the applicable standards, which are used to determine suitable protective coatings. Regarding the ageing of insulating materials, it is recommended to perform ageing tests defined in the technical specification IEC/TS 62271-304 which is applicable to indoor enclosed MV switchgear to be used in severe climatic conditions.

The next 3 papers are related to internal arc testing, which is an important safety topic for electrical installations.

Paper 0767 explains how computational fluid dynamics (CFD) simulation can be used effectively to determine the pressure rise in case of internal arc inside E-House enclosures not equipped with overpressure relief devices to the outside, such as for fire rated, ATEX/IECEx, and blast rated applications. The numerical simulation, adjusted on actual tests results, can accurately predict the pressure rise inside the room and evaluate the efficiency of various systems, such as arc-flash protection (to reduce the arc duration) and heat absorbers (to cool the hot gases generated by the arc, cf. Figure 7 below). This allows to select the best suitable technology for E-House construction, in order to meet pressure withstand requirements in case of arc faults, while optimizing weight and cost.

Figure 7 from paper 0767: metal foam absorber, top side

Paper 0371 reports on experiments performed to assess the nature and temperatures of hot gases expelled from the equipment in case of internal arc fault. For this purpose ultra-fast camera recordings have been made, both in the visible and infra-red ranges, at the exhaust of gases and through windows added to the equipment. It appears that first hot air is expelled in the room, then gases generated by the arc are burning and flames are produced, with much more radiating power: these flames represent a larger risk in terms of burning and ignition. Therefore fast arc flash protection, or heat absorbers, are considered to be efficient means of reducing the risk linked to these flames.

In paper 0486 are reported the results of other experiments made to compare internal arc phenomena in enclosures filled with air and SF6 respectively. The purpose of these investigations was to better understand the possibility of performing tests of SF6 GIS filled with air instead of SF6 to reduce the environmental impact. The experiments were done in closed containers with short duration (40 ms) arcs: significant differences have been observed between air and SF6, in terms of amplitude of pressure rise and pressure oscillations. These differences are explained by the respective properties of the two gases: the conclusion is that care should be exercised when SF6 is replaced by air for testing because the results may change significantly.

The last 4 papers in this sub-block provide a variety of examples of new network components and show how the safety, reliability or environmental requirements have been taken into account.

Paper 0212 presents the advantages of the Compact Equipment Assembly for Distribution Substation (CEADS) solution covered by the recently published IEC 62271-212 standard, for integration of the substation in a building intended for other, non-electrical, uses. Similarly to the prefabricated substations covered by the IEC 62271-202 standard, the CEADS approach allows to benefit from a tested design that meets the requirements in terms of safety (internal arc classification and fire resistance), environment (EMF, noise, cooling) and integration of smart functionalities (automation, monitoring, communication, etc.) without having to study and validate its installation in a building on a case by case basis.

Figure 3 from paper 0253: Cabinet compartment in the open position

Paper 0253 describes the development process of a new type of LV distribution cabinet intended for urban areas where the visual impact of current cabinets is considered unacceptable. The new underground cabinet solves this issue while being easy to operate in open position where it stands above the ground like the existing ones (cf. Figure 3 above). A first prototype has been installed successfully and is currently being monitored to confirm the validity of this solution before expanding its application to other locations concerned by the same constraints.

Paper 1069 focuses on the auxiliary relays, components of the protection and control auxiliary circuits of switchgear not often addressed in CIRED papers. The different characteristics required for different applications (like control of tripping coils, signalling, load control, etc.) are explained and indications are given on how to select the proper ranges of relays and configurations (e.g. wiring of contacts in series) for reliable operation.

Finally paper 0475 presents a high-accuracy calibration system developed for transformer loss measurement (TLM) systems. According to the European Ecodesign Directive 2009/125/EC and the Regulation N° 548/2014 for its application to power transformers, the total losses of transformers should comply with the maximum requirements of Tier 1 since July 2015, and the TLM system used for measuring them should have an accuracy better than 5%. Periodical calibrations (every 2 years is recommended) with a high-accuracy system are therefore necessary to ensure that this requirement is met.

Testing and numerical simulation methods for development of network components (8 papers)

The first 3 papers in this sub-block deal with testing of components.

Paper 0943 proposes a methodology for defining the testing specification and performing the validation tests of innovative network components for which standards are not yet available, on the basis of the experience gained in testing different types of 11 kV Fault Current Limiting devices (FCL) in the frame of the FlexDGrid project.

Paper 0138 describes the new testing laboratory UDEX, connected to the High Power Laboratory (HPL, cf. Figure 1 below) of manufacturer Ormazabal, which allows to perform combined testing beyond the requirements of standards for type tests, in order to check the influence of ageing on performances and simulate the real life behaviour of the switchgear.

Figure 1 from paper 0138: Photo of HPL installation

Paper 1100 presents the new Power Hardware-In-the-Loop (PHIL) test bench developed at Fraunhofer IWES SysTec in order to perform power systems studies related to the integration of new types of equipment in the system. Two examples are given showing how the interaction between power systems (simulated by real-time computation) and power electronics hardware (windfarm converter) can be investigated depending on the algorithms implemented in the hardware controller: the conditions for power system stability can be explored (cf. Figure 6 below), thus helping in the growing integration of renewable energy sources in the network. However, it is also shown that careful adaptations of the test conditions are necessary in order to provide valid conclusions and realistic scenarios investigations.

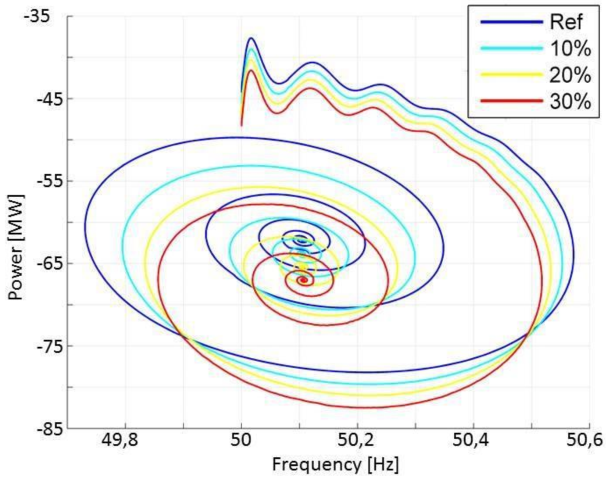

Figure 6 from paper 1100: Power over frequency curves

The next 3 papers are related to thermal simulation.

Paper 0345 presents the results of thermal CFD simulation performed to evaluate the impact of the height position of heat sources in a closed envelope on the temperature rise of the air contained in the enclosure. The considered geometry was that of a MV RMU, where the main heat sources are located in the upper part of the tank. The simulations have shown that the temperature rise profile inside the tank would be significantly more favourable if the heat sources were located in the lower part. It has been shown also that the empirical method defined in IEC/TR 60890 for calculating the temperature rise in a LV switchgear enclosure was not applicable to MV switchgear enclosure where the location of heat sources is not evenly distributed in the volume.

In the wake of 0345, paper 0349 reports complementary work focussing on the heat transfer coefficient between a RMU load-break switch (LBS) and the surrounding air inside the tank. Experiments have shown that convection is the main component of heat transfer but nevertheless the contribution of radiation could be significant (from 20 to 40% of the total power dissipated, depending on the emissivity coefficient). The total heat transfer coefficient can be used in a first approach to estimate the temperature rises of LBS contacts for different designs considered when attempting to keep good thermal dissipation inside compact enclosures filled with gases not as thermally efficient as SF6.

Paper 0091 uses a simplified thermal model of oil transformer (based on IEC 60076-7) and compact secondary substations to compare the behaviours with three types of enclosure materials: steel, concrete and double-layer glassfibre reinforced polyester (GRP). It is shown that this material, thanks to lower thermal conductivity and specific heat, provides some advantages in terms of temperature and therefore ageing of the transformer.

The last 2 papers of this sub-block deal respectively with mechanical and electromagnetic simulation.

Paper 0852 reports numerical simulation and experimental work performed to evaluate the mechanical stress caused on outer-cone type bushings of MV GIS by the thermal expansion of the connected cables (due to changes in the load current, or short-time fault current). It is shown that in normal conditions of cable clamping, according to the manufacturer's instructions, the forces induced by the cable conductor thermal expansion are well below those generated by the electrodynamic forces in case of short-circuit, which are successfully withstood by the bushings during type tests.

Finally paper 1268 illustrates how the advances in 3D electromagnetic and thermal numerical simulation and modelling have allowed to reconsider the design of the 100 MVA power transformers of Enedis substations, in order to increase the short-circuit impedance of these transformers while managing the impact of increased leakage fluxes on losses and thermal behaviour. These new 100 MVA transformers can be directly connected to the standard 500 MVA short-circuit rating MV switchgear used by Enedis without requiring the use of additional limiting reactors: for instance they can be used to easily upgrade primary substations by replacing 70 MVA transformers.

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS a.m.	RIF	PS
0819: Holistic evaluation of the performance of today's SF6 alternatives proposals	X		X
0795: Characteristics of g^3 - An alternative to SF6	X		X
0658: RMU with Eco-Efficient Gas Mixtures: Field Experience			X
0389: Application of HFO1234zeE in MV switchgear as SF6 alternative gas			X
0614: Low Current Interruption in SF6-alternatives			X
0604: Comparative Study on Arc Extinction Process under Air, CO2 and SF6 Gas Blasting Using Two-Dimensional Electron Density Imaging Sensor		X	X
0230: Environmental and Safety Aspects of AirPlus Insulated GIS	X		X
0385: Hazard study of MV switchgear with SF6 alternative gas in electrical room	X		X
0250: Transferred Charge - Indicator for Vacuum Applicability	X		X
0872: Difference between Switching of Motors & Generators with Vacuum technology			X
0229: DC Vacuum Circuit Breaker	X		X
0244: Safety Features in the Design of MV Circuit-breakers and Switchboards			X
0220: Mastering all sub-assemblies of an MV Circuit-Breaker and Racking Truck System ensures Reliability and Robustness			X
0372: Extreme Weather Has Become The Norm- Is Your MV Switchgear Ready For It?			X
0767: Mitigate Arc Effects within an E-House			X
0371: Mitigate gas Combustion in case of Internal Arc			X
0486: Pressure Oscillation due to Arcs in a Closed Container Filled with Air and SF6			X
0212: New HV/LV Transformer Substation within a building intended for other non-electrical uses with advanced functionalities			X
0253: Innovative Underground Distribution Cabinet For Low Voltage Network			X
1069: How to Select Auxiliary Relays for different Isolation Applications			X
0475: Meeting Ecodesign Efficiency Requirements: Ensuring Accuracy in Power Transformer Loss Tests via TLM System Calibrations			X
0943: Developing Testing Procedures for High Voltage Innovation Technologies			X
0138: Proven Reliability Beyond the Standards		X	X
1100: Power Hardware-in-the-Loop Setup for Power System Stability Analyses		X	X
0345: Influence of Heat Source Location on the Air Temperatures in Sealed MV Switchgear			X
0349: Estimating the Temperature Rise of Load-Break Switch Contacts in Enclosed MV Switchgear			X
0091: Comparative Advantage of Using GRP in Compact Substations			X
0852: Stress on Outer Cone Cable Connection of MV Gas Insulated Switchgear due to Cable Thermal Expansion at Rated Current			X
1268: A high short-circuit impedance power transformer versus short-circuit limiting reactance			X

Block 3: “Management and architecture evolution of the installed base of Network Components – Cables & their environment”

The block 3 is composed of 31papers and subdivided in 3 sub-blocks:

- Smart Grids solutions and applications in smart metering;
- Applications of methods and tools to asset management of cables and distribution lines;
- Enabling solutions and methods for the integration of renewable energy generation.

