

Special Report - Session 1 NETWORK COMPONENTS

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Introduction

102 papers have been selected for the Session 1 – Network Components – of CIRED 2007. About half of these papers are dealing with existing, in-service, network components (NC). The other half is centred on innovation, in the broad sense, in this field.

The papers have been organised into 4 blocks, both in this special report and in the Main Session.

The structure of these blocks is the following.

Block 1 Behaviour and ageing of NC

- Sub block 1.1: Maintenance and asset management (9 papers)
- Sub block 1.2: Ageing of NC (14 papers)
- Sub block 1.3: Network phenomena (2 papers)

Block 2 Diagnostic tools and methods

- Sub block 2.1: Insulation diagnosis (14 papers)
- Sub block 2.2: Thermal diagnosis (4 papers)
- Sub block 2.3: Other diagnosis and miscellaneous (7 papers)

Block 3 Interaction between NC and their environment

- Sub block 3.1: Safety (4 papers)
- Sub block 3.2: Environment (6 papers)
- Sub block 3.3: Modelling and design tools (7 papers)
- Sub block 3.4: Test methods and applications (6 papers)

Block 4 New designs and solutions

- Sub block 4.1: New designs (23 papers)
- Sub block 4.2: Prospective solutions (6 papers)

Compared to the previous edition of the Conference, a reduced number of papers (about 6 per block) have been retained for oral presentation in the Main Session (MS), in order to allow more time for presentation by the authors and

subsequent discussion on the papers and submitted written contributions.

Therefore the vast majority of papers will be presented by their authors in the Poster Session (PS). Guided tours of the PS will be organised this year in order to help conference attendees in meeting the authors and getting the most from the wealth of this session.

In addition to the Main and Poster Sessions, three Round Table (RT1A, RT1B and RT1C) discussions and a Research and Innovation Forum (RIF) will take place within Session 1.

The subjects of the Round Tables are respectively:

RT1A - How to integrate safety in design?

Safety (for customers, workers and environment) is a major challenge for all designers of networks components. Manufacturers must include these requirements in their specifications and at the same time reduce their costs. What are the good ideas and the good practices?

RT1B - Reliability of cables links: the challenge of on-line partial discharges monitoring

Distributors are waiting for efficient solutions to evaluate the quality of their cables, and anticipate the renewal of weak links. A state of the art will be presented.

RT1C - Where are the well-fitted borders between transmission and distribution networks?

The situation can be very different in the countries attending CIRED. A large overview of the existing organisations with advantages and disadvantages attached to the different choices will be presented.

For RT1A and RT1B several authors will be among the panellists and have the opportunity to present and discuss their papers as invited speakers. Those papers which will be presented in the round table discussions are signalled in the special report tables, as well as the MS and PS papers.

Finally the authors of about 10 papers will be invited to present their work in the RIF, where academics and researchers can meet and exchange on the wide variety of subjects covered by this forum.

Block 1 - Behaviour and ageing of network components

Sub block 1.1 – Maintenance and asset management

Condition-based maintenance (2 papers)

A good introduction to the condition-based maintenance methodology can be found in paper 779 which gives several examples of application: on line quick scan for condition indexing of substations components; determination of spare parts requirements; establishment of knowledge rules from partial discharges (PD) diagnosis.

This methodology is further illustrated in paper 178 which describes how PD diagnostic data available for MV cables are statistically processed in order to define boundary values used for determining the condition indexes applicable to these components.

Question 1 Block 1: Condition based maintenance methods have been introduced since several years. What is the experience feedback on their application: have they been used to change globally the maintenance and replacement cycles or have they resulted in actually adjusting maintenance frequency to the condition assessed for each component ?

Remaining life of cables and accessories (2 papers)

Paper 221 provides a general introduction to the subject of MV cables remaining life evaluation. After presenting the characteristics of the main components of cable systems, the failure mechanisms are described and the analytical methods used for assessment of the ageing condition of cable circuits are introduced. Finally a practical method is proposed for estimation of the remaining life of cables on the basis of their present degradation level and of the maximum admissible degradation.

Specific application of this general approach to cable accessories is described in paper 136 which reports on MV cable joints ageing issues in Hydro-Québec distribution networks. In this case PD detection and infrared diagnostics have been used to establish a condition-based maintenance program for the joints that need replacement.

Optimal use of cables capacity (2 papers)

Papers 64 and 355 are centred on asset management of cable circuits, through increased rate of use.

Paper 64 presents the Cable Loading Guideline which has been developed in the Netherlands on the basis of data collected in the field and dynamic thermal modelling of cables, for use in the daily cables network planning and operation.

Paper 355 describes the CRATER software tool which has

been developed by EA Technology in order to provide Distribution Network Operators with complete information on the admissible rating of cable circuits, taking into account dynamic load, type of cables and installation conditions.

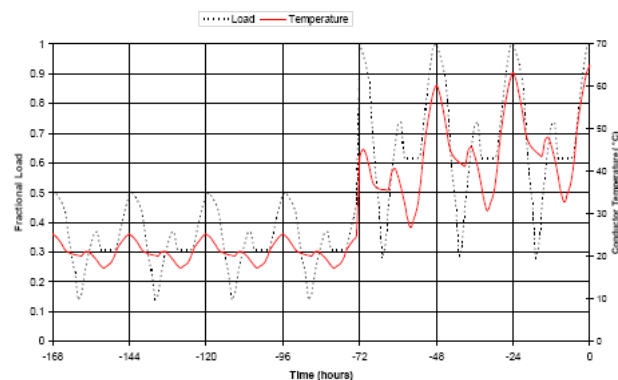


Fig. 1: Showing typical load and temperature profiles before and after the limited time excursion

Fig. 1: Figure 1 in paper 355

End of life management (3 papers)

Paper 661 presents a methodology for remaining life estimation in case insufficient data are available for statistical analysis. Condition assessment and expert advice on remaining life time are used to determine failure rates on which economical analysis can be based to select the best maintenance strategy.

A tool for such economical analysis in the case of MV switchgear, similar to those used for investment profitability analysis, is proposed in paper 407. It can provide assistance in choosing the most valuable scenario in those available when switchgear is approaching its end of life: retrofit, refurbishment, replacement.

Question 2 Block 1: Is rational economical assessment of various scenarios possible when costs are valued on a conventional basis ?

Steps undertaken by EDF for lifespan prolongation of ageing MV switchgear are presented in paper 446. In that case refurbishment actions have been found to be an alternative to replacement as they allow 10 to 15 years life extension for the equipment. Considering the large number of units to be repaired, instructions and training are set up to provide operators with the necessary information for fast and efficient maintenance work.

