A3 - 00

SPECIAL REPORT FOR SC A3
(High Voltage Equipment)

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Special Reporters

For the SC A3 Session 2016, three Preferential Subjects have been selected and a total of 29 Reports (306 pages) were submitted.

Preferential Subject 1: High voltage equipment for emerging system conditions

- Requirements for AC equipment, e.g. disconnecting switch, earthing switch, instrumental transformer.
- Requirements for DC equipment, e.g. DC circuit breaker, disconnecting switch, earthing switch, surge arrester / varistor.
- Developments in testing and verification.

Nineteen Reports are numbered under Preferential Subject 1.

Preferential Subject 2: Lifetime management of transmission and distribution equipment

- Influence of environmental and operating conditions.
- Optimized maintenance practices.
- Mitigation methods for overstresses and overloads

Five Reports are numbered under Preferential Subject 2.

Preferential Subject 3: Application of information technology tools for development & management of high voltage equipment

- Advanced simulations and design tools.
- Integration of intelligence into high voltage equipment.
- Translating data into useful information and actions..

Five Reports are numbered under Preferential Subject 3.

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Preferential Subject 1

HIGH VOLTAGE EQUIPMENT FOR EMERGING SYSTEM CONDITIONS

Emerging system conditions are (1) changing by recent environmental constrains (renewable sources, space restrictions, severe weather and earthquakes, reduction of SF_6 emission) and (2) a wider application of higher system voltages, both AC and DC, with larger power transmission. For AC systems such developments lead to the application of more and longer cable systems, more shunt and series compensation, also at higher rated voltages. For DC as well as AC systems, this leads to innovative equipment based on power electronics (HVDC converters, FACTS, flexible power generation and consumption), thus provoking more attention to power quality issues. And for HVDC a trend towards more mature (i.e. multi-terminal and meshed) grids can be seen.

In three Reports (**A3-104, A3-116, A3-118**) the accurate measurement of voltage disturbances, among others for power quality assessment, is addressed. These Reports will be dealt with under the heading power quality measurement. Another three Reports give information on issues related to higher voltages for AC circuit breakers: **A3-102, A3-105, A3-108**. Two Reports show the developments of SF_6 alternative gases: **A3-113** and **A3-114**. Four Reports are devoted to HVDC, especially HVDC circuit breakers: **A3-106, A3-109, A3-112, A3-117**. The increasing load currents lead to more severe stresses during bus-transfer current switching, as explained in one Report: **A3-103**. Another Report shows the possibility of auxiliary power supply to a remote substation through a power voltage transformer: **A3-111**. In three Reports transient phenomena in an AC network are analysed and their impact on equipment is described: **A3-107, A3-110, A3-119**.
The Reports **A3-101** on non-intrusive diagnostic techniques and **A3-115** on the voltage withstand stress of polluted composite insulators will be discussed under Preferential Subject 2.

Transient phenomena

The authors of Report **A3-119** discuss ferro-resonance that occurred while switching a short 420 kV cable. The switchgear is a GIS, that includes inductive voltage transformers (VTs). A one-line of the cable and the switchgear at both cable ends is missing. In this case the VTs are probably directly connected to the cable terminals, as may be deduced from the presented traces. However, the paper is a typical example of submitting some oscillograms recorded during and before a failure, without giving adequate and detailed information and an thorough analysis of the voltage patterns shown. After switching off the cable, ferro-resonance took place through such a voltage transformer in one of the phases (figures 8 and 9). Based on the (25%) residual voltages of the healthy phases, one could assume that the cable capacitance is three times that of the circuit breaker's grading capacitors. Further the development of the rms voltage in the faulty phase (figure 9) shows a varying but rather low amplitude, what seems to be strange in relation to ferro-resonance. Later that day, the 420 kV cable has been energized again, but tripped within two seconds: figure 4 and 5. A large pole discrepancy at closing as well as opening of the CB is visible and, again, a too low voltage level for the blue phase. Surprising is that after tripping the voltage patterns of the healthy phases are so different from the traces of the earlier cable de-energizing.