Smart Grids solutions and applications in smart metering (11 papers)

The continuous development and integration of sensors (137, 226, 709, 882), electronics devices (226, 709) and communications (391, 933) generates more and more accurate and reliable data that can be used as support for decision or even to trigger automatically some local actions. These actions are aiming at using the assets at their full potential (110, 715 and 820).

Paper 137 is presenting a wireless phasor measurement unit that could be widely installed over large networks and give accurate basic information that could be collected for operation or asset management.

Paper 226 is presenting an intelligent fault sensor able to send information directly to SCADA and not only indicating lightning occurrence on the pole. The new set of information comprises momentary fault, permanent fault, shutdown/outage, power disturbance and capacitor bank switching and even discards reclosers’ operations during a reinstatement. Benefit can reach 50% on reaction time and 10% in reduction in outage.

Paper 110 is presenting a work package of the project “Flexible Urban Network LV” (UK Power Network). The system based on power electronics allows using free capacity of neighbouring substation when maximal output of the local substation is reached. The power flow is depending on network impedance. Other functions related to power quality could be carried out in the future.

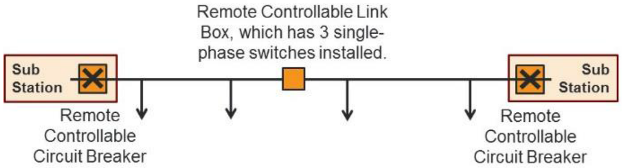

Figure 1 of paper 0110: Schematic of a FUN-LV installation

Paper 709 is proposing the replacement of usual current transformer in switch gear by an association of basic sensors and power electronics. The evolution is enabled by recent evolution of standard on communication chain (IEC 61850).

In order to keep a high level of rating accuracy, Paper 715 is showing the different elements starting by an accurate cable modelling associated with a real time environmental data and precise network and components mapping. The concept allows to detect abnormal external conditions (heat sources) by comparing prediction from load measurement and calculation of conductor temperature from external temperature (see figure below).

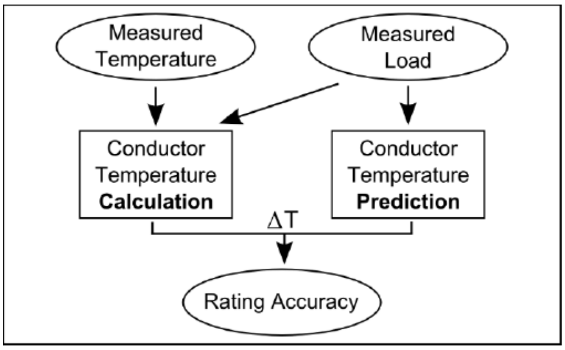

Figure 2 of paper 0715: Rating accuracy concept

Paper 820 is presenting a comparison of IEC standard and FEM simulation for a MV cable road crossing. The calculation has been validated by measurement on a full scale artificial model. IEC equations can still be used but with a corrected soil resistivity to take in account cable position in pipe or presence of inhomogeneous backfill materials layer.

Paper 882 is proposing a standard covering the association of MV connectors with low power current transformer (Rogowski coil). Standards exist for both components but their coordination raises new issues treated by this paper.

Paper 391 is addressing the compatibility of the G3 PLC equipment designed for 400 V for 3 phases 230 V circuit. The study shows that this 3 wires configuration improves the data transfer length only when the density of other PLC equipment is low.

Paper 933 is presenting a broadband network privately owned and operated by DNO/DSO. The network backbone is expended thanks to PLC and capacitive coupling using cable and lines to connect and control devices throughout the MV energy network.

The question of LVDC network is regularly raised as more and more equipment could be supplied in DC and some type of generation can happen in DC (PV, battery…). The paper 0519 gives an answer by investigating the conditions for the deployment of a bipolar LVDC network +/- 750 V with possible issues and proposals to build a safe and reliable network. An in-depth analysis is carried out on the need for new components (conversions AC/DC, DC/AC or DC-DC) and the compatibility with existing component (protection, cables). The increased presence of power electronics is enabling on one hand smarter network but on the other hand may lead to some issues with short circuit protection and Electromagnetic Emission for high power system. Paper

1215 is presenting the result of a survey of the IEC System Evaluation Group 4 on potential stakeholders and market of LVDC network. There is a feeling of urge to develop standardization but very few LVDC components are proposed and this lack of maturity hinders standardization progress.

Applications of methods and tools to asset management of cables and distribution lines (13 papers)

Continuous improvement of asset management can be achieved by reducing the main causes of failure by appropriate recommendations or routes in particular regarding accessories (417, 737, 1104).

Paper 417 is giving recommendation to evaluate and optimize mountability of accessories in order to insure long term reliable accessories. The joints and cable are the weak point of underground cable and major source of fault due to bad installation or ill adapted designs for easy installation.

In order to decrease the number of joints to increase global reliability Paper 737 is presenting a way to manage installation of cable length up to 3 km. The study is addressing all the aspect from the drum to the screen voltage drop and concludes on the feasibility of this solution. For the French market the savings may be from 142 M€ to 285 M€ by using long length cables on a period of 15 years.

Paper 1104 is focused on the quality of installation and commissioning to insure long term reliability of cable systems. The accumulation of PD diagnostic data, root causes analysis and post mortem studies (has resulted in proposal by DSO and service providers of new cost effective quality insurance procedures, for example by requiring photos during installation to ensure respect of rules.

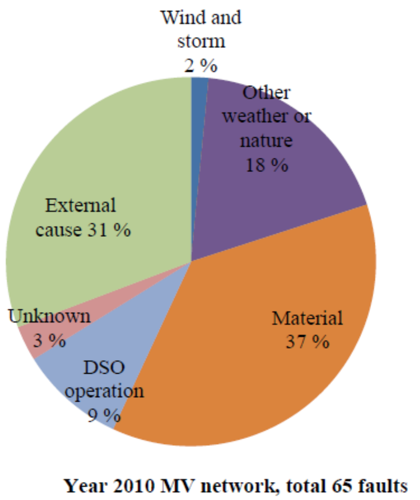

Figure 2 of paper 1104: MV network faults in Helsinki year 2010

Predictive maintenance consists in analysis of array of interrelated data coming from service failure (134), measurement, design, characteristics and history assets themselves (328). When a good quality of the data is obtained the approach prove to be cost effective (895). Another aspect of asset management is the quality of field operations that can be improved thanks to augmented reality (413) and interactive maps (681). For some type of maintenance and watch operations robots and drones can be useful. The development of such autonomous agents requires that all the parties are involved with a very precise load chart (479) and in case of exchanges of large amount of data the reliability of communication system (835, 1048) and real time data treatment (1193) is key.

Paper 134 describes a condition based maintenance based on diagnostics method using oscillating voltage coupled with PD detection for cable systems and for switchgear PD and ultrasonic detection are used. Each time an event occurs the predictive maintenance parameters of each equipment are updated. Higher level of efficiency is expected by the building of a database associated with real time decision through automated systems.

Paper 0328 is dealing with the way to condition the data coming from network to be useful for asset management. Different levels of maturity are presented; from the establishment of links between failure data and components population to the ability to connect failure modes to detailed design of assets groups. A practical case has been applied to MV cables (PILC and XLPE). Several bottlenecks in the data management have been identified and a first solution has been to introduce the operational stress date and the diagnostic data in order to develop a decision support tools to trigger preventive replacements.

The safe cable guard is a monitoring system to help to localize a fault with 1% accuracy and to reduce the time to repair. Paper 546 shows that it is also possible to use such monitoring system to identify first sign of degradation. The degradation is creating intermittent fault too weak to trigger the protection system but sufficient to identify the network components about to fail and to plan the replacement.

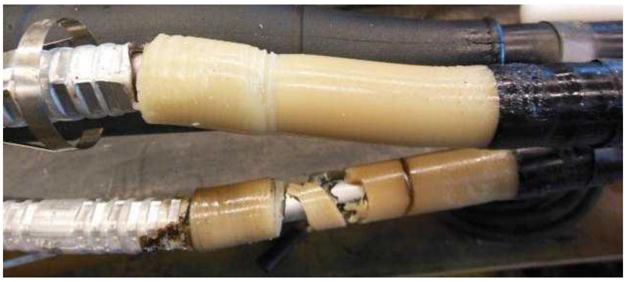

Figure 4 of paper 0546: Joint after dismantling. The joint has been replaced before the failure due to defective connector overheating and subsequent XLPE fast ageing and crack

Paper 895 shows the continuous improvement of network reliability linked to the establishment of more and more consistent data on components and links between service failure and the assets concerned. The scope of data is covering the cable, the connection box, the cable end and civil works.

Paper 413 is proposing solutions based on augmented reality for maintenance of equipment and network operation in order to assist field technicians in their missions. Recent developments allow to connect the field of operations with remote experts or central data systems through a smartphone connection to provide an interactive guidance for different situations, or to support field technicians' maintenance tasks with artificial intelligence software for equipment recognition and safety instruction. A first Proof of concept in 2015 was aiming at localizing existing underground cables using GPS and superposition of existing data/map with reality using glasses (see Figure 8 below). Next steps of development are an improvement of the GPS cable positioning, a better management of changing field conditions (light) and an interface optimized for business performances.

Figure 8 of paper 413: Technician equipped with augmented-reality glasses.

The expected benefit can be summarized in an increased reactivity to solve field operations through faster preparation, no limitation due to documentation access (procedures, equipment's characteristics, maps) and possibility to contact experts.

Paper 681 is presenting a complete system of network monitoring based on real time network parameters adjustment and algorithm able to be selective in the identification of the origin of fault. The fault location can be directly visualized on a city map and has proven improvement of time to repair in dense urban areas.

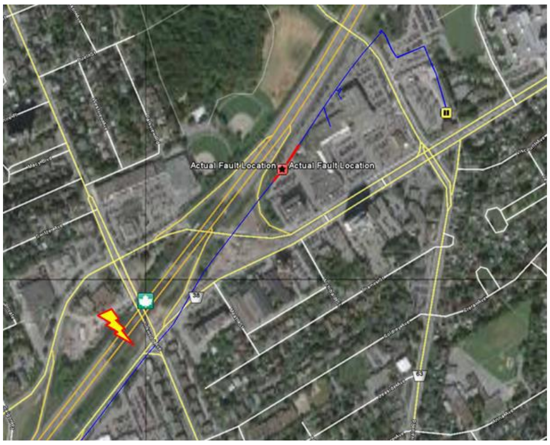

Figure 6 of paper 681: Example One-Line Diagram Showing Estimated Fault Locations and Actual Location Displayed with Aerial Map Data

Paper 479 is dealing with robotized solutions for easier maintenance of street light comprising the lamp cleaning and pole painting. The robots should be portable and able to work in urban or rural environment with temperature above 0°C up to 40°C in direct sunlight. The article is following all the steps of development of cleaner and painter robots.