Question 3 Block 1: What is the main output of studies performed on life time: better understanding of the suitable replacement dates or better knowledge of ageing mechanisms in order to expand lifespan ?

Sub block 1.2 – Ageing of network components

Corrosion and water-treeing of XLPE MV cables (4 papers)

Papers 489 and 143 present experiences in Romania on ageing of buried components, notably MV cables, due to galvanic corrosion. A correlation has been found between the decrease of insulation resistance of MV cables and the corrosion of their armour shields. A form of cathodic protection of the cable shields is proposed, based on the rectifying of capacitive currents between shield and earth by zener-type diodes. It is claimed that application of this protection can improve the condition of cables affected by water-treeing.

Question 4 Block 1: Can water-treeing damage to XLPE insulation be considered in some cases as reversible ?

Paper 724 reports on condition assessment performed by Hydro-Québec on aged XLPE MV cables: time domain spectroscopy (TDS) was found to be a suitable diagnostic tool to evaluate water-treeing and joints condition. The overall condition of 30 years old XLPE insulated cables was found to be satisfactory, with a life expectancy that could be estimated to 50 years.

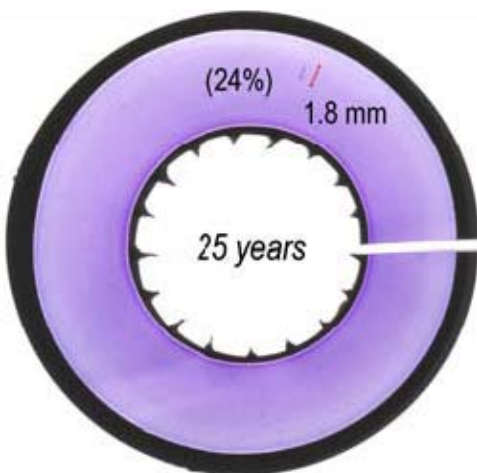


Fig. 2: Typical water-treeing shown in figure 5 of paper 724

Finally paper 527 presents results of water tank ageing tests performed on various XLPE compounds: they show that some compounds with water-tree retardant properties have a significantly lower reduction in their dielectric strength after ageing.

Thermal ageing of distribution transformers (2 papers)

Paper 720 reports on research work performed in order to optimize distribution transformers overload factors while staying within ageing and safety limits. Thermal modelling of transformers supplying different types of loads has yielded interesting results, showing that the best choice may vary significantly, depending on the following factors: load profile and load factor; peak season; grouping of loads.

Similar work is presented in paper 53 which reports on studies done for assessing the overload capabilities of

distribution transformers in hot summertime period. A thermal modelling of the transformer has been implemented, which has allowed to define the relation between overload factor and ambient temperature in order to: prevent fire risk and safety hazards; remain within acceptable limits for loss of life of the transformer.

Question 5 Block 1: Will the studies on loading of transformers eventually result in specification changes in order to better adapt their behaviour to actual load cycles and service conditions ?

Power transformers (4 papers)

Papers 546 and 292 are based on analysis of failures data for power transformers, in the Netherlands and South Africa respectively.

Paper 546 describes how statistical analysis and probability distribution fitting can help in establishing the failure rate as a function of age. On this basis it is possible to predict the evolution of failure numbers for a given population of ageing power transformers.

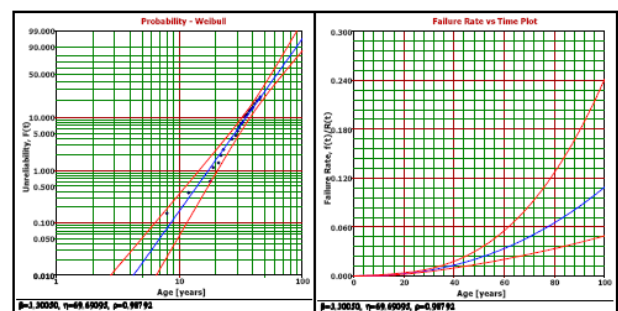


Figure 4 Fitted two parameter Weibull CDF (left) and the accompanying failure rate function (right) with the 90% confidence bounds for the total population

Fig. 3: Figure 4 in paper 546

Paper 292 reports on power transformers failures observed during 10 years in the Eskom network. Causes of failures, as well as evolution of failure rate with age, are given. Based on this comprehensive study, changes have been introduced in the design specification of power transformers, as well as in their operation and maintenance.

Paper 108 focuses on statistical tools and probabilistic modelling applied to population of power transformers, instead of individual transformers. Progresses made in this field upon previous work are presented: it is expected that such tools can assist in better asset management of these ageing components.

Finally paper 187 reports on statistical data processing of state parameters measured on power transformers, in order to detect those which have the main impact on the reliability of these components.

Thermal ageing of current joints (1 paper)

Paper 537 presents a review of the ageing mechanisms applicable to high current joints. On the basis of long term tests, an ageing model has been developed, which allows estimation of the residual life time of joints when their present resistance is known (by instance through infrared measurements) and future load currents are forecasted.

Ageing of electronic components of control system (1 paper)

Paper 299 reports on the actions undertaken by EDF to check the condition of the ageing control systems of HV/MV substations and define a maintenance strategy for these components. Overall the control systems have been found to be in good condition and maintenance solutions have been identified to keep them in service for yet a long time (e.g. 10 more years for 25 years old equipment).



Fig. 4: Damaged chemical capacitor shown in figure 1 of paper 299

Question 6 Block 1: Are there other studies under way on ageing of electronic equipment associated to power equipment? Is replacement of control systems mostly caused by functional evolutions or by ageing and loss of reliability?

Outdoor insulation (2 papers)

Paper 294 describes an accelerated ageing test procedure suitable for outdoor polymer surge arresters used in Korea: 3000 hours of this test procedure have been found to be approximately equivalent to 6 years of ageing under typical outdoor conditions in this country.

Paper 344 presents the results of comprehensive condition assessment tests performed on MV composite insulators after 6 years in service in the central part of Iran: these tests confirm the good condition of these insulators and their suitability for application in severe desert environment.

Ageing of vacuum interrupters (1 paper)

Paper 156 in sub block 3.4 addresses this topic, among others which explain its filing in Block 3.

Sub block 1.3 – Network phenomena

Ferroresonance (1 paper)

Paper 197 provides a comprehensive review of ferroresonance phenomena involving three-phase distribution transformers in the network. The causes, symptoms and preventive solutions that can be used are presented.

Unequal sharing of currents in parallel circuits (1 paper)

Paper 275 presents a practical and effective method for improving the sharing of load currents between parallel MV single-core cable feeders. This method is based on field measurements and network simulation to find the best permutation of cable terminals in order to achieve optimal sharing of the load currents.