Q. 1-1 Such papers are provoking more questions than providing answers, mainly due to a lack of basic information and an explanation of the phenomena presented in the recordings. Are the authors capable to shed more light on this incident? Ferro-resonance has been elaborated in CIGRE Technical Brochure 569 (2014) of WG C4.307 and the case described looks like the example B5 in this Technical Brochure. Can the authors or the audience reflect on the usefulness of Technical Brochure 569 as a means to understand, to predict and to prevent ferro-resonance? Can experts provide further investigations, recommendations, and guidances, in this field? Ferro-resonance is also mentioned in Report **A3-107** for parts of a system with floating neutral, but not further elaborated.

In both Reports **A3-107** and **A3-110** transient phenomena are described and simulated. The authors of **A3-110** draw attention for the possibility of very fast transient overvoltages (VFTO) in air insulated

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substations, due to restrikes/re-ignitions in gas circuit breakers or due to disconnector switching in mixed technology substations. To the authors, VFTO may damage oil/paper insulated inductive voltage transformers. Simple models are used to calculate the voltage stresses along the windings of the VTs. Simple- models are used in Report **A3-107** as well, but with partially a more accurate representation of the network and equipment. It deals with situations where for economic reasons or space restrictions (permits) circuit breakers are omitted. In the Report the transient phenomena are analysed during power transformer energization in combination with a feeding cable or in combination with an outgoing unloaded OH-line (i.e. without a circuit breaker between transformer and cable or line). In particular the switching overvoltages at the secondary side (50 kV) are investigated and the tap position plays an important role in the transferred overvoltage by the winding ratio and the tap position dependant transfer function. The authors differentiate between time domains of (1) the capacitive transferred switching voltages, (2) the travelling wave phenomena, (3) the transformer natural frequency phenomena and (4) the resonances between transformer inductance and adjacent capacitances. Unfortunately, not enough information from FRA-measurements is available to build one transformer model that covers all these time domains.

Q. 1-2 As a result of their analyses the authors of Report **A3-110** propose to test an air insulated inductive VT for VFTO withstand capability by means of a chopped wave. The authors of **A3-107** warn for the possibility of resonances between transformer and cable or line. What is the service experience with VFTO in air insulated substations? Are experts dealing the opinion that VFTO in air insulated substation may form a risk and that the chopped wave test should be recommended? What is the service experience with switching voltages in constrained system configurations (also at other voltage levels); is it acceptable to delete circuit breakers or are special precautions necessary? Are the simple transient models as used by the authors of both papers suited to achieve firm conclusions?

Power voltage transformers

For substations at remote locations, there seems to be a need for inexpensive means to supply the substation load. To that purpose, one has designed a so-called power voltage transformer, which is capable to provide hundreds of kVA. It is not a VT, but a separate device (single phase or three-phase, AIS or GIS): Report **A3-111**. Some pilots are running, but no pictures are shown.

Q. 1-3 Is there a need for such devices and a need for standardization? Are the power voltage transformers as reliable as VTs? According to CIGRE Technical Brochure 512 (2012). the explosion rate of instrument transformers (ITs) is 0.02 fire/explosion per 100 IT-years (AIS); i.e. 10% of the MaF-rate. Are such failure rates to be considered as reliable and safe enough for users of ITs and users of power voltage transformers? What is the consequential policy and experience of utilities with respect to monitor, test and/or replace ITs?