In Paper 835, the large deployment of different group of satellites is presented as an opportunity to improve assets' monitoring and diagnostic. The European Spatial Agency has identified different functions like SCADA, GPS, telecom (drones, remote areas) or detection of external factors that can be directly or indirectly supported or brought by satellite-based sensors or antenna systems.

Paper 1048 is presenting the management system of a drones 'fleet for inspection of overhead lines. The system load chart has been validated by all the parties and a simulation has shown the feasibility and the viability of communication system especially in the management of large quantities of data from cameras.

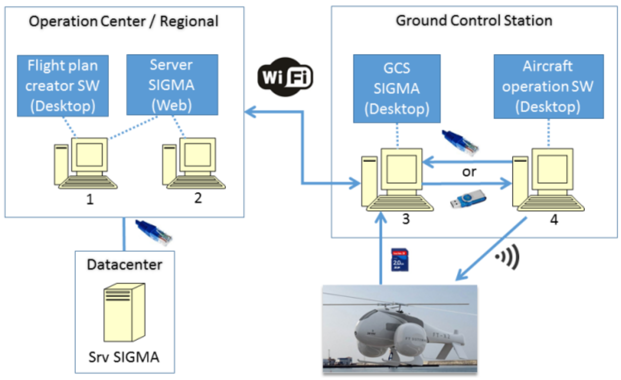

Figure 3 of paper 1048: Communication Infrastructure Overview for OHL drones

Paper 1193 is describing the first test of the key system elements presented in Paper 1048. One of the challenges is the recognition of network components like tower, suspension and insulator. The recognition level is globally satisfactory to go ahead and deploy further the concept. The detection of insulator is still to be improved in the future.

Enabling solutions and methods for the integration of renewable energy generation (7 papers)

A first set of paper (4, 207, 348 and 832) are dealing with integration of intermittent renewable and the mitigation of power or voltage fluctuations due to natural conditions changes. These fluctuations start to be a problem when exceeding certain limit set by regulation.

Paper 004, 348 and 832 are proposing on-load tape changers. In Paper 004 a 3 phases booster transformer is associated with a control unit to keep the voltage in acceptable range by dynamic tape changing. The system has been optimized to be compact, with low losses and passing standard tests.

In Paper 348 and 832 the advantage of the use of voltage regulation transformers is presented as a possibility to spread and even replace standard transformer in a grid with intermittent, distributed and remote generation.

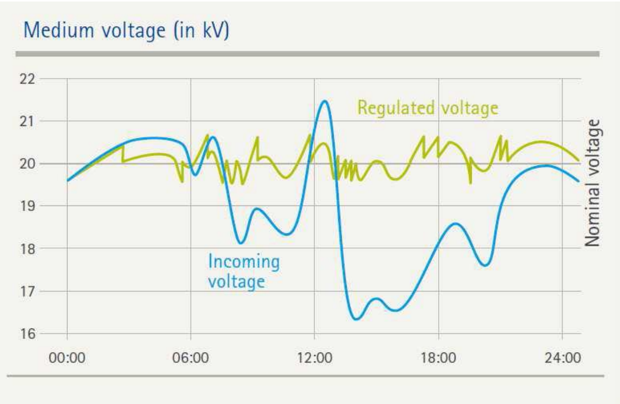

Figure 4 of paper 0348: Incoming and regulated voltage

Paper 207 proposes the use of magnetic component in saturated state to set a non-linear response above a voltage which is adjusted thanks to a controlled excitation current on the inductor. A numerical modelling has been developed to improve the dynamic behaviour and to anticipate adverse impact on the power quality.

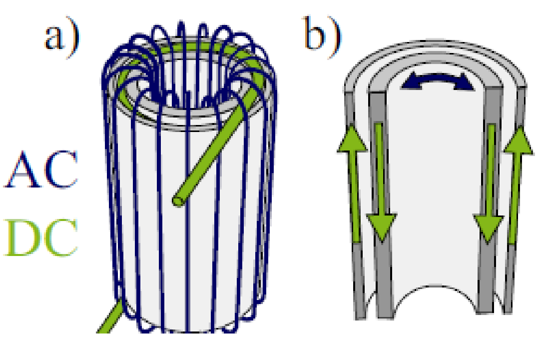

Figure 3 of paper 0207: a) Setup of the MCI - b) Magnetic Flux in the Iron Core

Paper 86 is presenting a new type of power router able to control several power supplies, in particular clean energy generation, and to allocate the electrical energy thanks to strong communication equipment. This power router is based on a central DC bus fed by a three phase inverter able to act as voltage or current source. If the grid is fault a island mode is automatically set if the voltage source is present (PV, battery…).

Paper 922 is pointing out that cable rating standard based on daily LLF (Loss Load Factor) are adapted for demand driven (IEC6287) but no for generation driven situation. The evaluation of the representative load cycle requires the analysis of at least one year of operation. A case of wind farm has been studied and show rating enhancement of 25% compared to IEC6287.

Paper 941 is presenting a flexible power link based on a AC/DC/AC architecture. This system is able to balance power flow and to compensate voltage drop between separated grids or systems.

Table 3: Papers of Block 3 assigned to the Session

Paper No. Title	MS p.m..	RIF	PS
0137: An Novel Micro PMU for Distribution Power Lines			X
0226: Fault Sensors			X
0110: Field Trial Results of Power Electronics in LV Distribution Networks			X
0709: Sensor Technology in a Medium Voltage Switchgear for the US Market Applications			X
0715: Continuous Safeguarding of Rating Accuracy	X		X
0820: Full-scale Case study of Thermal Bottlenecks in Buried MV Cable Installation			X
0882: Low-power voltage transformers for use with cable connectors in MV secondary Gas Insulated Switchgear - new challenge for standardization	X		X
0391: Compatibility of a G3PLC telecom solution on a three phase 230 V network			X
0933: Complete MV-BPL Communications Solution for Large AMI and Grid Automation Deployments			X
0519: LVDC RULES - Technical Specifications for Public LVDC Distribution Network	X		X
1215: Survey of Market Prospects and Standardisation Development Needs of LVDC Technology			X
0417: Evaluation of the mountability of the Medium Voltage accessories	X		X
0737: Improve the Reliability of MV Underground Links by Using Long Cable			X
1104: Improving reliability by focusing on the quality and condition of medium voltage cables and cable accessories			X
0134: Research and Application of 10kV Distribution Equipment Testing New Technology in Condition-based Maintenance			X
0328: Managing the Maturity of Decision-support Data for Extending Lives of MV Cables			X
0546: Accurate on-line Fault Location and PD Activity Location Results Obtained with SCG - A Long Term Utility Experience	X		X
0895: Analysis of failure in power cables for preventing power outage in Alexandria electricity distribution company			X
0413: Contribution of Augmented Reality to the maintenance of network equipment			X
0681: Using Smart Grid Sensors and Advanced Software Applications as an Asset Management Tool at Hydro Ottawa	X		X
0479: Maintenance of Street Lights by Climbing Robots in Alborz Electric Power Distribution Company			X
0835: Opportunities to Use Satellite Technologies for Asset Condition Monitoring of Power Networks Under the European Space Agency's Integrated Applications Promotion (IAP) Programme			X
1048: Information and Communication Architecture for Transmission Power Lines Inspection using Unmanned Aircraft System			X
1193: Analysis of the Recognition, Localization and Evaluation techniques of Power Transmission Lines Components in Aerial Images Acquired by Drones			X
0004: Introducing the new product line of regulated distribution transformer Cooperation of Siemens AG and A. Eberle GmbH & Co. KG.			X
0348: Beyond Grid Integration of Renewables - Voltage Regulation Distribution Transformers (VRDT) in Public Grids, at Industrial Sites, and as Part of Generation Units			X
0832: A new Smart Distribution Transformer with OLTC for Low Carbon Technologies integration			X
0207: Line Voltage Regulator Based on Magnetic-Controlled Inductors for the Low Voltage Grid			X
0086: Power Router based on Conventional three phase bridge Inverter and DC-DC Converter			X
0922: Cyclic Rating of Wind Farm Cable Connections			X
0941: Steady-state Modelling for the Integration of a Bi-directional AC-DC-AC Flexible Power Link			X

Block 4: "Solutions for managing the installed base of Network Components – Substations"

The 38 papers of this block have been organized in the following sub-blocks:

- Condition assessment, ageing behaviour and maintenance strategy;
- Monitoring solutions for asset management and operation of Network Components;
- Diagnosis tools and methods.

Condition assessment, ageing behaviour and maintenance strategy (15 papers)

The first 5 papers in this sub-block are centred on the topics of condition assessment and risk-based maintenance.

Paper 0445 presents the solution proposed by a MV switchgear manufacturer for the asset management of primary substations: it provides also a good introduction to the different concepts used for a risk-based maintenance strategy. The method is based on condition assessment (collection of relevant data, processed by analytics to determine the health index HI), criticality assessment ("cost of failure", expressed as importance level IL, which depends not only on the function of the component in the system but also on its position in the product life cycle) and risk assessment (mapping by HI and IL). Finally, mitigation actions are proposed by the software tool to reduce the risks, for instance maintenance actions or retrofit/upgrade of some components.

Paper 0774 also explains the principle and advantages of risk-based maintenance strategy over plain condition-based maintenance. Taking into account both the importance of a distribution substation in the network (loss of energy in case of failure) and its condition is more efficient in terms of total costs and loss of energy. Statistical and simulation methods that can be used to compare different maintenance strategies are presented. It is shown that various characteristics of substations, other than the simple transformer rating, can be used to provide better indication of their importance, and more efficient maintenance strategy.

Paper 1174 discusses the challenges of using a health index as a unique indicator of the condition of network components. These challenges are related to the data acquisition, the definition and calculation of the index, and finally its interpretation. An example based on a population of power transmission transformers is given to show that careful selection of the data and calculation of the index are necessary to avoid misleading interpretation.

In the wake of papers 0472 and 0217 presented at the previous CIRED 2015 conference, paper 1001 explains why visual inspection and measurements must be combined in order to achieve condition assessment of assets with a reduced uncertainty. Some suitable measurement methods applicable to MV or LV components are described: PD detection by acoustic or transient earth voltage devices, earth-loop testing and thermal imaging. These methods have significant uncertainty, but they are economical to perform and, combined with visual inspections, they provide sufficient data for a reliable condition assessment of the components.