Table 1: Papers of Block 1 assigned to the Session

Paper No. Title	MS am	RIF	PS
779 : Experiences and new developments with Condition Based Maintenance in the Netherlands	X		
178 : New Generation of On-site Diagnosis for Distribution Power Cables			X
221 : A Practical Approach towards Estimating Remaining MV Cable Life	X		
136 : Field case study of MV cable accessories with PD in the Hydro-Québec underground distribution network			X
064 : A Practical Approach towards Optimizing the Utilization of MV Cables in Routine Network Planning			X
355 : Modern approaches to cable ratings in the UK	X		
661 : Assessment of remaining lifetime and failure probability for network components - a practical approach	X		
407 : Economic decision model for end of life management of distribution switchgear			X
446 : Lifespan prolongation of MV switchboards of MV/LV public distribution substations			X
489 : Corrosion – key factor of durability and safety in the operation of the distribution power networks			X
143 : Technical Solution and Solid State Devices for Increase of Durability and Reliability of Underground Power Lines (UPL)			X
724 : Water Tree Aging Characterization of MV XLPE Cable Insulation by Time Domain Spectroscopy (TDS)			X
517 : AC strength test data of unaged and water tank aged XLPE compounds for transmission and distribution power cables			X
720 : Distribution Transformer Thermal Behavior and Aging in Local-Delivery Distribution Systems	X		
053 : Thermal behavior of distribution transformers in summertime and severe loading conditions			X
546 : A statistical approach to processing power transformer failure data			X
292 : Large Power Transformer Reliability Improvement in Eskom Distribution			X
108 : Forecasting Reliability of Transformer Populations			X
187 : Defining and Evaluating the Parametrical Reliability of Power Transformers in Oil			X
537 : Ageing of High Current Joints in Power Transmission and Distribution Systems			X
299 : Aging of the control system of the EDF primary substations	X		
294 : Long Term Reliability Assessment Method and Aging Characteristics of Polymer Surge Arresters			X
344 : Performance Evaluation of Medium Voltage Composite Insulators in Desert Area of Iran			X
197 : Ferroresonance in three-phase power distribution transformers: Sources, consequences and prevention			X
275 : Mitigation of severe unequal sharing of the load currents in medium-voltage single-core parallel cable-feeders			X

Block 2 – Diagnostic tools and methods

Sub block 2.1 – Insulation diagnosis

Off-line diagnosis of MV cables (4 papers)

Partial discharges (PD) measurements in laboratory are made with power frequency test voltage: this method is not applicable to cable circuits in the field because of the excessive value of capacitive cable-charging current. Alternative test methods are described in the first two papers.

Paper 84 presents the oscillating wave testing systems which allow off-line PD diagnosis of MV cables to be performed at approximately power frequency but with decreasing amplitude of the test voltage wave. Typical patterns of PD for different types of cables and defects are presented. In complement to part 3 of paper 779 (see in sub block 1.1) it is shown how statistical analysis of PD data can be used to deduce knowledge rules for the condition assessment of cable circuits.



Fig. 5: OWTS shown in Figure 1 of paper 84

Paper 627 describes the more common very low frequency (VLF, 0.1 Hz) test method and reports on recent studies done for comparison of VLF and power frequency test voltages for PD diagnosis. Both techniques seem to give similar results regarding PD inception voltages and phase resolved pattern when applied to typical defect samples. Hence it is concluded that VLF test sets can be used as a convenient and suitable tool for accurate PD diagnosis of

MV cables and accessories.

The next two papers are centred on diagnostic methods applicable to the older technology used in MV cables, paper insulated lead covered (PILC), which has been generally substituted by cross-linked polyethylene (XLPE) insulation. However many ageing PILC cable circuits are in operation and it is important to use suitable diagnostic methods to check their condition.

Paper 413 reports on the experience of TNB in Malaysia in the condition assessment of PILC cables. It is shown that a combination of PD mapping and polarization index diagnosis is suitable for adequately evaluating the severity of cable condition.

Paper 457 presents a diagnostic method tested by EDF for detection of defective joints on PILC cables due to water ingress. $\tan \delta$ measurements have been found to be a suitable tool for that purpose, while PD diagnosis cannot be used for detection of this kind of defect.

PD diagnosis applied to MV switchgear (5 papers)

Paper 230 reports on experiments performed by ABB Italy on several commercially available PD detecting devices, to check their ability to detect and locate PD sources in MV metalclad switchgear. These devices, which are of variable sophistication level, confirm their usefulness for detection of PD either in routine check or in permanent monitoring.



Fig. 6: UltraTEV device shown in Figure 4 of paper 230

Paper 475 focuses on one of the devices tested by the authors of paper 230 and reports on the experience of two utilities in using the Ultra TEV PD detector developed by EA Technology. This basic, easy to use, device has proved effective in pointing out strongly defective equipment and has increased the confidence of operators by allowing them to check the condition of equipment before working in a substation.

Contrarily to those mentioned in the previous two papers the devices presented in paper 516 are still experimental and restricted to surface discharge detection. This paper reports on research work performed to check feasibility of applying low cost optical and acoustic sensors for corona and surface

discharge phenomena in MV switchgear configuration. Promising results are presented for combined light and noise optical detectors.

Finally papers 759 and 782 report, from the manufacturer's and user's points of view, on development and experimental work performed in Korea on external and internal UHF PD sensors applicable to MV gas-insulated switchgear. A specific sensor installed inside the MV switchgear is presented, which allows permanent PD monitoring.

On-line PD monitoring of cables (4 papers)

The papers in this section will be presented by the authors and discussed in round table RT1B "Reliability of cable links: The challenge of on-line partial discharges monitoring".

A good introduction to this topic can be found in paper 551 which describes the potential benefits of the newly available on-line PD monitoring and mapping equipment. Convincing results in detection of critical cable sections and prevention of failure have led EDF Energy to launch a targeted deployment of this technology, covering about 10% of their MV distribution network.

Paper 276 describes the latest on-line PD monitoring system from IPEC, which incorporates fully automated collection and analysis of PD data. It is therefore possible to provide, without human expert intervention, criticality information allowing timely maintenance on monitored circuits.



Fig. 7: Advanced substation monitor shown in Figure 3 of paper 276

On-line PD monitoring systems are usually applied to cables and other indoor MV equipment: paper 675 discusses adaptation of these systems to outdoor equipment monitoring. In this case the challenge is sorting out internal PD signals from the corona and other surface discharge signals which are of lesser concern. New test techniques and analysis of pulse signals have proved efficient in detecting PD phenomena in these difficult conditions.