Power quality measurement

The accuracy of VTs, especially when taking harmonics into consideration, is becoming a concern. Not only for power quality measurement, but also for accurate fault location, phasor measurements, protection and voltage control: **A3-104**. For that reason the authors are applying capacitive VTs (CVTs) for the higher rated voltages. For the sub-transmission levels, they will either use the existing inductive VTs, that may be upgraded by a calibration table or they replace them by special sensors.
In Report **A3-116** specially adapted CVTs with a separate wide band output are proposed to measure the higher harmonics. To verify the linearity of the CVT, the authors investigated the frequency response by means of a high voltage (repeated) impulse test with a fast Fourier analysis of input and output. Report **A3-118** is devoted to the calibration of electronic voltage transformers with respect to accurate measurement of harmonics. Since straight forward traceability is a problem, the authors use a capacitive divider with active self-calibration, in order to calibrate the tested electronic voltage transformer. Based on existing standards for electronic current (!) transformers, they analyse the errors and uncertainties of this calibration method.

Q. 1-4 All authors give examples of the developments that lead to more harmonics and voltage disturbances. Consequently, the importance of accurate voltage distortion measurements is increasing.

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But, is there indeed a strong relationship between the developments described and the actual percentages of harmonics? Is the THD (total harmonic distortion) increasing and higher harmonic orders? Are the criteria for the acceptable levels of harmonics based on hindrance for the customers? What is the influence of the varying short-circuit power levels in the transmission systems?

Q. 1-5 Is there a need for voltage transformers that are better suited to measure harmonics? Apart from only monitoring the network, is there a real application for the data gathered with the more accurate sensors? What technology is proposed: CVT, special outputs, special dividers (see also **A3-305**), electronic devices? What is the opinion of the experts of WG A3.31 "Instrument transformers with digital output"? And is there a need for better suited calibration methods, round robins or special test facilities?

AC circuit breakers

Series compensated lines are used for long distance transmission of large amounts of power; in the case of Report **A3-102** along 345 kV OH-lines. When clearing a fault (i.e. at current zero) the series capacitor bank is fully charged and this voltage contributes significantly to the transient recovery voltage of the line circuit breaker. The authors apply a Fast Protective Device that will bypass the series capacitor bank, when required, thus eliminating the additional voltage. The Fast Protective Device exists of an enclosed high voltage triggered gap in parallel to an enclosed very fast making switch. It is applied in combination with a current limiting and damping circuit. Further the capacitors are protected by MO surge arresters (varistors).
Bulk power transfer leads to higher rated voltages and Report **A3-108** pays attention on testing methods for the highest voltages for single pole circuit breakers as well as for the highest voltages for three-pole circuit breakers. Double synthetic circuits are applied for the full pole make and break tests at 800 kV and at 1100/1200 kV voltage levels, and to test closing resistor switches. Multiple synthetic tests are also necessary for the three-phase synthetic make and break tests, even after extension of KEMA High Power Laboratory's direct power capacity.
At a first glance, three-phase testing is also applicable to the 72.5 and 145 kV/40 kA/2000 A metal enclosed vacuum circuit breakers, described in Report **A3-105**. The single pole enclosure has an influence on the electric field inside the 72.5 resp. 145 kV vacuum bottles and requires special design of the vacuum interrupter. At 72.5 kV the enclosures are filled with 0.3 MPa dry air, but at 145 kV with 0.1 MPa SF_6-gas.

Q. 1-6 Synthetic test circuits (**A3-108**) require several triggered gaps. What is the experience with triggered gaps in synthetic test installations, gaps as used to by-pass series capacitor banks (CIGRE WG A3.33) and Fast Protective Devices as described in Report **A3-102**? To **A3-102** the Fast Protective Devices in all three phases are triggered, but is that necessary for single phase and double phase faults? And what happens with the series capacitor banks in nearby lines, as they may lead to an increase of the TRV at the source side? Synthetic testing with current as well as voltage injection is rather complicated, especially because of the critical moment of triggering the gaps. Can the principle be explained and also how pre-insertion resistors (closing and opening) are type tested?