Finally, paper 0149 presents a method for evaluating the ageing and failure rate curves for network components whose population is too small to rely only on statistical treatment of the data. This method has been applied to 50 kV HV circuit-breakers of the Dutch DNO Alliander: it could also in the future be applied to other components like power transformers, which also have a limited population. For establishing the ageing models of the different categories of sub-components (cf. Figure 1 below), consideration of the physical principles of operation is used to determine condition indicators, based on inspection measurements, that scale for an individual circuit-breaker the failure curve derived from statistics. Combining physics and statistics has shown to be an efficient approach for ranking components according to the condition, when large sets of data are not available to allow using statistics only.

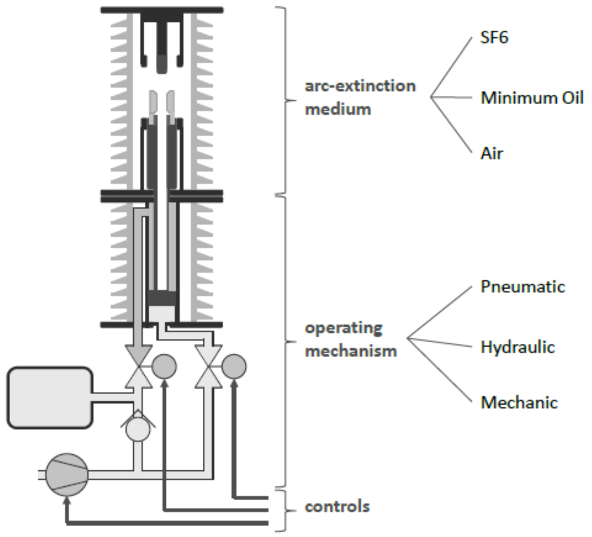

Figure 1 from paper 0149: Circuit breaker subcomponents and categories

The next 3 papers are dealing with the ageing behaviour of some network components.

Paper 0665 reports on measurement campaigns performed in primary and secondary distribution substations, in Belgium, to assess the actual service conditions of MV switchgear in terms of temperature, relative humidity and pollution level (dust deposit). It is shown that in most cases the service conditions could be considered as normal according to the IEC 62271-1 standard: however, the behaviour of air insulated switchgear (AIS, cf. Figure 4 below) is not always satisfactory in areas of high electric field, notably when the relative humidity is larger than 60%.

Based on the field experience it is considered that successful testing according to level 2 of IEC 62271-304 is a minimum requirement to expect a 30 years service life in typical secondary substations service conditions.

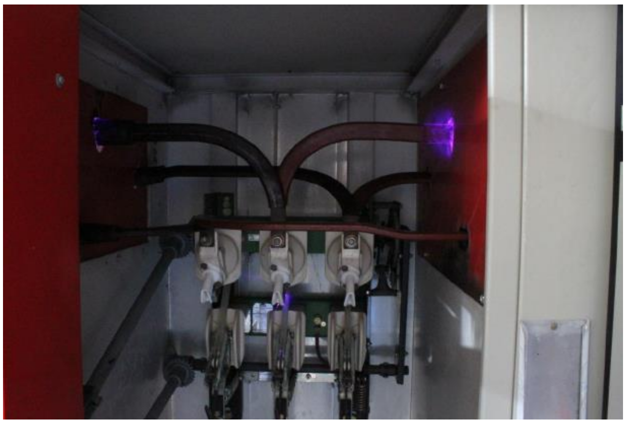

Figure 4 from paper 0665: AIS equipped with switches and a busbar in ambient air – Corona effect around the busbar going through the insulating plate and on the insulating rod of the switch

Paper 0206 reports about the inspections carried out on damaged pole-mounted sectionalizing switchgear which are widely used in the overhead lines distribution network of Kansai Electric Power in Japan (170000 units installed, 30 failures per year due to excessive ageing). It has been found that about 2/3rd of the defects found in units removed from service are due to various types of corrosion of the tank (coated iron and aluminium are the main materials used). In a first step the learnings from these investigations have allowed to improve the specification of current switchgear (use of stainless steel tank, and some structure changes). In a second step it is expected that it will be possible to establish a residual lifetime prediction method based on precise assessment of the rust condition.

Paper 0703 presents application of systematic Failure and Root Cause Analysis (FRCA) to investigate early oil leakage failures in the mechanism of HV GIS circuit-breakers. Although classified as minor, these failures are a real nuisance to users and represent significant repair costs. The application of FRCA methodology has been efficient in fully understanding the causes of failures and in determining the corrective and preventive actions that allow to restore the quality and the reliability of the product.

The next 4 papers of this sub-block are discussing the matter of life extension and retrofit of components.

In paper 0846, SP Energy Networks presents its life extension strategy for legacy assets. About 50% of the 11 kV circuit-breakers in SP Energy Networks are more than 35 years old, and so have exceeded their expected life duration. In the majority of cases it appears that a life extension strategy (by refurbishing the fixed portion, if its condition can be improved to mid-life equivalent, and retrofitting the moving portion by a vacuum circuit-breaker) is a better option than complete replacement: more economical, less network disruption, sufficient to extend the life expectancy by 20 years.

Paper 0796 presents different retrofit solutions to modernize aged MV switchgear and improve the safety of operators. This is achieved by providing means for motorized racking-in/out of the circuit-breaker with closed door, a significant improvement over the manual racking with open door that is the normal way with old switchgear (cf. Figure 1 below). This solution is available for the 2 types of retrofit that can be proposed by this manufacturer: Roll-in Replacement (where the new circuit-breaker keeps the same interface with the cubicle as the old one) and Retrofill (where a new circuit-breaker and associated cradle is inserted in the circuit-breaker compartment of the old switchgear). Retrofill offers better safety features and is more easily applicable to switchgear of different manufacturers, without needing accurate knowledge of the interface design, when enough space is available.

Figure 1 from paper 0796: Open-door circuit breaker racking-in operation

Another type of “retrofilling” is discussed in paper 0989, which reports the investigations made to monitor the evolution in insulation performance of several large size mineral oil distribution transformers which have been drained and refilled in 2015 with natural ester fluid after 12 to 15 years in service. The analyses performed on samples taken regularly since the retrofilling operation confirm the expected increase of moisture content in the natural ester fluid (drying effect of paper due to the hygroscopic quality of natural esters) without any adverse effect on the breakdown voltage and the overall good behaviour of the new insulation system. These results confirm the feasibility of retrofilling with natural esters as a technically and financially viable solution for enhancing the loading capacity of distribution transformers and extending their operation life.

Pursuing along the line of natural esters, paper 1078 presents the results of the assessment of a prototype compact distribution transformer which has been removed from service after 12 years of operation at the high average loading of 82 kVA (for a rating of 88 kVA) for teardown, inspection and analyses of materials. This compact transformer was built with conventional kraft paper insulation and filled with high temperature natural ester fluid. The results of inspection and tests show that this unit, removed at mid-life after severe loading, was still in excellent condition (cf. Figure 4 below) and confirmed a life expectation of more than 25 years, thanks to the properties of natural ester insulating liquids, which protect the paper insulation and allow it to withstand higher temperatures than with mineral oil insulation.

Figure 4 from paper 1078: Core and coil assembly immediately after untanking

The last 3 papers in this sub-block give miscellaneous examples of maintenance or operation strategies for different components.

Paper 1308 presents the asset management lifecycle strategy which has been defined by TNB in Malaysia to reduce the impact of failures due to on-load tap changers (OLTC) of power transformers. The analysis of failures occurring in the oil switch type OLTC used by TNB has shown that the main causes of failures were the degradation/carbonisation of oil and the coking of contacts due to the switching arcs in oil. For this reason, it has been decided, for the new transformers to be installed by TNB, to change the specification and use vacuum switch type OLTC (and maintenance-free self-dehydrating breather). A total lifecycle cost assessment has shown that savings in maintenance and operation costs were larger than the initial extra-cost of these equipment. For the installed base, fitted with the oil switch type OLTC, the strategy has been to implement a condition-based maintenance based on oil quality and dissolved gas analyses. These diagnosis methods have been found efficient to properly assess the health condition of OLTC and to plan timely preventive maintenance in order to avoid failures. These strategies have been tested in the field before being successfully adopted by TNB since 2011.

In the wake of several papers previously presented in CIRED conferences on the topic of maintenance of power transformers, paper 0042 reports on the experience gained and lessons learned from a major in-field repair operation performed on a 40 years old 300 MVA transformer. Thanks to the expertise of the in-house maintenance personnel, to the proper assessment of the failure and of the feasibility of in-site repair, and to the existence of pre-established procedures in case of emergency situation, it has been possible to perform in the short period of one month a full repair and upgrade of the damaged transformer, saving time and transportation costs with comparison to the factory repair option. The solutions implemented to protect the windings from contamination by ambient moisture and to perform verification overvoltage tests with the means locally available at the substation are presented and explained in the paper.

Finally paper 0698 presents the first multi-purpose mobile battery energy storage developed by MEEDC in Iran. This mobile unit uses lead-acid batteries and has a capacity of 40 kVAh and can be used to replace diesel generators for supplying power during planned outages, avoiding the drawbacks of noise, environment impact, cost and fire risks. The power converter is able to control the voltage and frequency of an islanded grid and resynchronize it to the grid when power is restored for seamless reconnection.

Monitoring solutions for asset management and operation of Network Components (16 papers)

The first 6 papers of this sub-block are focussed on the monitoring for asset management of MV switchgear.

Paper 0952 presents the strategy of SP Energy Networks, based on its past experience in power quality (PQ) monitoring, which has launched a large scale deployment of 700 PQ and asset monitors in its primary substations which will provide useful data for improving the performance of the network and reducing downtimes. In addition to PQ information these monitors allow to check the condition of circuit-breakers and station battery, give an indication of fault distance for faster repair and, in the future, will also provide PD and fault level monitoring. A particular attention is given to the handling of data, which will be done within the network “cell” concept, in order to keep it simple and effective, in spite of the amount of data available.

In the wake of the previous one, paper 0263 specifically focus on the way condition monitoring of circuit-breakers can be performed thanks to the new substation monitors deployed by SP Energy Networks. The collected data related to the operation of MV circuit-breakers are: the operating times (through auxiliary contacts), the release currents (trip and close), the battery voltage, the phase currents. All operations are recorded and a report is emailed: remote control can be used to check the condition of a circuit-breaker without intervention on site. Examples are given to show how characteristics of each operation, as well as trends, provide meaningful information allowing to detect and prevent circuit-breaker faults.

Paper 0415 presents the on-line monitoring solution proposed by manufacturer ABB for MV circuit-breakers and switchgear. This solution is modular and scalable in order to adapt to the different cases of installation: it covers mechanical, insulation, thermal and interrupting wear aspects of the behaviour of the equipment. Data collected by the monitoring system are processed by diagnosis algorithms (cf. Figure 8 below) to provide usable indicators (health indexes) of the equipment condition. Thanks to its flexibility, this solution can be applied to both green fields and brown fields.