Finally paper 691 describes the new possibilities offered by the combination of on-line PD detection and RCC ground fault neutralizer. Adjustment of the neutral-to-ground voltage allows particularly PD quenching and PD detection at voltages higher than U_0 , and is therefore a valuable addition to the on-line PD monitoring system.

Question 1 Block 2: How can be compared the costs of on-line and off-line diagnostic methods, in terms of equipment, data processing and performance ?

Fault location (1 paper)

Paper 327 presents the advances in fault locating for underground LV distribution networks. Sophisticated signal processing applied to conventional time domain reflectometry method allows relatively easy location of faults, without requiring expert interpretation of the recorded data, in spite of the complexity of these networks.

Question 2 Block 2: Are these locating methods easy to use by field workers or are they still close to laboratory tools ? Have they already changed the way repair work is planned and carried out ?

Sub block 2.2 – Thermal diagnosis

Infrared thermography (2 papers)

Paper 279 reports on the experience of Edenor in Argentina of applying systematically infrared thermographic inspections as part of its predictive maintenance program. Positive results in terms of decrease in failures or abnormalities, and increase in maintenance teams' skills, are presented.

Paper 564 reports on the application of aerial infrared thermography inspection to HV and MV overhead lines in Slovenia. Statistics of faults detected and prevented, as well as results of experiments performed to determine emissivity coefficients of new and aged circuit components, are presented.

Temperature monitoring (2 papers)

Paper 788 describes a new temperature monitoring system based on surface acoustic wave (SAW) technology passive sensors which is applied to overhead lines of transmission networks, in order to optimize the line capacity and adjust the load to external conditions.

Paper 102 describes the implementation of a temperature monitoring system for disconnecting contacts of withdrawable circuit-breakers in metalclad switchgear. The system is based on self supply by means of an auxiliary current transformer and wireless data transmission: reliability of operation and economic performance are said to be suitable.

Sub block 2.3 – Other diagnosis and miscellaneous

Diagnosis of power transformers (2 papers)

In addition to the papers presented in block 1, power transformers diagnosis is also addressed in the following two papers.

Paper 649 presents the modelling work performed to forecast water content in oil as a function of operating temperature. This allows accurate interpretation of data provided by water in oil sensors under varying load and temperature conditions, and opens the way to efficient on-line monitoring of power transformers.

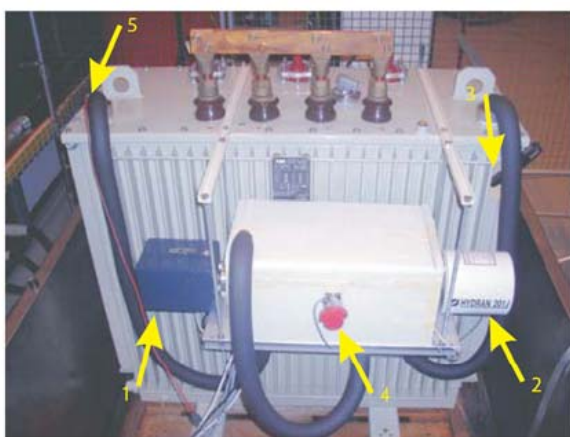


Fig. 8: Installation of the sensors at the experimental setup shown in Figure 4 of paper 649

Paper 784 describes a mathematical model correlating the degree of polymerization (DP) of paper with measured values of known indicators of paper insulation ageing, such as furans, CO, CO₂ contents in oil.

Question 3 Block 2: Is valid modelling achievable when there is so much scatter of the data used for establishing relationship between indicators and age, as is the case in examples given in paper 784 ?

Diagnosis of circuit-breakers (1 paper)

Paper 388 describes investigation work performed to assess the condition of in service SF₆ circuit-breakers in order to upgrade their reclosing capability. It was found that measurement of main and arcing contacts resistance during opening operation was a good indicator of the wear of the

circuit-breaker interrupting chamber. On this basis it has been possible to select circuit-breakers in good condition which can be upgraded to the new reclosing duty specified by ENEL, as this has been demonstrated by switching tests performed in CESI laboratory.

Question 4 Block 2: Is contact resistance measurement a possible wear indicator for other types of SF₆ circuit-breakers ?

Methods for data mining (2 papers)

Paper 68 explains how Rough Set theory can be used to put in relation known fault conditions and attribute data recorded by on-line PD monitoring systems. This method helps to work out knowledge rules and the significant attributes that are useful to be recorded.

Paper 379 presents new developments in expert system for fault diagnosis of power transformers. The use of several artificial intelligence methods provides improved performance in data mining and establishing a reliable diagnosis.

Instrument transformers accuracy check (2 papers)

Paper 778 reports on work in progress for development of voltage and current transducers, as well as associated measuring system, that can be used for live on-site accuracy check of HV instruments transformers used for metering.

Paper 833 describes a solution developed for using existing protection-class current transformers (CTs) as metering CTs. For this purpose accuracy errors of existing CTs are recorded, through comparison with a reference CT installed by means of live-line techniques, and corresponding correction factors are programmed into an adaptation module of the associated revenue meter.

Question 5 Block 2: A great variety of diagnostic methods and measured indicators have been described: will the future be based on global sophisticated diagnosis using exhaustive data collection or rather on the selection of one method simpler and more effective than the others ? What is today the cost/profit assessment that can be made of these methods ?

Table 2: Papers of Block 2 assigned to the Session

Paper No. Title	MS am	RT1B	RIF	PS
084 : Experiences with Offline PD-Diagnosis on MV cables – Knowledge Rules for Asset Decisions	X			
627 : New Studies on PD Measurements on MV Cable Systems at 50Hz and sinusoidal 0.1Hz (VLF) test voltage	X			
413 : Condition Assessment of in service Medium Voltage Underground PILC Cables Using Partial Discharge Mapping and Polarization Index Test Results.	X			
457 : Diagnostic for cable system asset management and preventive maintenance at EDF				X
230 : Non intrusive operational MV switchgear condition assessment	X			
475 : Benefits and Experiences of Non-Intrusive Partial Discharge Measurements on MV Switchgear				X
516 : A new approach to integrity assessment of electrical components of the medium voltage distribution network				X
759 : Development and application of UHF PD detection system for SF6 insulated MV switchgear	X			
782 : Partial Discharge Measurement System and Fault Analysis of 25.8kV SF6 Gas Insulated Switchgear in Korea				X
551 : Innovative asset management and targeted investments using on-line partial discharge monitoring & mapping techniques		X		
276 : Advances in continuous Partial Discharge monitoring		X		
675 : On-line PD testing of outdoor HV plant – Applying experiences from 10 years of PD testing indoors		X		
691 : On-Line Partial Discharge Measurement and Control		X		
327 : Intelligent Fault Location for Low Voltage Distribution Networks	X			
279 : Experience performing infrared thermography in the maintenance of a distribution utility				X
564 : The analysis of thermographic reports with emphasis on emissivity coefficient determination of bare conductors and joints				X
788 : Temperature measurement on overhead transmission lines (OHTL) utilizing surface acoustic wave (SAW) sensors				X
102 : Online Temperature Monitoring Instrument for Contact of CB Truck in AIS Switchgear				X
649 : Implementation of a model-based diagnosis system for power transformers.	X			
784 : Estimating the age of paper insulation in 33/11 kV distribution power transformers using mathematical modelling				X
388 : Diagnostic methodology to enhance operational performance of SF6 insulated circuit-breakers				X
068 : Rough Set Theory for Data mining in an On-line Cable Condition Monitoring System			X	
379 : A Fault Diagnostic System for Insulation Diagnosis of Power Transformer Based on Multi Artificial Intelligence			X	
778 : A New Tool for Live, On-site, HV Instrument Transformers Accuracy Check				X
833 : Current Transformer Reclassification and Verification				X