Q. 1-7 Should the single pole metal-enclosed vacuum circuit breaker be type tested for its short circuit current making and breaking tests in a three-phase test circuit? Can the arc-circuit interaction of the vacuum breaker during short-line fault tests be explained? Can the authors of paper **A3-105** show more detailed test results from the capacitive current and out-of-phase current switching tests, being more critical for vacuum? Why did the authors apply a single break instead of a double break at 145 kV? What about the high X-ray radiation level of metal-enclosed, thus easy to access, equipment compared to the acceptable levels in the Standards? Since climate change is the main driver for the application of VCBs at higher voltage levels, why did the authors apply SF_6 gas to fill the 145 kV enclosure? Did the authors make a life cycle analysis on the CO_2-footprint of material production, gas depletion, energy consumption and material recycling and disposal processes, in comparison to alternative solutions?

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Alternative gases

In fact in Report **A3-105** an alternative for SF_6-gas is given, but in the Reports **A3-113** and **A3-114** alternative gases are presented. A mixture of Perfluoroketones with CO_2 and O_2 is proposed in Report **A3-113** as a SF_6 alternative gas. The authors claim it to be applicable to standard high voltage circuit breakers, that are designed for SF_6-gas. The authors show that the behaviour of a circuit breaker filled with the new mixture is slightly inferior to pure SF_6-gas during the initial (thermal) stage of current interruption. This has an impact on the interruption performance during the short-line fault type test. As a pilot the new mixture has been applied in HV and MV circuit breakers in a Swiss urban substation. In Report **A3-114**, the investigation is mentioned of another gas as a SF_6 alternative gas, but the developments seem to be less far as for the mixture described in Report **A3-113**. The gain in reducing the greenhouse effect is also inferior.

Q. 1-8 How critical are the mol-percentages in the gas mixture (**A3-113**) for the performance and how can manufacturers and users keep that under control? Can experts provide scientific data on interrupting performance in comparison with SF_6? What is the effect of the bad regeneration or degeneration of the Perfluoroketones? What are the components and mixtures of the other gas, mentioned in Report **A3-114**? Is it known as a fluoronitrile? What is the long-term stability of both gas mixturers and what happens with the gas composition at and after low temperatures?
How do assetmanagers assess the reduced performance of the gas mixture compared to pure SF_6-gas in combination with the improved greenhouse effects? Everything has been done to prevent future problems such as faced with SF_6-gas, but why do manufacturers choose such horrible names for technological solutions that have to calm down the society?

HVDC

Two years ago much attention has been paid to HVDC meshed cable network models and the reasons why DC fault currents have to be cleared within a time frame of some ms, even though there are different definitions on DC fault clearing time between system and equipment experts. Opposite to HVAC OH-line networks, the HVDC cable network is characterized by its low inductances (no transformers) and its large capacitances. Because of the low inductance a voltage dip is rapidly spread over in the entire HVDC network. Voltage source converters are sensitive to voltage dips larger than 20% and lasting longer than a few ms. At longer lasting voltage dips, a meshed HVDC network supplied by voltage source converters will collapse. The large capacitances (applied at DC-side of the converters and in addition the capacitances of the DC cables) lead to large discharge currents (fast raising fault currents), that may become harmful for the HVDC equipment. By additional reactors and fast acting circuit breakers it can be prevented that a short circuit evolves into a system collapse. JWG A3/B4.34 is dealing with the topic of switchgear for HVDC applications.

The HVDC circuit breaker is often required to clear a fault current within a few ms. Depending on the installed current limiting DC reactors, the fault current through the circuit breaker increases by several kA/ms or more. Such a duty can be handled by power electronic (PE) switches at costs of large investments and large energy losses across the PE devices. An alternative solution is offered by so-called hybrid (mechanical-electronic) circuit breakers, where the main current path flows through mechanical contacts, thus reducing the losses to lower values. However, the mechanical switch has to open its contacts very fast. In addition a current zero has to be forced in order to extinguish the arc. Several alternative solutions to fulfil these requirements are under study (**A3-106**, **A3-109**, **A3-117**) and most manufacturers apply a very fast electromagnetic actuator to open the contacts of the switch. In Report **A3-117** the current zero is forced by blocking a full PE bridge (of limited voltage rating and consequentially limited losses) in series with the switch and commutating the current to a parallel PE path. In fact the fault current is interrupted by the parallel path, as soon as the mechanical switch is in open position. In the other Reports a charged capacitor is discharged across the arc between the switch contacts, thus forcing a current zero. Discharging at the right moment is performed by a triggered gap (**A3-109**) or by a thyristor bridge (**A3-106**).