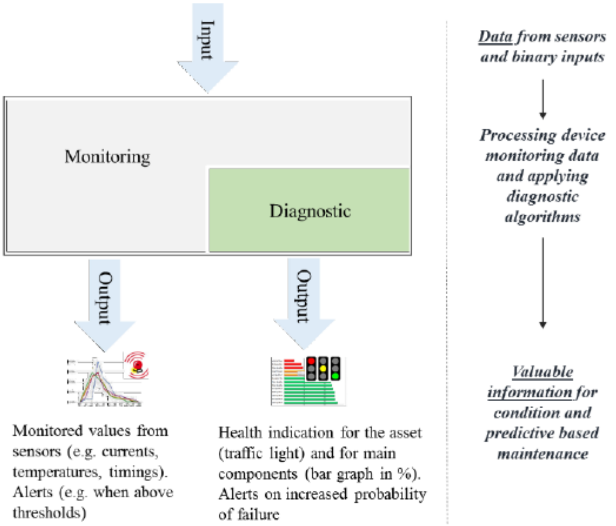

Figure 8 from paper 0415: Data flow, from monitoring data to diagnosed information

Paper 0322 discusses the main factors of severe environment conditions for MV switchgear (temperature, humidity/condensation, pollution/corrosion) and reviews the applicable standards that can be used to specify the environment conditions of MV switchgear. In order to increase the lifetime of MV switchgear exposed to severe conditions, it is necessary to work on the design of the switchgear, on the installation, but also to implement environment and thermal monitoring with e.g. wireless sensors, and analytics to decide when it is necessary to perform maintenance or implement corrective actions.

Paper 0752 presents a new HV circuit-breaker monitoring Intelligent Electronic Device (IED) which is independent from the circuit-breaker or protection relay manufacturers. In a first step it is able to monitor the number of operations and the value of interrupted currents in order to provide an estimate of the contacts wear and of the condition of the circuit-breaker with respect to its expected electrical endurance life (as provided by the manufacturer's data). The IED has communication ability in order to transmit measurements to the central asset management system where asset health index is estimated. It is planned in further steps to add more measurement capabilities to the IED, in order to complete the spectrum of parameters which are monitored.

Finally paper 0273 reports on a demonstration project implemented to show how commercially available wireless sensor network (WSN) systems could be used to modernize the monitoring of HV GIS substation. In that case the application was to implement SF6 monitoring: the SmartMesh IP technology has been selected. The experiment was successful to demonstrate how these WSN can be easily deployed, overcome failure of nodes, operate in RF noisy environments. It is possible to achieve battery life of up to 5 years with sampling rate of 1 measurement per 5 minutes.

The next 4 papers are related to the monitoring of "smart secondary substations", which is the subject of round table RT2 at this conference.

The first one, paper 0103, reports on the field testing of several types of advanced monitoring systems in 6 secondary substations of Ellevio in Sweden. The lessons learnt are presented and the experimentation will be pursued with the retrofit of monitoring equipment in 16 additional substations, in order to better understand how these systems can be used to improve the availability and capacity of the network. The continued evaluation will also be used for developing a standard solution for the future.

Paper 0839 describes the integrated solution experimented by ENERGA-OPERATOR in Poland, in the frame of the European UPGRID project, for the deployment of advanced metering infrastructure and smart grid monitoring and control functions in MV/LV distribution substations. The advantages of the integration at the hardware level of the communication solution of the MV/LV substation are explained and the cybersecurity measures to be implemented are presented.

Paper 0894 describes a new type of sensor, a high-frequency current transformer, developed by the authors for partial discharges (PD) monitoring purposes in MV networks. This sensor can also be a low cost solution for power quality monitoring and earth fault location: it could be the basis for a wideband multi-purpose monitoring concept at the MV side of MV/LV secondary substations.

Finally paper 1098 presents the requirements to be met in order to successfully develop an on-line PD monitoring system for secondary substations. Until recently the cost of these systems restricted their use to primary substations or critical locations. Now the recent innovations in microprocessors allow to design systems with enough computing power, ability to withstand harsh conditions without maintenance, and at a cost level that makes PD monitoring systems affordable and effective also for secondary distribution substations: this may be quite a game changer in the field of condition monitoring.

The last 6 papers of this sub-block are related to various topics of transformer monitoring, for condition assessment and also dynamic rating purposes.

Paper 1262 describes the new NSET system developed for power transformer monitoring. The ICT architecture is presented, as well as the user's interfaces of the controller and server. The monitoring system is connected to sensors providing comprehensive data about temperature, dissolved gases and moisture in oil. It is also possible to implement on-line PD monitoring of the insulation through the capacitive dividers of bushings. The analyses of the trends of data provided by the monitoring system can provide useful information, not only to the users, but also to the transformer manufacturers.

Paper 0840 presents the concept of MV/LV distribution transformer monitoring by means of a smart meter connected to the LV side. The computation and communication capabilities of the smart meter allow to embed a soft sensor that runs coupled thermal and electrical models of the distribution transformer and performs remote monitoring of the transformer's loading and thermal condition. The input data used by the soft sensor are the time-dependent LV quantities (currents, voltages, total harmonic distortion: THD) and the ambient temperature. The output data estimated by the models are the oil and hot spot temperatures, the MV quantities, the active and reactive losses and the ageing rate of the transformer (see Figure 2 below).

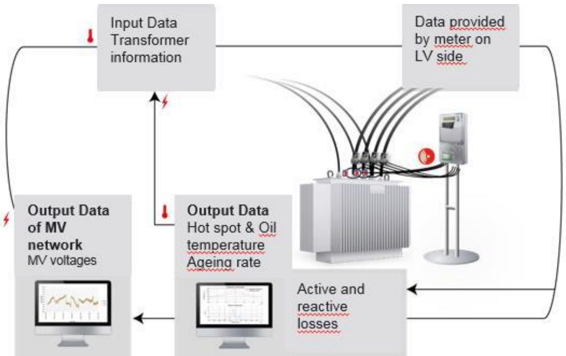

Figure 2 from paper 0840: Global synoptic of the Distribution Transformer Monitoring meter

Paper 0876 presents the possibilities offered by self-supplied wireless sensors for the thermal monitoring of cast resin distribution transformers. These sensors, similar to those used for MV air insulated switchgear, are easy to install on the MV and LV connections of dry-type transformers and can detect abnormal temperature rise due to loose connections or other defects. Several levels of monitoring solutions, from simple to sophisticated, can be implemented with these sensors and their eco-system (communication modules, algorithms and computing for estimation of ageing, or early detection of abnormal situation in order to prevent failures).

Paper 0539 compares three top oil temperature (TOT) models for the purpose of dynamic loading of oil insulated transformers. As some of these models are strongly non-linear (to take into account e.g. the viscosity of oil) support vector regression (SVR), with the optimal parameters of SVR determined by genetic algorithm (GA), has been used for finding the best fit for each model with datasets of measurements corresponding to respectively ONAN and OFAF transformers. It has been found that the Susa model gives the best results (minimal errors) for ONAN transformers, while for OFAF transformers the modified IEEE Clause 7 TOT model of C57.91 has even better performance.

Paper 1102 reports experiments performed on an oil-filled distribution transformer fitted with internal fibre optic temperature sensors to evaluate the parameters of the IEC thermal model and the hot spot temperatures. The conclusion is that using internal sensors is the best way to determine accurately the thermal parameters, better than using external sensors, or than applying the generic parameters proposed by the standard. Therefore, the use of fibre optic sensors is the recommended method to obtain a reliable thermal model of a transformer, which is key to establish its dynamic rating.

Finally, paper 1053 presents the enhanced (seasonal) thermal ratings (of primary substations power transformers) approach experimented by SP Energy Networks. Experiments of overloading an actual transformer in winter time have been performed, with associated thermal monitoring, in order to accurately model its thermal behaviour. It has been found that more capacity increase for peak loading is available than predicted by the IEC 60076-7 standard which tends to be conservative. Based on the adjusted thermal model it is possible to determine (by spreadsheet calculations) enhanced seasonal ratings for power transformers, which can be used as a first step in the operation and planning of the network, more simply than the real-time dynamic rating approach. Enhanced thermal ratings in many cases allow to differ capacity increase by setting the allowable peak load of some transformers above rating: when this solution is selected, it is recommended to implement improved thermal monitoring of these transformers, in order to refine their actual thermal models and possibly release more capacity.

Diagnosis tools and methods (7 papers)

The papers of this last sub-block are dealing with the following types of network components (in the order of presentation): circuit-breakers, on-load tap changers (OLTC), transformers (3 papers) and batteries for energy storage (2 papers).

Paper 0541, from the same authors as paper 0539 mentioned previously, presents research work performed in order to implement mechanical condition diagnosis of HV (or MV) circuit-breakers through the vibration signature analysis. The vibration signal collected by (e.g.) accelerometer is processed by fast Fourier transform (FFT) and wavelet packet technique (WPT) to extract the significant characteristics. Then a support vector machine (SVM) classifier, whose parameters have been optimized by the particle swarm optimization (PSO) algorithm, is used to determine the type of fault correlated to the observed signal. The proposed method has demonstrated a good prediction capability, that shows it can be effective for the condition assessment of HV circuit-breakers.

Paper 0326 reports preliminary results from the work in progress in order to define algorithms able to deliver a condition indicator for power transformer OLTC from off-line dynamic resistance measurement (DRM) patterns. It is expected that eventually a fully automated defects recognition system will be achieved.

Paper 0283 reports an on-going study performed in connection with the IPSEP laboratory in Argentina, where frequency response analysis (FRA) is systematically carried out before and after short-circuit withstand tests of transformers, in addition to the other routine tests prescribed for assessing the behaviour of the test object. Statistical indicators of changes in FRA show good correlation with other recognized indicators for the occurrence of defects in the transformer's structure, such as the variation of leakage inductance. These first results are promising and the study will be pursued to ascertain that FRA can be used as an efficient diagnosis tool, not only for the assessment of tests results, but also probably for condition assessment and preventive maintenance.

Along the same line, paper 0296 proposes an improved measurement method for the FRA and the impedance measurement of transformers. The proposed method avoids the errors due to stray capacitances and residual magnetic flux and allows to perform accurate diagnosis of transformers in the full frequency domain: its principle has been tested and demonstrated on a single phase 3 kV/110 V 60 VA voltage transformer.

Paper 0008 reports the results of research work aiming at correlating the results of dissolved gas analysis (DGA) of damaged transformers with the findings about the fault nature by visual inspection. This has led to the observation that a large number of faults are actually of mixed (discharge + thermal) nature, but are not properly identified as such by the current Duval triangle 1 method defined by the IEC 60599 guide. Therefore, an improved Duval triangle 1 (cf. Figure 10 below) is proposed which gives correct fault diagnosis according to the data base of DGA and defects results which has been analysed.