Block 3 – Interaction between network components and their environment

Sub block 3.1 – Safety

The 4 papers in this section will be presented and discussed in the round table RT1A “How to integrate safety in design?”.

Paper 133 proposes a broad approach to the topic of safety in MV electrical installation. It shows that this matter far exceeds the type testing of MV switchgear for internal arc faults. A comprehensive review of the risks, the failure causes and the possible solutions for mitigating the effects of an insulation failure is presented. Arc-proof switchgear is only one of the available solutions: simpler and more efficient ones can be applied when suitable choices are made at the design stage of the installation.

Paper 227 presents the “Arc eliminator” active device which can complement internal arc withstand passive protection when added to MV switchboards. Light detection and fast actuator allows for short-circuiting of the fault current and suppression of the arc in about 5 ms, thus achieving a drastic reduction in the effects of the fault.

Question 1 Block 3: How is reliability of equipment affected by the addition of such active short-circuiting devices to MV switchboards ?

Paper 256 describes Eskom approach to safety of MV switchgear and substations. Significant improvements over previous situation have been brought by the use of oil-free switchgear, specification of internal arc tested switchgear and prefabricated substations, and application of safe working practices.

Paper 785 provides a comprehensive review of internal arc test conditions and requirements in the IEC62271-200 standard. It shows how simulation tools can be used to assist in the design of switchgear, by proper evaluation of the mechanical and thermal stresses imposed by the arc fault, and reduce the number of iterations in actual testing.

Question 2 Block 3: What is the experience feedback on adequacy of safety standards (notably for internal arc protection) with effects of actual faults occurring in the field ?

Sub block 3.2 – Environment

This is a transverse theme which can be addressed in many different ways: the 6 following papers give a good example of the variety of possible approaches to this topic.

Paper 104 presents the new integrated information system developed by Iberdrola in order to incorporate environmental constraints into the planning of network

growth. Application to evaluation of new overhead lines projects is described, as well as new designs for improved avian faun protection.

Paper 357 presents the process developed by EA Technology for removal of insulating oil from decommissioned PILC cable circuits. This process is effective in removing approximately 90% of the total oil content in the cable circuit.

Question 3 Block 3: What is the environmental risk associated with the remaining oil content after treatment of cables ?

Papers 409 and 465 describe the eco-design methodology used by Areva T&D to evaluate the materials and design choices for respectively new insulating rod and ZnO surge arrester. Life cycle analysis and end of life assessment tools are applied and result in better recycling of the new components at the end of their service life.

Paper 555 reports on experimental work carried out to compare in accelerated ageing tests the behaviour of ester-based oils (either natural or synthetic, they are characterized by high biodegradability) and mineral oil. It was found that paper insulation ageing is reduced in the case of ester-based oils and that retro filling of transformers with such oils is a way to extend their life expectancy.



Fig. 9: Single phase device for thermal ageing shown in Figure 1 of paper 555

Finally paper 626 reports on investigation performed by ENEL to assess the risks associated with conversion to lead-free soldering process for electronic circuit boards used in

energy meters. Several potential failure mechanisms have been investigated through ad hoc ageing tests. It turns out that the component delamination (for both integrated circuits and printed circuit boards) failure mechanism presents a high risk in lead-free technology: careful implementation of the new process is therefore required to master the risk level and keep same satisfactory behaviour as previous generation electronic circuits (see paper 299 in block 1).

Sub block 3.3 – Modelling and design tools

Thermal modelling (2 papers)

Paper 271 describes modelling tools applied in the development of prefabricated substations. Thermal simulation is used for the design of enclosure, taking into account conduction, convection and solar radiation, in order to minimize the temperature rise and the subsequent ageing of transformers. In addition environmental impact evaluation tools are used to compare the merits of the two main classes of materials which can be considered for enclosure manufacture, i.e. metal and concrete.

Question 4 Block 3: Is it possible to apply finite elements tools for thermal simulation of substations, in order to accurately model air flows inside the enclosure and obtain predictive results ?

Paper 576 describes a finite elements software tool applied for thermal simulation of MV fuses: good correspondence between modelling results and experimental measurements has been obtained.

Network simulation (4 papers)

Paper 207 presents EMTP/ATP simulation study of a Rogowsky coil tentatively applied as PD sensor for detection of fallen trees on covered conductors: comparison of experimental results and simulation has allowed to understand the origin of excessive attenuation in the used circuit.

Paper 689 presents the application of ATP simulation to assist in the interpretation of recorded signals during impulse voltage testing of transformers presenting interturns windings failures. Recommendations on characteristics of recording equipment and test procedures are made for improved detection of such failures.

Paper 1 introduces a black box arc model which has been developed for use in EMTP software. This model allows to evaluate the influence of circuit-breaker switching characteristics on the recovery voltage and over voltages.

Finally paper 700 discusses three-phase electric arc modelling by the Park method.

Question 5 Block 3: What are the major advances which are still needed in the physical modelling of the components and their behaviour ? Could further progress in modelling significantly reduce the resort to destructive testing ?

Mechanical simulation (1 paper)

Paper 309 presents the thermal, mechanical and fatigue analysis and calculation performed to check the behaviour of hermetically sealed oil transformers against the mechanical stresses caused by the loading cycles in the transformer tank.

Sub block 3.4 – Test methods and applications

Tightness tests (2 papers)

Paper 41 focuses on the gas-tightness performance of SF₆-insulated, sealed for life, switchgear. It is shown that temperature, elapsed time after mechanical operations, and measuring principles can have significant influence on the results of type tests according to the (future) IEC62271-1 standard. Statistical variations, as well as accuracy of the measuring system used for routine testing in factory, are also to be taken into account: accordingly several proposals are made for revision of the present standard requirements, in order to effectively ensure a service life longer than the 30 years expected lifetime.