Q. 1-9 All three Reports show the transient voltage across the HVDC circuit breaker and the current through the whole circuit breaker and its individual parallel paths. The commutation of the current from one branch to another is rather clear until the varistor (MOV or MOSA) comes into play: what exactly determines the moment t_5 in the three papers? What happens at that moment and how is the source voltage counteracted? What determines the dimensions of the capacitor, its charging and residual voltage and the discharge frequency? And why are the three figures slightly different? Can experts foresee a solution for the rapid DC protection with different DCCB technologies applicable for the future meshed HVDC networks?

Report **A3-112** pays attention to surge arresters that have to protect the thyristor stacks in converter stations (in this case LCC or current source inverters). A “high cooling” arrester (i.e. without housing and with special cooling fins) is described, offering a 10% lower protective level to the thyristor stack than conventional arresters. The number of thyristors in series can be limited. To the authors the service experience is excellent.

Q. 1-10 Such “naked” MOSA could be applied for other indoor applications, but also for other applications such as for the HVDC circuit breaker or to protect series capacitor banks? Can examples be given and service experience? Are there alternative solutions? What is the opinion of experts from WG A3.25 “MO varistors and surge arresters for emerging system conditions”?

Testing of the HVDC circuit breaker fault current interruption includes the verification of the dissipation capability of the MOSA. In Report **A3-109** the authors put emphasis on the difficulty in a test circuit to present adequately the energy stored in the system’s inductances and converters, as this energy has to be dissipated by the MOSA. Note that HVAC circuit breakers interrupt usually at a natural current zero of the current in the branch to be disconnected, thus without stored energy in the inductances involved. However, in case of current chopping or virtual current chopping and similar phenomena, HVAC circuit breakers face the same problem of the need to dissipate the magnetically stored energy; for instance when switching shunt reactors.

Q. 1-11 Can the authors of **A3-106**, of **A3-109** and especially of **A3-117** highlight how they achieve a representative energy dissipation by the HVDC circuit breaker? How about other experts? How is the energy dissipation per column controlled in an MOV consisting of highly non-linear elements? What is the difference in energy dissipation phenomena between HVDC and HVAC circuit breakers in case of current chopping or forced current zero creation? Is it necessary to take an auto-reclosing duty cycle into consideration for HVDC circuit breakers? Can the experts show an alternative testing method for HVDC circuit breaker?

Bus-transfer current switching

IEC TC17 requested CIGRE SC A3 to update the DS bus-transfer current requirements. Several countries provided information on load and (extrapolated) bus-transfer currents in service. In addition to former publications on the statistics of bus-transfer current switching in Japan (300 kV and 550 kV), the authors of Report **A3-103** deal with the statistics of bus-transfer at the voltage levels of 72, 84 and 168 kV substations in Japan. Bus-transfer switching is performed with the disconnectors in a bay that are used to select to which bus the bay has to be connected. When switching from one bus to the other, the buses are shortly coupled by both bus select disconnectors and form a loop with the coupling bay. Currents to be switched and voltages to be encountered are determined by this loop and the sum of the voltage drops along the buses (from bay to bay). Similar to the 300 and 550 kV cases, the bus-transfer current may reach values up to 80% of the rated current of the disconnectors and in some cases it may become larger than 1600 A. For the larger bus-transfer currents, the bus-transfer voltage tends to be larger than the specified values in IEC Std 62271-102.