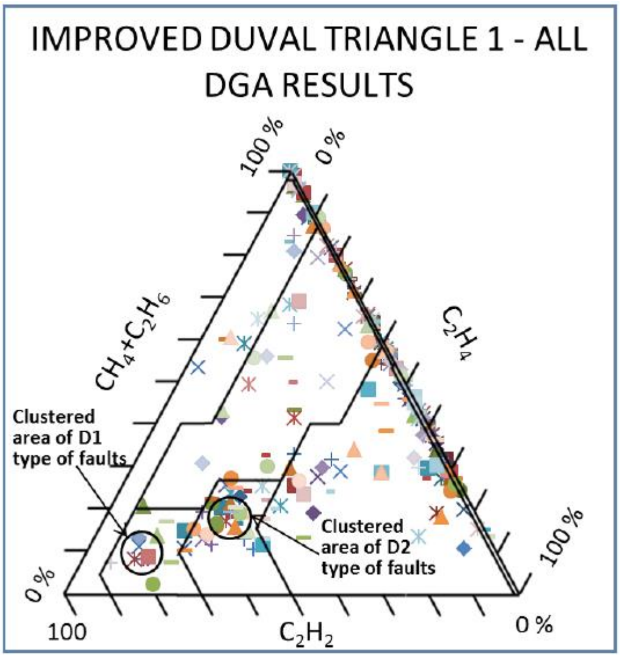

Figure 10 from paper 0008: Improved Duval triangle – all DGA results

Paper 0657 presents research work conducted to develop a data analysis method capable of predicting the remaining useful life (RUL) of Li-ion batteries used for energy storage systems. The proposed method is based on a relevance vector machine (RVM) learning technique associated to an iterative expectation-maximization (EM) algorithm for training. This method has been tested with the battery life cycle test data provided by the NASA and has proven capable of predicting the RUL with a sufficient accuracy for prognosis and health management purpose.

Finally paper 0039 explains how a methodology based on big data analytics applied to the real time monitoring data of battery energy storage systems can efficiently detect abnormal battery cell(s) and estimate the degradation degree of the system. Such battery storage health evaluation and diagnosis tools are necessary for efficient operation of renewable energy plants.

Table 4: Papers of Block 4 assigned to the Session (continued on next page)

Paper No. Title	MS p.m.	RIF	PS
0445: Maximize Asset Availability and Reduce Maintenance Costs - An Integrated Approach Combining Condition Assessment with Data Analytics			X
0774: Analysis of Condition and Risk Based Maintenance Planning for MV/LV Substations			X
1174: Health Index as Condition Estimator for Power System Equipment: A Critical Discussion and Case Study Title			X
1001: Economical and Practicable Condition Assessment of MV- and LV-Distribution Grids			X
0149: Combining statistics and physics to rank circuit breakers on condition			X
0665: Evaluation of Lifetime of Air Insulated Switchgear versus Service Conditions in MV substations	X		X
0206: Analysis of rusty closed type switchgears			X
0703: Reliability Measures: Failure and Root Cause Analysis (FRCA) for 72.5kV GIS Early Failure			X
0846: SPEN Switchgear Life Extension Strategy	X		X
0796: Switchgear Operating Personnel Safety Upgrade Solutions for Aged Installed Base	X		X
0989: Natural Esters for Life and Capacity Enhancement of Distribution Transformers			X
1078: Teardown of a Compact Distribution Transformer After Twelve Years of Severe Loading Conditions			X
1308: Managing On-Load Tap Changer Life Cycle in TNB Distribution Power Transformers			X
0042: Dealing with in-field Repair Tasks of Large Power Transformers			X
0698: Design and Successful Utilization of the First Multi-Purpose Mobile Distributed Energy Storage System in Iran			X
0952: Power and asset monitoring strategy to facilitate a smart network			X
0263: Smart Asset Management using Online Monitoring			X
0415: Modular Online Monitoring System to allow Condition Based Maintenance for Medium Voltage Switchgear			X
0322: How to Control the Impact of the Severe Environments Surrounding Medium Voltage Switchgear			X
0752: A Novel Approach for Wide Area Real Time Health Condition Assessment of the Power Circuit Breakers			X
0273: Design and Demonstration of a Wireless Sensor Network Platform for Substation Asset Management			X
0103: Different Monitoring Systems for Secondary Substations - a Comparative Study	X		X
0839: Advance Control and Monitoring in Secondary Substation - Project UPGRID			X
0894: Field Testing of a Wideband Monitoring Concept at MV Side of Secondary Substation			X
1098: Improving Asset Management with Online Partial Discharge Monitoring of Ring Main Units and Secondary Substations	X		X
1262: Power transformer monitoring system for better asset management			X
0840: New Soft Sensors for Distribution Transformer Monitoring			X

Table 4 continued: Papers of Block 4 assigned to the Session

Paper No. Title	MS p.m.	RIF	PS
0876: Management and Easy Communication of Temperature Rise on distribution Cast Resin Transformers connections Linked To Network during the Life of transformer and/or After Installation			X
0539: Comparisons of Transformer Top Oil Temperature Calculation Models Using Support Vector Regression Optimized by Genetic Algorithm		X	X
1102: Experimental Study of Dynamic Thermal Behaviour of an 11 kV Distribution Transformer		X	X
1053: Application of Enhanced Thermal Ratings to Primary Substation Transformers	X		X
0541: Fault Diagnosis of High-Voltage Circuit Breakers Using Wavelet Packet Technique and Support Vector Machine		X	X
0326: An innovative approach towards an algorithm for automated defect recognition for On-Load Tap Changers			X
0283: Experience of the applications of FRA methodology to evaluate short-circuit tests in distribution transformers			X
0296: Frequency Response Analysis for Exact Power Transformer Impedance			X
0008: Improvement of Duval Triangle 1			X
0657: Data Analysis of Energy Storage Systems		X	X
0039: Battery Anomaly and Degradation Diagnosis for Renewable Energy Plant			X

SESSION 1 - Network components

Block 1 : Research & development of network components – cables systems

Sub-block 1 – New materials & designs

0107 **ABC cables in colour other than black**
Z Pamić, *HEP ODS doo. ELEKTRA ZAGREB, Croatia*

0266 **External conductive layer on EDP MV underground cables leads to new oversheath requirements**
E Francisco, J Cruz, J Silva, F Costeira, *EDP Distribuição, Portugal*

0272 **Design of MV overhead lines to maximise bird safety**
A Beutel, B McLaren, H Geldenhuys, N Khoza, R Kruger, R Branfied, *Eskom Holdings SOC Ltd, South Africa,* J Van Coller, *University of the Witwatersrand, South Africa,* C Hoogstad, *Endangered Wildlife Trust, South Africa*

0430 **The use of high temperature conductors in existing lines: economic and environmental benefits**
L Moreira, A Lopes, *EDP-Distribuição, Portugal*

1108 **Sensitivity analysis of earthing system impedance for single and multilayered soil**
V Vycital, D Topolanek, P Toman, M Ptacek, *Brno University of Technology, Czech Republic*

0279 **Anti-ice and snow coating for EDP Distribuição's overhead lines**
R Bernardo, J Cardoso, R Catalão, *EDP Distribuição, Portugal,* L Ilharco, *IST-CQFM, Portugal*

0602 **An innovative power cable connection of property equivalence and non-joint**
H Zhong, Y Xia, Z Liang, *Athens, Greece, CYG Electric Technology Co, LTD*

0414 **Self-healing materials for autonomous cable repair**
R Rhodesl German, S Basu, G C Stevens, *Gnosys Global Ltd., United Kingdom*

0912 **New HVDC nanocomposite electrical insulation for improved MV and HVAC performance**
N Freebody, G Stevens, *Gnosys Global Ltd, United Kingdom,* A Vaughan, *University of Southampton, United Kingdom,* F Perrot, A Hyde, *GE Grid Solutions, United Kingdom*

1066 **Using nanomaterial to enhance the performance of medium voltage insulators and street lights considering environmental impacts**
M Fazaee, M Abdoli, *Tehran University, Iran,* B Jamshidieini, *AEPDC, Iran/Tehran University, Iran,* N Eskandari, *AEPDC, Iran*

0917 **High performance thermoplastic cable insulation systems**
A Pye, G Stevens, *Gnosys Global Ltd, United Kingdom*

Sub-block 2 – Development of accelerated ageing tests & failure detection methods

0114 **Parameters of influence on LV cable ageing**
Q De Clerck, J M Meunier, *Laborelec, Belgium,* J Van Slycken, *Eandis, Belgium,* M Van Den Berg, *Sibelga, Belgium,* P Colin, *Ores, Belgium*

0418 **Determining cables metrics using 3D ultrasonic scanning**

S Sutton, *University of Southampton, United Kingdom,* P Willmott, *Acuity Products Ltd, United Kingdom*

0200 **Investigations on the mechanical and electrical behavior of HTLS conductors by accelerated ageing tests**
C Kühnel, S Grossmann, *IEEH TU Dresden, Germany,* R Bardl, D Stengel, *BAM Berlin, Germany,* W Kiewitt, *50Hertz Transmission GmbH, Germany*

0260 **Medium voltage shielded busbar long term ageing test method**
K Helal, R Maladen, F Gentils, O Kozlova, *Schneider Electric, France*

0537 **Evaluation of aging degradation of 6kV CV cable (three-layer co-extruded structure)**
M Kobayashi, M Kuze, *Chubu Electric Power Company, Japan,* T Fuseya,*TOENEC Corporation, Japan*

0598 **10 Years of experience with 3 kHz water tree test**
M Burceanu, Q De Clerck, Y Tits, *Laborelec, Belgium*

1134 **Developement of long-term reliability evaluation method for polypropylene insulated MV cables**
Y Jung, D Kim, B Lee, S Lee, *KEPCO, Korea*

0893 **Long-time evaluation of cable joints in water**
M Dreßler, S Kornhuber, *University of Applied Science Zittau/Görlitz, Germany,* G Jacob, *Behr Bircher Cellpack BBC Radeberg GmbH, Germany,* B Knüpfer, *Cellpack GmbH, Germany*

0826 **Experiences with cable faults located at metallic screen connections**
H L Halvorson, S Hvidsten, H Kulbotten, J K Lervik, *SINTEF Energy Research, Norway*

Sub-block 3- Diagnostics methods development

0270 **Integration challenges of high accuracy LPIT into MV recloser**
B Kerr, N Uzelac, *G&W Electric Co., United States,* L Peretto, *University of Bologna, Italy,* E Scala, *Altea S.r.l., Italy*

0049 **Offline PD diagnostics using several excitation voltages**
H Putter, F Petzold, P Legler, *Megger, Germany*

0056 **On line monitoring of medium voltage overhead distribution lines polluted insulators severity**
O E Gouda, *Cairo University, Egypt,* D M Khalifa, *Egyptian Electricity Transmission Company, Egypt*

0291 **Sensitivity analysis of cable oscillating wave test system on multi-source defects diagnostics**
G Lu, G Wu, J Xiong, Y Liu, *Guangzhou Power Supply, China*

0797 **Analysis and evaluation of dielectric parameters for design verification and calibration of a newly developed diagnostic system for MV power cables**
F Eppelein, C Weindl, *Coburg University of Applied Sciences, Germany,* I Mladenovic, *Siemens AG, Germany*

0813 **Measurement results of a spatially-resolved diagnostic method and influencing factors in field environment of MV power cables**
E Fischer, C Weindl, *Coburg University of Applied Sciences, Germany*