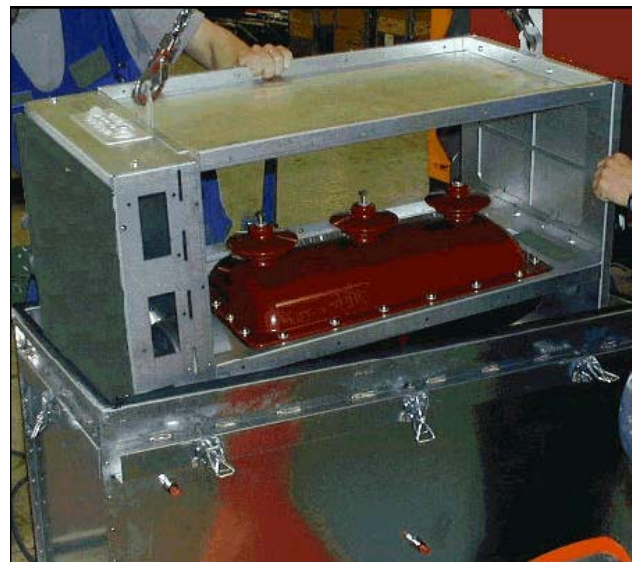


Fig. 10: Tightness test setup shown in paper 41

Paper 156 is related to vacuum tightness and addresses the concern raised over the expected lifetime of vacuum interrupters, as expressed for instance in reference [1]. Although now a significant number of vacuum interrupters have exceeded their initial design life of 20 years, there is no sign that they are approaching the end of their service life. Actually vacuum interrupters are sealed for life devices which are characterized by a zero leakage rate. For this reason loss of vacuum will not be due to time only, but will

involve some other failure cause (e.g. corrosion, mechanical life of bellows exceeded, static fatigue of ceramic insulator). If these factors are under control, life expectancy of vacuum interrupters can be much longer than 30 years.

Question 6 Block 3: What are the prospects of developing the suitable diagnostic technique called for in conclusions of [1], in order to detect those vacuum interrupters which are prone to early failure after their design life is exceeded ?

Switching tests (2 papers)

Paper 383 reports on development and testing of a generator vacuum circuit-breaker for mid-size (100-200 MVA) generators. The specific issues in application and testing are discussed and the differences between generator circuit-breakers and general-purpose (distribution) circuit-breakers are outlined.

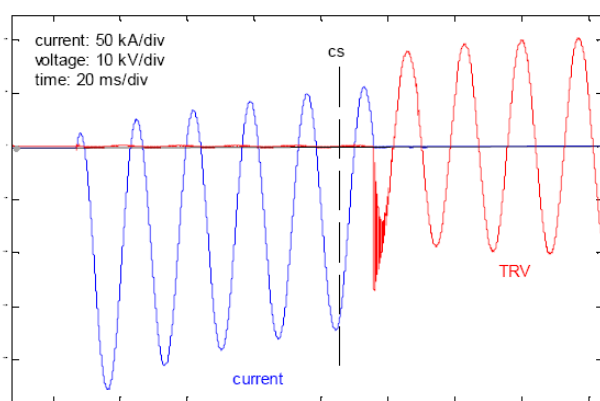


Fig.4: Interruption of 80.1 kA_{RMS} current with 53% asymmetry by a vacuum generator circuit breaker. cs: contact separation. The figure shows one phase of a direct three-phase test.

Fig. 11: Figure 4 in paper 383

Paper 387 presents experiences in testing vacuum switchgear according to the new requirements included in Amendment 2 of IEC62271-100 for short-line fault and transformer-fed fault. The fast rate of rise of corresponding transient recovery voltage (TRV) is a challenge to test circuits and measurement systems, but does not appear to be of concern for vacuum switchgear which are known for their fast dielectric recovery after current interruption. Also the influence of TRV circuit (series or parallel damping) on the switching behaviour of vacuum circuit-breakers is discussed.

Question 7 Block 3: Does the available experience feedback allow to compare life duration of SF₆ and vacuum switchgear ?

Question 8 Block 3: Is the parallel damped TRV circuit considered by KEMA as more realistic favourable to vacuum switchgear performance ? If not should it be prescribed as compulsory in the standards ?

Capacitive current switching (2 papers)

A good review of the subject is given in paper 579 which reports on experiments performed on various types of contact materials for vacuum circuit-breakers in order to compare their behaviour in capacitive current switching duty. Pre-arcing and restrike characteristics are discussed and shown to be related to different phenomena. The choice of a suitable contact material is one of the main factors in achieving good capacitive current switching performance with vacuum switchgear.

Question 9 Block 3: Are the contact materials used for circuit-breaker vacuum interrupters suitable for frequent capacitive current switching duty ?

Paper 639 presents EMTP simulation work done to investigate protection of capacitor banks by surge arresters, in order to prevent excessive over voltages across capacitor terminals in case of multiple restrikes and voltage escalation phenomenon.

Question 10 Block 3: What protection should be considered in the more common case (for vacuum switchgear) of single restrike or NSDD, in order to prevent excessive phase-to-ground over voltages ?

Vacuum switching devices are not as suitable as SF₆ ones for control of MV capacitive loads, therefore substitution of SF₆ switchgear in this field is still the subject of research work to investigate novel concepts, such as the one described in paper 665 (see sub block 4.1).

REFERENCE:

[1] L. T. Falkingham, 2006, "The assessment of vacuum insulation condition in time expired (> 20 years old) vacuum interrupters and switches", Proceedings of 10th INSUCON, p. 41-45