Q. 1-12 Although the bus selection disconnectors belong to a line (cable) or transformer bay, the bus-transfer current is determined by the buses and the coupling bay rather than by the maximum load of the bay. How do utilities determine the rating of the bus selection disconnectors (based on the rating of the buses or of the bay)? Since bus switching does not necessary take place at maximum load and further the load of the bay is not the most determining factor, how is in Report **A3-103** the maximum load determined and the bus-transfer current? Can the design of the order of the bays be adapted or the procedure for bus switching in order to reduce the bus-transfer current and voltage? Can other countries or users supply additional information on the load and bus-transfer currents in relation to the rated currents of the disconnectors? Can the experts provide experience with large bus-transfer currents? How can manufacturers deal with the more severe requirements for bus-transfer current switching? What are the developments in the related international standards?

Preferential Subject 2

LIFETIME MANAGEMENT OF TRANSMISSION AND DISTRIBUTION EQUIPMENT

Life management continues to be a topic of major interest for utilities and asset managers. Seven Reports deal with three different aspects on life management. Two Reports (**A3.101** and A3.**203**) are directly related with monitoring and life management, two Reports (**A3.115** and **A3.202**) discuss testing of polymeric insulators to determine their performance under pollution conditions and three Reports (**A3.201**, **A3.204** and **A3.304**) are directly related with overstresses, overloads and related mitigation measures. The latter topic has been discussed by WG A3.29, dealing with equipment ageing, and WG A3.30, dealing with overstresses applied to substation equipment.

<u>Composite insulators performance under pollution</u>
In the Reports **A3-115** and **A3-202,** the problems are discussed, when the dielectric performance of polymeric insulators is demonstrated by means of the tests. Nowadays it is recognized that the IEC 60815 still does not cover adequately polymer insulators for both AC and DC applications. The behavior of polymer insulation surface under pollution conditions cannot be accurately represented by the ESDD (Equivalent Salt Deposit Density) and NSDD (Non soluble material Deposit Density) levels determined for ceramic insulators, mainly due to the hydrophobicity properties. Tests performed (**A3.115**) either with salt fog or solid layer procedures showed a much better performance of polymer insulators than ceramic ones. Report **A3.202** investigated polymer hollow core insulators with 15 year service and proposes a new formula for pollution withstand voltage, based on the levels defined in IEC 60815-1 for ceramic suspension insulators.

Q. 2-1 Why more accurate and standardized approaches are not established for determining the withstand voltage of polymer insulators under pollution conditions? Which criteria are advisable to determine the maximum operation voltage under pollution? What are the next steps to overcome the continuous investigation of polluted polymer insulation?

<u>Monitoring, condition assessment & life management</u>
Report **A3.101** summarizes the aim, goals and progress surveyed by the CIGRE/CIRED JWG A3.32: Non-Intrusive Condition Assessment of distribution and transmission switchgears. The value of non-intrusive condition assessment of transmission equipment at HV levels is quite evident when analyzing the failure statistics, which point out a clear relationship between intervention and failure. Therefore, non-intrusive condition assessment is quite promising for HV equipment. It might be more convenient, if the equipment can be assessed in-service, but in some situations, off-service diagnostics could be applied. A survey carried out by the JWG A3.32 shows that there are still many open issues or need for more studies or developments on non-intrusive condition assessment practices, mostly at HV system levels. Different non-intrusive practices have been described and the JWG A3.32 will provide a user guideline for selection and application of suitable non-intrusive methods in function of utilities and system operator needs.

Report **A3.203** describes the evolution of condition monitoring techniques during past 20-25 years in an Indian Power System. It is a practical example of monitoring added value for utilities. Three evolving monitoring stages were applied and are described in the Report, i. e, off-line CB timers / CB

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analyzers, off-line CB analyzers with dynamic contact resistance measurement (DCRM) and on-line monitoring.

Q. 2-2 Based on experience collected by the JWG A3.32, can authors and experts prospect the future applications of non-intrusive condition assessment application in distribution and transmission levels? Are the existing non-intrusive methods satisfactory covering the needs for efficient asset management and maintenance practices? If not, what are the most critically uncovered areas or technical constraints to be solved? What do grid operators or experts require for a broader application of non-intrusive monitoring practices?