0532 **Investigation of partial discharge frequency dependence in distribution system cables**
T S Negm, M Refaey, A A Hossam-Eldin, *University of Alexandria, Egypt*

1130 **Underground and overhead monitoring systems for MV distribution systems**
F Zavoda, *IREQ (Hydro-Quebec), Canada,* E Rodriguez, *3M, United States,* G C Fofeldea, *3M, Canada*

Block 2 : Research and development of network components – substations

Sub-block 1- SF6 alternatives & vacuum switching

0819 **Holistic evaluation of the performance of today's SF6 alternatives proposals**
S Kosse, P G NikolicG Kachelriess, *Siemens AG, Germany*

0795 **Characteristics of g3 - an alternative to SF6**
Y Kieffel, F Biquez, D Vigouroux, P Ponchon, *GE Grid Solutuions, France,* A Schlernitzauer, R Magous, G Cros, *University of Montpellier, France,* J G Owens, *3M, United States*

0658 **RMU with eco-efficient gas mixtures: field experience**
M Kristoffersen, T Endre, M Saxegaard, P A Wang, *ABB, Norway,* M Hyrenbach, *ABB, Germany,* D Harmsen, T V Rijn, R Vosse, *Liander, Netherlands*

0389 **Application of HFO1234zeE in MV switchgear as SF6 alternative gas**
C PreveR Maladen, *Schneider Electric, France,* D Piccoz, *Piccoz SASU, France*

0614 **Low-current interruption in SF6-alternatives**
M Saxegaard, E Attar, M Kristoffersen, H Landsverk, O Granhaug, *ABB, Norway,* A Di-Gianni, S Scheel*ABB, Switzerland*

0604 **Comparative study on arc extinction process under air, CO2 and SF6 gas blasting using two-dimensional electron density imaging sensor**
Y Inada, *Saitama University, Japan,* S Yamaguchi, A Kumada, H Ikeda, K Hidaka, *The University of Tokyo, Japan,* T Nakano, K Murai, Y Tanaka, *Kanazawa University, Japan*

0230 **Environmental and safety aspects of AirPlus insulated GIS**
M Hyrenbach, *ABB AG, Germany,* T A Paul, *ABB Ltd., Switzerland,* J Owens, *3M Company, United States*

0385 **Hazard study of MV switchgear with SF6 alternative gas in electrical room**
C PreveR Maladen, *Schneider Electric, France,* G Lahaye, T Penelon, *INERIS, France,* M Richaud, S Galas, *Universite De Montpellier, France*

0250 **Transferred charge: indicator for vacuum applicability**
M Leusenkamp, *Eaton, China,* G C Schoonenberg, *Eaton, Netherlands*

0872 **Difference between switching of motors & generators with vacuum technology**
K R Venna, H Urbanek, N Anger, *Siemens AG, Germany*

0229 **DC vacuum circuit breaker**
L Liljestrand, M Backman, L Jonsson, *ABB, Sweden,* M Riva, *ABB, Italy,* E Dullni, *ABB, Germany*

Sub-block 2 – Safety, environment & reliability considerations in the design of network components

0244 **Safety features in the design of MV circuit-breakers and switchboards**
D Fulchiron, J-P Meley, P Pulfer, *Schneider-Electric, France*

0220 **Mastering all sub-assemblies of an MV circuit-breaker and racking truck system ensures reliability and robustness**
D Serve, T Milan, C Mombard, J P Meley, E Frangin, *Schneider-Electric, France*

0372 **Extreme weather has become the norm - is your MV switchgear ready for it?**
K Tandel, *Schneider Electric, India,* T Cormenier, *Schneider Electric, France*

0767 **Mitigate arc effects within an E-house**
J Douchin, A Clavel, *Schneider Electric, France,* A Brown, *Schneider Electric, Singapore,* J Rintala, *Schneider Elctric, Finland*

0371 **Mitigate gas combustion in case of internal arc**
J Douchin, *Schneider Electric, France,* Y Cressault, *Toulouse University, France,* R Danjoux, *FLIR, France*

0486 **Pressure oscillation due to arcs in a closed container filled with air and SF6**
M Kotari, T Tadokoro, S-I Tanaka, M Iwata, *Central Research Institute of Electric Power Industry, Japan*

0212 **New HV/LV Transformer Substation within building intended for other non electrical uses with advanced functionalities**
J Cormenzana, S Sebastian, *Ormazabal, Spain*

0253 **Innovative underground distribution cabinet for low voltage network**
N Santos, M Lagarto, C Rodrigues, *EDP Distribuição, Portugal*

1069 **How to select auxiliary relays for isolation applications**
N Calvo Cuadra, S Rementeria, *Arteche, Spain,* R Calister, *Arteche, Brazil*

0475 **Meeting ecodesign efficiency requirements: ensuring accuracy in power transformer loss tests via TLM System calibrations**
G Rietveld, E Houtzager, M Acanski, D Hoogenboom, *VSL, Netherlands*

Sub-block 3- Testing & numerical simulation methods for development of network components

0943 **Developing testing procedures for high voltage innovation technologies**
D Hardman, N Murdoch, *WSP | Parsons Brinckerhoff, United Kingdom,* J Berry, *Western Power Distribution, United Kingdom*

0138 **Proven reliability beyond the standards**
I Oruel Gilbert, J Larrieta, S Sebastian, *Ormazabal, Spain*

1100 **Power hardware-in-the-loop setup for power system stability analyses**
R Brandl, T Degner, *Fraunhofer IWES, Germany,* M Calin, *DERlab e.V., Germany*

0345 **Influence of heat source location on the air temperatures in sealed MV switchgear**
E Fjeld, W Rondeel, K Vaagsaether, *University College of Southeast Norway, Norway,* E Attar, *ABB, Norway*

0349 **Estimating the temperature rise of load break switch contacts in enclosed MV switchgear**
E Fjeld, W Rondeel, S T Hagen, *University College of Southeast Norway, Norway,* M Saxegaard, *ABB, Norway*

0091 **Comparative advantage of using GRP in compact substations**
C Martinez Nieto, D Türk, A Palgi, *ABB, Estonia*

0852 **Stress on outer cable connection of MV gas insulated switchgear due to cable thermal expansion at rated current**
J Snajdr, R Huck, P Novak, *Schneider Electric, Germany,* J P Bentley, *Schneider Elctric, France*

1268 **A high short-circuit impedance power transformer versus short-circuit limiting reactance**
M Zouiti, *Enedis, France,* A Kirche, O Moreau, *EDF, France*

Block 3 : Management & architecture evolution of the installed base of network components – Cables & their environment

Sub-block 1 – Smart Grids solutions & applications in smart metering

0137 **A novel micro PMU for distribution power lines**
X Wang, X Xie, S Zhang, L Luo, Y Liu, G Sheng, X Jiang, *Shanghai Jiao Tong University (SJTU), China,* X Cheng, *Beijing Electric Power Research Institute, China*

0226 **Fault sensors**
M Scarabeli, G Ortenzi, J Aith, *Elektro, Brazil*

0110 **Field trial results of power electronics in LV distribution networks**
C Newton, S C Terry, *Ricardo Energy & Environment, United Kingdom,* P Lang, *UK Power Networks, United Kingdom*

0709 **Sensor technology in a medium voltage switchgear for the US market applications**
P Milovac, *IEM, United States,* R Javora, *ABB, Czech Republic,* V Skendzic, *SEL, United States*

0715 **Continous safeguarding of rating accuracy**
M Olschewski, P Schaefer, W Hill, *LIOS Technology GmbH, Germany*

0820 **Full-scale case study of a road crossing thermal bottleneck in a buried MV cable installation**
E Eberg, S M Hellesø, S Hvidsten, *SINTEF Energy Research, Norway,* K Espeland, *REN AS, Norway*

0882 **Low-power voltage transformers for use with separable connectors in MV secondary gas insulated switchgear - new challenge for standardization**
R Javora, V Prokop, *ABB s.r.o., Czech Republic,* E De Ridder, S Mensaert, *Nexans, Belgium*

0391 **Compatibility of a G3PLC telecom solution on a three phase 230 V network**
H Halluin, H Grandjean, *ORES, Belgium*G Ethève, *Enedis, France,* A Jeandin, *EDF R&D, France*

0933 **Complete MV-BPL communications solution for large AMI and grid automation deployments**
J Aguirre Valparis, A Amezua, J A Sanchez, *Ormazabal, Spain,* A Sendin, J Simon, *Iberdrola, Spain,* S Dominiak, *HSLU, Switzerland*

0519 **LVDC RULES - technical specifications for public LVDC distribution network**
P Nuutinen, T Kaipia, J Karppanen, A Mattsson, A Lana, A Pinomaa, P Peltoniemi, J Partanen, *Lappeenranta University of Technology (LUT), Finland,* M Luukkanen, *Ensto Finland Oy, Finland,* T Hakala, *Elenia Oy, Finland*

1215 **Survey of market prospects and standardisation development needs of LVDC technology**
T Kaipia, *Lappeenranta University of Technology, Finland,* P Sebellin, *International Electrotechnical Commission, Switzerland,* V Mahendru, *Legrand India, India,* K Hirose, *NTT Facilities, Japan,* W De Kesel, *Legrand Group, Belgium,* G Luber, R Pelta, *Siemens AG, Germany,* D Goswami, *Bureau of Indian Standards, India*

Sub-block 2 – Applications of methods and tools to asset management of cables & distribution lines

0417 **Evaluation of the mountability of the medium voltage accessories**
H Tanzeghti, A Kirche, *Enedis, France*

0737 **Improve the reliability of MV underground links by using long cable**
H Tanzeghti, *Enedis, France,* Y Brument, F Gaillard, *EDF R&D, France*

1104 **Improving reliability by focusing on the quality and condition of medium voltage cables and cable accessories**
O Siirto, J Vepsäläinen, A Hämäläinen, M Loukkalahti, *Helen Electricity Network Ltd, Finland*

0134 **Research and application of 10kV distribution equipment testing new technology in condition-based maintenance**
M Wenxiong, F Jian, W Jin, W Yong, L Le, L Shengnan, *Guangzhou Power Supply Bureau Co. Ltd, China*

0328 **Managing the maturity of decision-support data for extending lives of MV cables**
Q Zhuang, *GEIRI Europe SGCC, Germany,* J Janssen, N Steentjes, *Liander, Netherlands*

0546 **Accurate on-line fault location and PD activity location results obtained with SCG - a long term utility experience**
D Harmsen, S Lamboo, F Van Minnen, *Alliander, Netherlands,* P Wagenaars, *DNV GL, Netherlands*

0895 **Analysis of failure in power cables for preventing power outage in Alexandria Electricity Distribution Company in Egypt**
A Attia, *Alexandria Electricity Distribution Company, Egypt*

0413 **Contribution of augmented reality to the maintenance of network equipment**
M Cordonnier, S Martino, C BoisseauS Paslier, J P Recapet, F Blanc, *Enedis, France,* B Augustin, *EDF R&D, France*