Table 3: Papers of Block 3 assigned to the Session

Paper No. Title	MS pm	RT1A	RIF	PS
133 : Safety analysis of a MV installation, regarding arcing fault risk		X		
227 : Active protection against internal arcing for operators and equipment protection		X		
256 : Operator and public safety revisited: The application of IEC 62271-200/202 with specific focus on internal arc testing of metal-enclosed switchgear and controlgear		X		
785 : Experiences with IEC62271-200 in case of internal arc testing of medium voltage switchgear		X		
104 : Implementing new overhead lines eco-design using GeoEnvironmental Information System.	X			
357 : Advances in the decommissioning of end-of-life oil filled cables	X			
409 : The management methodology used for the introduction of new "Eco -Friendly" materials within medium voltage switchgear systems.				X
465 : Global impact assessment of an optimised environmentally friendly lightning arrester				X
555 : Experimental characterization of ester based oils for the transformer insulation				X
626 : Technological conversion to "Lead Free" production: assessment of the reliability for the electronic energy meters	X			
271 : Analysis of the impacts of thermal exchanges in HV/LV prefabricated substations within a global eco-design approach	X			
576 : New FEM model for the thermal analysis of medium voltage fuses			X	
207 : Modeling of Rogowski Coil for On-line PD Monitoring in Covered-Conductor Overhead Distribution Networks			X	
689 : Model of Transformers Winding for Lightning			X	
001 : Universal arc resistance model "ZAGREB" for EMTP			X	
700 : Park three-phase approach to electric arc dynamic analysis			X	
309 : Calculation of Mechanical Stresses in Hermetically Sealed Transformers			X	
041 : Compatibility between metal-enclosed switchgear and typical network conditions – Feedback from Belgian DNO	X			
156 : Vacuum Interrupters -Sealed for Life	X			
383 : Test experiences with a new generator circuit breaker based on vacuum technology				X
387 : Test experiences with new medium-voltage TRV requirements in IEC 62271-100				X
579 : Requirements for Vacuum Circuit Breakers under Capacitive Switching Duty				X
639 : Surge arrester application of MV capacitor banks to mitigate problems of switching restrikes				X

Block 4 – New designs and solutions

Sub block 4.1 – New designs

Cables: new materials, standards, applications (6 papers)

The first 2 papers present innovations in the materials used for cables manufacture.

Paper 121 explains the advantages provided by the introduction of XLPE and HDPE for, respectively, insulation and jacketing of LV cables: higher capacity for a given size, lower laying costs and higher reliability.

Paper 441 describes development work and test results relative to a new formulation of semi-conductive compound for cable shields, which is expected to perform better than existing compounds, in terms of both processability and quality.

The next 3 papers are centred on evolutions in the field of specifications and standards applicable to cables and accessories.

Paper 678 reports on the introduction of a new type of LV service cable in EDF and EDF Energy networks. Specification, validation and economic assessment of the new solution are presented.



Fig. 12: Single core cables (old and new) shown in paper 678

Paper 854 presents the EuroMVcable project and the achieved results. The proposal of 4 models and the relative tests data provide a good basis for further European harmonising work in the field of MV distribution cables.

Paper 414 reports on the standardisation work which is done to collate national standards and specifications and harmonise them into the new European standard EN50483 on low voltage aerial bundled conductors (LV ABC) accessories, which will be circulated as a draft at the end of 2007.

Question 1 Block 4: Is launching of standardisation work to promote innovation and evolution of equipments considered as a priority ? If yes, in what fields ?

Finally paper 879 reviews technically and economically the various solutions available for sub sea cable connections between future high power offshore wind farms and the main land. Proposals are made which take into account all involved costs (installation, operation, repairs, availability).

Switchgear (8 papers)

Paper 155 reviews the evolution of disconnecting and earthing devices in MV switchgear, from historical background to modern trends. The various options available are discussed and their merits compared. 2-positions change-over switch associated to a vacuum switching device is presented as the most efficient solution.

Question 2 Block 4 : 2-positions change-over switches seem indeed sufficient for secondary distribution switchgear, but aren't 3-positions disconnect switches preferable for primary distribution switchgear ?

Paper 504 describes the new range of 3.6 kV RMU developed by Eaton Holec for the retrofitting of the signalisation circuits of the French national railways (SNCF), on the basis of the well-proven Magnefix switchgear.

The next 2 papers expose the viewpoint of users on the specification and development of new types of switchgear and enclosures.

Paper 523 presents the specification established by ENEL for introducing a new type of MV switchgear incorporating a vacuum circuit-breaker into existing MV/LV substations. The purpose is to upgrade these substations in order to expand application of the automatic fault detection system developed by ENEL.

Paper 302 explains the new approach used by EDF for the development of a new range of LV service box. This approach is based on definition of cost target and functional specification, subcontracting of the development to one supplier and finally tendering for manufacture according to the design owned by EDF.

The next 2 papers are presented by Tavrida Electric.

Paper 126 introduces the new concept of ETALON 12 kV metalclad switchgear developed by Tavrida. The main features of this design are: combined switching module (vacuum circuit-breaker and 3-positions disconnect), high compactness (for air-insulated switchgear) and mechanical

resistance of the structure to internal arc effects.

Paper 762 describes untypical applications of Tavrida reclosers in Russia, where reliability of supply is sought through the use of these remote controlled protection devices which allow fast reconfiguration of the circuits.

Paper 688 presents an innovative design of bus bars connecting system for MV gas-insulated switchgear. The B-Link design from Areva combines the respective advantages of the two commonly used bus bars connecting systems (i.e. the bi-cone and the separable connector types) at the price of some additional spacing between two adjacent cubicles.

Question 3 Block 4: Considering globally innovation in designs, is it possible to rank the main evolution drivers: cost reduction, notably in order to offset raw materials increases; the need for new functions and performances; present and forecasted environmental constraints ?

Finally paper 665 introduces a novel concept of MV capacitor switch based on solid-state switching and synchronised operation. This proposed device features the advantages of transient-free operation (low inrush currents), very low probability of restrike and high electrical and mechanical endurance. This makes it suitable for back-to-back capacitor banks switching, where frequent operations are performed to adjust the reactive power required by the network.

Question 4 Block 4: This novel concept appears interesting to overcome the drawbacks of vacuum switchgear for frequent capacitive switching duty, has the economic feasibility been validated for higher voltage ratings than 12 kV ?

Substations (5 papers)

The first 2 papers are related to underground vaults specific conditions.

Paper 58 presents the new design of underground substations developed by Hydro-Québec as well as the solutions retained for upgrading existing vaults. Reduction of water infiltration, as well as improved air circulation and cooling, are the advantages obtained in this new design and after upgrading.

Paper 644 reports on experimental work and economic analysis performed to define the most suitable cooling system for underground vault transformer substations: forced air cooling during peak hours was found to be the most efficient solution to keep acceptable transformer life with reduced energy cost.

The next 2 papers introduce new designs of prefabricated substations.

Paper 342 presents a new concept of transformer substation whose main features are: compact footprint thanks to 2-levels arrangement of internal equipment; double

enclosure in order to provide an attractive outside enclosure which can be used as advertising support.



Fig. 13: Internal equipment layout shown in Image 3 of paper 342

Paper 436 describes the new concept of compact secondary substation which is proposed by ABB for densely populated city areas. Both surface and underground substations have the following advanced features: internal arc protection; comprehensive local monitoring and control system; docking system for increased availability; low environmental impact (for visual, noise, electromagnetic fields and pollution aspects).

Finally paper 506 describes new types of mobile primary substations developed by ABB in Sweden. These substations are intended for quick restore of service in case of major fault in a substation. They can also be used in case of maintenance or upgrade work, and in some cases be considered as stand-by units, thus avoiding the use of redundant power transformers.