Q. 2-3 The application of Condition Based Maintenance (CBM) has been increasing worldwide. Do the authors of Report **A3.203** and experts believe that CBM is a necessary evolution of other less sophisticated maintenance philosophies and a necessary stage before adopting on-line monitoring? Are maintenance philosophy short-cuts realistic in practice, like going from time based maintenance directly to on-line monitoring? What are the main difficulties to start applying CBM and on-line monitoring in the traditional utilities environment? Could on-line monitoring be helpful to end-of-life decision when the equipment is subjected to overstresses in the network?

Q. 2.4 On-line monitoring offers a series of advantages for asset managers. However, in the event of false alarms an unnecessary equipment intervention could be done. How do asset managers go around with this kind of risk? On-line monitoring systems generally make use of CB travel measurements instead of DCRM. In such cases, do users actually lose relevant information for maintenance/intervention decision? Could experts comment on the advantages and disadvantages of both methods?

<u>Overstresses, overloads and mitigation measures</u>

Report **A3-201** presents the current practices of utilities and system operators in 6 different countries on HV equipment life management with special regard on overstresses management and end-of-life decisions. In most of analyzed countries overstress is a major concern for system operation, but is not always considered as a key factor for end-of-life decision. Local issues, like power system growth rate, system connection of new renewable energy sources and regulation plays a quite important role in overstress management process. Most common types of stressing parameters regularly checked by system operators and utilities are load current and short-circuit levels. Both are in most cases the consequence of open system access polices or fast growing networks in developing countries. Other overstress parameters, like overvoltages, are treated mostly at planning stage, but it was also identified some utilities practices to check for temporary overvoltages and/or TRV, whenever indication of such kind of overstress is identified at operation level. Some ageing assessment for substation equipment is also a common practice and can vary from simple observation of equipment performance up to elaborated mathematical and statistical analysis for indicating equipment end-of-life

Report **A3-204** presents an on-line monitoring system for temperature measurement. This system seems to be a quite promising technological solution for on line temperature measurement of different HV equipment. The idea is to apply this non-intrusive and self-powered miniature device in pre-selected points of the equipment to monitor critical thermal parts, thus allowing an optimization of equipment loading in function of ambient temperature. By means of calculation algorithms it is also possible to foresee equipment overstress risks and take measure to avoid it.

Report **A3-304** presents an operating mechanism with precise mechanical scatter applied for EHV multi-break circuit breakers. As stated in the ELECTRA papers titled “Guide for application lines, reactors, capacitors, transformers”, published in ELECTRA 183 and 185,1999 by WG 13.07, the desirable CB mechanical and electrical scatters for an efficient controlled switching system should be +/- 1 ms. The test results of the presented circuit-breaker shows a mechanical scatter in the range of +/- 0,75 ms (3σ value), making it eligible for controlled switching applications. Transient system analysis with controlled switching are performed and led to the conclusion that the achieved precision using the operating mechanism is good enough for controlled switching applications.

WG A3.35 is currently updating the field experience of controlled switching designed and tested based on the guidelines by WG A3.07 and the technical Report by IEC62271-302.

Q. 2-5 End of life decision due to overstress is a relatively new practice observed in different countries. According to authors experience, what are the main drivers for pushing towards the dissemination of this new aspect of end of life decision? Why are there big differences in overstress criteria between different countries? Can the authors and experts comment on the possibility of applying controllable overstresses to HV equipment at real-time system operation, like dynamic loading? Considering the aspects of system reliability and liability, is it possible to allow for overstresses in system operation?
Is it possible to correlate the influence of overstress on equipment ageing? What about the application of higher power frequency service voltages than the rated voltage of equipment? Are utilities facing this kind of problem and why?

Q. 2-6 Would the miniature device presented in paper A3-204 be a solution sufficiently mature to be applicable in evaluating a full scale equipment? Can it be applicable to evaluate the performance relevant to the mechanical strength, environment influence and life-time expectation for such a device? Could this kind of device be applicable to smart grid concepts? Is it economically competitive in relation to other temperature monitoring solutions?