0681 **Using smart grid sensors and advanced software applications as an asset management tool at Hydro Ottawa**
D Sabin, *Electrotek Concepts, United States,* G MacLeod, *Current Power Services, Canada,* M Wojdan, *Hydro Ottawa, Canada*

0479 **Maintenance of street lights by climbing robots in Alborz Electric Power Distribution Company**
N Eskandari, M Rafiei, E Abooei, *AEPCS, Iran,* B Jamshidieini, *AEPCS, Iran/Tehran University, Iran*

0835 **Opportunities to use satellite technologies for asset condition monitoring of power networks under the European Space Agency's Integrated Applications Promotion (IAP) programme**
I Downey, *ESA IAP Ambassador Platform, United Kingdom,* M Segovia, C Harrison, *University of Strathclyde, United Kingdom*

1048 **Information and communication architecture for transmission power line inspections using unmanned aircraft system**
R Z Homma, *Celesc, Brazil,* C Szymanski*Inerge/Evoluma, Brazil,* R Ávila Faraco, *Inerge/Unisul, Brazil*

1193 **Analysis of the recognition and localization techniques of power transmission lines components in aerial images acquired by drones**
R Z Homma, *Celesc, Brazil,* O SohnR C Bose, *INERGE, Brazil*

Sub-block 3 – Enabling solutions and methods for the integration of renewable energy generation

0004 **Introducing the new product line of regulated distribution transformer Cooperation of Siemens AG and A. Eberle GmbH & Co. KG.**
S H Hoppert, *A Eberle GmbH & Co. KG., Germany,* L K Kelemen, Z N Nádudvari, G V Vörös, *Siemens, Hungary*

0348 **Beyond grid integration of renewables - Voltage Regulation Distribution Transformers (VRDT) in public grids, at industrial sites, and as part of generation units**
M Sojer, W Hofer, *Maschinenfabrik Reinhausen GmbH, Germany*

0832 **A new smart distribution transformer with OLTC for low carbon technologies integration**
L Del Río Etayo, A Soto, A Ulasenka, *ORMAZABAL Corporate Technology, Spain,* P Lauzevis, *ENEDIS, France,* P Cirujano, G Perez De Nanclares, *ORMAZABAL COTRADIS, Spain*

0207 **Line voltage regulator based on magnetic-controlled inductors for low voltage grids**
M Holt, J Maasmann, C Rehtanz, *TU Dortmund University, Germany*

0086 **Power router based on conventional three phase bridge inverter and DC-DC converter**
L Ren, C Zhang, M Du,*Tianjin University of Technology, China*

0922 **Cyclic rating of wind farm cable connections**
R Chippendale, J Pilgrim, *University of Southampton, United Kingdom,* A Kazerooni, *WSP | Parsons Brinckerhoff, United Kingdom,* D Ruthven, *SP Energy Networks, United Kingdom*

0941 **Steady-state modelling for the integration of a bi-directional AC-DC-AC flexible power link**
J King, N Murdoch, *WSP | Parsons Brinckerhoff, United Kingdom,* J Berry, *Western Power Distribution, United*

Kingdom

Block 4 : Solutions for managing the installed base of network components – substations

Sub-block 1 – Condition assessment, ageing behaviour and maintenance strategy

0445 **Maximize asset availability and reduce maintenance costs - an integrated approach combining condition assessment with data analytics**
A Hauser, B Fenski, *ABB AG, Germany,* L Cavalli, *ABB SpA, Italy*

0774 **Analysis of condition and risk based maintenance planning for MV/LV substations**
P Köhn, A Schnettler, *RWTH Aachen University, Germany,* N Schultze, *SAG GmbH, Germany*

1174 **Health index as condition estimator for power system equipment: a critical discussion and case study**
J H Jürgensen, A Scheutz Godin, P Hilber, *KTH, Sweden*

1001 **Economical and practicable condition assessment of MV- and LV- distribution grids**
C Johae, D Beerboom, E Pawlowski, M Zdrallek, *Wuppertal University, Germany,* N Schultze, *SAG GmbH, Germany,* R Timmreck, *Stadtwerke Iserlohn GmbH, Germany*

0149 **Combining statistics and physics to rank circuit breakers on condition**
E Tazelaar, D Breteler, J van Tongeren, *Alliander, Netherlands,* R Stijl, *Bearing Point, Netherlands*

0665 **Evaluation of lifetime of air insulated switchgear versus service conditions in MV substations**
Y Tits, H Van Lijsebeth, *Laborelec, Belgium,* W De Maesschalck, W Van Vaerenbergh, *Eandis, Belgium,* P Thiry, *Ores, Belgium,* B Godeau, *Elia, Belgium,* M van den Berg*Sibelga, Belgium*

0206 **Analysis of rusty closed type switchgears**
K Morii, *Kansai Electric Power Co. Inc. Japan*

0703 **Reliability measures: Failure and Root Cause Analysis (FRCA) for GIS early failure**
M Lee, M Park, Y Kim, *LSIS, South Korea*

0846 **SPEN switchgear life extension strategy**
A Santandreu, D Neilson, *SP Energy Networks, United Kingdom*

0796 **Switchgear operating personnel safety upgrade solutions for aged installed base**
C Gemme, P Bassi, G Magno, *ABB, Italy*

0989 **Natural esters for life and capacity enhancement of distribution transformers**
R Pillai, F HavaldarC Chitnis, *The Tata Power Company Ltd, India*

1078 **Teardown of a Compact Distribution Transformer After Twelve Years of Severe Loading Conditions**
V Vasconcellos, *CPFL Energia, Brazil,* A Sbravati, *Cargill CIS, Brazil,* K J Rapp, *Cargill CIS, United States,* L C Zanetta Jr, *PEA USP, Brazil*

1308 **Managing on-load tap changer life cycle in TNB Distribution Power Transformers**
YZ Yang Ghazali, T*enaga Nasional Berhad, Malaysia*

0042 **Dealing with in-field repair tasks of large power transformers**
J L Martínez, *Edenor, Argentina*

0698 **Design and successful utilization of the first multi-purpose mobile distributed energy storage system in Iran**
N Nakhodchi, N Aghli, S Alishahi, M H Pourarab, *MEEDC, Iran*

Sub-block 2 – Monitoring solutions for asset management and operation of network components

0952 **Power and asset monitoring strategy to facilitate a smart network**
A Elena de Leonardo, K Lennon, A Beddoes, M Bebbington, *SP Energy Networks, United Kingdom*

0263 **Smart asset management using online monitoring**
D Courtney, *Embedded Monitoring Systems, United Kingdom,* J Livie, *Scottish Power Energy Networks, United Kingdom,* T Littler, *Queen's University, United Kingdom*

0415 **Modular online monitoring system to allow condition based maintenance for medium Voltage Switchgear**
K PerdonM Scarpellini, S Magoni, L Cavalli, *ABB S.p.A, Italy*

0322 **How to control the impact of the severe environments surrounding medium voltage switchgear**

T Cormenier, P Veuillet, V Ferraro, *Schneider Electric, France*

0752 **A novel approach for wide area real time health condition assessment of the power circuit Breakers**
L Maruša, A Souvent, S Vižintin, *EIMV, Slovenia,* R Maruša, *ELES d.o.o., Slovenia*

0273 **Design and demonstration of a wireless sensor network platform for substation asset management**
N T Huynh, *ECE Associates Ltd, United Kingdom,* V Robu, D Flynn, *Heriot-Watt University, United Kingdom,* S Rowland, G Coapes, *Siemens, United Kingdom*

0103 **Monitoring systems for secondary substations - a comparative study**
J Johansson, H Sporre, L Selberg, O Hansson, *Ellevio AB, Sweden*

0839 **Advance control and monitoring in secondary substation - project UPGRID**
S Noske, D Falkowski, *ENERGA-OPERATOR SA, Poland,* A Babs, *Institute of Power Engineering, Poland*

0894 **Field testing of a wideband monitoring concept at MV side of secondary substation**
B A Siddiqui, P Pakonen, P Verho, *TUT, Finland*

1098 **Improving asset management with online partial discharge monitoring of ring main units and secondary substations**
C Eastham, D Longo, K Tavernier, L Pickford, *IPEC Ltd., United Kingdom*

1262 **Power transformer's monitoring system for better asset management**
S Ceferin, G Janc, *Kolektor Sisteh d.o.o., Slovenia,* Z Toroš, T Kastelic, *Elektro Primorska d.d., Slovenia,* B Prašnikar, *Kolektor Etra d.o.o., Slovenia*

0840 **New soft sensors for distribution transformer monitoring**
J F Tissier, J Cornet, *ITRON, France*

0876 **Management and easy communication of temperature rise on distribution cast resin transformers connections linked to network during the life of transformer and/or after installation**
A Hammen, G Ranalletta, C Macri, *Schneider Electric, France*

0539 **Comparisons of transformer top oil temperature calculation models using support vector regression optimized by genetic algorithm**
T Qian, W H Tang, W J Jin, *South China University of Technology, China,* L Gan, Y Q Liu, G J Lu, *Guangzhou Power Supply Co. Ltd., Guangzhou, China*

1102 **Experimental study of dynamic thermal behaviour of an 11 kV distribution transformer**
R Villarroel, Q Liu, Z Wang, *The University of Manchester, United Kingdom*

1053 **Application of enhanced thermal ratings to primary substation transformers**
I Elders, K Bell, *University of Strathclyde, United Kindgom,* K Smith, A Collinson, *Scottish Power Energy Networks, United Kingdom*

Sub-block 3 – Diagnosis tools and methods

0541 **Fault diagnosis of high-voltage circuit breakers using wavelet packet technique and support vector machine**
W J Jin, W H Tang, T Qian, T Y Ji, *South China University of Technology, Guangzhou, China,* L Gan, Y Q Liu, G J Lu, *Guangzhou Power Supply Co. Ltd., China*

0326 **An innovative approach towards an algorithm for automated defect recognition for on-load tap changers**
F Riaz, J Wetzer, *DNV GL Energy, Netherlands,* A Rodrigo Mor, *TU Delft, Netherlands*

0283 **Experience of the applications of FRA methodology to evaluate short-circuit tests in distribution transformers**
D Tourn, S Nesci, J C Gomez, L Sanchez, *UNRC, Argentina*

0296 **Frequency response analysis for exact power transformer impedance**
M Hiraide, T Nakajima, T Koshizuka, *Tokyo Denki University, Japan,* H Ikeda, Y Taniguchi, E Haginomori, *The University of Tokyo, Japan,* N Harid, N Al Sayari, B Barkat, A Devadiga, *The Petroleum Institute, United Arab Emirates*

0008 **Improvement of Duval Triangle 1**
S Spremic, *EPS Tehnical Centre Novi Sad, Serbia*

0657 **Data analysis of battery storage systems**
M Andoni, W Tang, V Robu, D Flynn, *Heriot Watt University, United Kingdom*

0039 **Battery anomaly and degradation diagnosis for renewable energy plant**
J Zhang, L Geng, Y Ma, *Hitachi (China) Research & Development Corporation, China*