Question 5 Block 4: What are the main expectations today: reduction in the size of substations; better reliability; no maintenance; cost reduction ?

Current and voltage measurement (2 papers)

Paper 118 describes a post insulator system incorporating low power current transformer and voltage transformer and a signal processing unit, which can be used on MV overhead lines to remotely monitor the current and voltage conditions.

Paper 280 presents current and voltage sensors embedded in the HV circuit of oil insulated distribution transformers in order to provide HV metering and protection.

On-load tap changer (1 paper)

Paper 420 reports on development work done on a low cost on-load tap changer system to be used in distribution transformers in order to prevent abnormal rise of voltage level due to combined heat and power distributed generation

at time of low load. Prototypes are under construction and tests will start at mid 2007.

Overhead lines support (1 paper)

Paper 367 describes stayed steel support for overhead lines networks: initially designed for use as emergency support for fast repair of damaged towers, their advantages in terms of low weight and ease of installation has led to them being used also for construction of new lines in Russia.

Sub block 4.2 – Prospective solutions

Superconductivity (4 papers, including late paper 497)

Paper 196 reports on the feasibility study in progress about implementing a long distance high temperature superconductor (HTS) 50 kV cable link in downtown Amsterdam. This ambitious project would be the first significant application of HTS in transport networks. The issues and solutions related to cable design, cooling system and HV grid adjustments are presented and discussed: at this stage no insurmountable obstacle has been identified.

Paper 511 reports on the SLIM FORMER project sponsored by the European Commission. The objective of this project is to implement and test a 100 kVA demonstration prototype of this hybrid device, which combines transformation between conventional and HTS circuits with fault current limitation in order to protect the HTS circuit in the event of short-circuit. Principles of operation as well as results of simulation work are presented: a 20 kVA pre-prototype device is under construction.

Paper 578 reports on design and testing of superconducting fault current limiter (SFCL) prototypes at CESI. In this device HTS conductors switch to highly resistive state when the critical current value is exceeded, thus providing limitation of the fault current.

Question 6 Block 4: what are the characteristics of the protection scheme associated to the SFCL, in order to prevent damage to this device in case of short-circuit ?

Power line carrier (PLC) systems (1 paper)

Paper 295 presents EDF’s experience in integrating PLC equipment for high flow internet service into the electricity distribution network. Contractual framework, technical principles of PLC operation and conditions of integration are explained, and experiments under way are reported. Using electricity distribution network appears to be a viable

solution for bringing high flow internet service to remote rural areas.

Power electronics (1 paper)

Paper 410 reports on experimental results obtained on a 300 kVAr prototype reactive power compensator for MV distribution network. The device is based on a four-level electronic power converter associated to a connecting transformer used also for filtering: after satisfactory results of validation experiments the equipment will be connected to the grid for field testing.

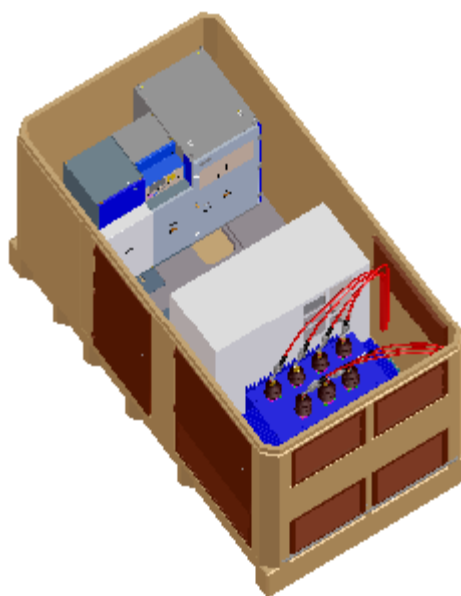


Fig. 14: Reactive power compensator layout shown in Figure 7 of paper 410

Nanotechnology (1 paper)

Paper 594 presents the prospects brought by applying nanotechnology in the field of power engineering. Possible reduction of conductor resistance (through the use of carbon nanotubes), improvement of insulating materials (by incorporating nanofillers) and surface insulation are listed. As an example are described experimental results showing improved hydrophobicity of ceramic insulators treated by nanocoating.

Question 7 Block 4: On the various prospective solutions presented, are there sufficient, even if limited, experience feedbacks available to demonstrate their operational advantage ?

Table 4: Papers of Block 4 assigned to the Session

Paper No. Title	MS Pm	RIF	PS
121 : Cable standards give opportunities for reduction of conductor metal resulting in lower cost of low voltage cables			X
441 : New Semiconductive Products Providing Higher Performance Cables.			X
678 : Evolution of the French LV underground service cable	X		
854 : Harmonising MV Cable System Design	X		
414 : European Work on LV ABC Accessories standard			X
879 : Subsea connections to high capacity offshore windfarms: issues to consider			X
153 : Evolution of disconnecting and earthing facilities in MV switchgear			X
504 : Smart solution for railway signalling infrastructure			X
523 : A low-cost high-performance MV switchgear for use in remote controlled MV/LV substations			X
302 : Presentation of an original step to develop a new box for single service connections			X
126 : New approach to design of advanced ETALON-type switchgear	X		
762 : Tavrida Electric Reclosers for Automation of the Distribution Networks of Russia			X
688 : A new and innovative busbar connection system for Gas Insulated Switchgear: B-Link			X
665 : A diode based transient free capacitor switch	X		
058 : Improved accessibility and cooling of underground transformer vaults			X
644 : Design of underground vaults with thermal simulation of transformer			X
342 : CeTur – Special urban transformer substation			X
436 : New design philosophies with Compact Secondary Substation	X		
506 : Mobile Substations			X
118 : Integrated Electronic Metering Insulator for Medium Voltage Overhead Lines			X
280 : Embedded Application of Voltage and Current Sensors In the Distribution Transformer			X
420 : Tap changer for distributed power			X
367 : Guy Polymer Cross-piece Supports for Overhead Power Lines of Distribution Network 35 - 110 kV Voltage			X
196 : Long distance Triax HTS cable			X
511 : A Novel Device protecting a superconducting cable and its connection to a conventional distribution network		X	
578 : Electrical Testing of 1 MVA-class Three-Phase Superconducting Fault Current Limiter Prototypes			X
497 : Development and demonstration of the 3-in-one high temperature superconducting power cable			X
295 : Integration of “High Frequency Power Line Currents” equipment in the public distribution networks			X
410 : Experimental validation of MV grid reactive power compensator based on a four level power electronic converter	X		
594 : The Prospects of Nanotechnology in Electrical Power Engineering		X	