Q. 2-7 Results present by the authors of Report **A3-304** showed a quite promising drive performance of +/- 0.75 ms scatter. What about the mechanical scatter performance of the new presented drive in function of CB age? Besides idle time, was the influence of other parameters investigated, like ambient temperature and auxiliary control voltage? Is a test with an idle time of only 200 hours sufficient? What are the exact measures to improve the mechanical scattering (e.g. greasing, latching)? How is the service performance of the new drive? Are utilities in general satisfied with the timing performance of CB in controlled switching application? What about the influence of circuit-breaker and controller maintenance procedures in controlled switching performance?

Preferential Subject 3

APPLICATION OF INFORMATION TECHNOLOGY TOOLS FOR DEVELOPMENT & MANAGEMENT OF HIGH VOLTAGE EQUIPMENT

Simulation and design tools for the development and project of HV equipment has been experiencing a remarkable development in the last two decades. A major drive was the huge progress of computer processors allied to an increasing data managing capacity at reasonable costs. Particularly for HV equipment, the development of CFD programs offered a bunch of new opportunities to rather improve the methodologies for development and design. Following this tendency, four Reports are presented (**A3.301**, **A3.302**, **A3.303** and **A3.305**) dealing with this kind of tools. Integration of intelligence into HV equipment was also the topic discussed in Report **A3.205**, where an interesting example of the application of full digital drive for disconnectors is presented.

Advanced simulation and design tools
Fluid-mechanical analysis is a fundamental methodology for CB interrupting chamber design, as presented in Report **A3.301**. This technique was quite improved since CFD programs were developed, allowing more precise simulation of the interruption phenomena, which includes hot gas flow inside the CB chamber, as shown in Report **A3.302**. These simulation tools allow design optimization with reduced testing efforts and CB performance analysis for different switching conditions. The applicability of multi-physic simulation tools is the domain of investigation by WG A3.36.
Other kind of non-conventional design testing procedures is the use of reduced models for temperature rise tests. This simulation tool is described in Report **A3-303** and was successfully applied for substation connectors. It opens opportunities for reducing the test requirements during equipment design phase and offer small and medium size testing laboratories the opportunity to expand their testing limits.

Mathematical and physical models are also applicable for development of other kinds of HV equipment, like voltage transformers. The feasibility of such models and tools to develop resistive voltage transformers was demonstrated by Report **A3-305**. The challenging balance between resistive elements, displacement and leakage currents could be achieved by the proposed design procedure, thus allowing designing an accurate resistive divider with optimized testing efforts. The accuracy of the proposed methodology was confirmed by tests.

Q. 3-1 According to authors experience, what was the actual contribution of CFD simulation in combination with the simulation of the cinematic chain for the interrupting chamber design? Is the simulation accuracy comparable to interruption test results? Are these methods accurate enough to reduce significantly the development test efforts? And what about routine tests and type tests, do the authors see good chances for simplifying test procedures by means of simulation tools? Even, since the investigations of WG A3.20 and WG A3.24 have shown how difficult it is to draw conclusions from simulations of much simpler physical stresses?

Q. 3-2 According to Report **A3-303**, reduced scale substation connector temperature rise testing seems to be quite promising during product optimization stage. Do the authors believe that this kind of procedure could in near future replace a real scale testing? How can the physical behavior of the micro contact points and its dependency on the contact pressure be scaled? At least for acceptance test? Which other equipment do the authors believe this testing procedure has good application potential to replace full scale temperature rise test? Do the authors and experts envisage other kinds of reduced scale testing for substation equipment? Can the authors explain the rather unfamiliar looking formula (5)?

Q. 3-3 Is it possible to accurately reproduce by calculation methods the environmental effects on the leakage current for resistive VT? How does the reader have to understand figure 15, where the temperature rise at 1.2 Un at an environmental temperature of 15°C is shown, instead of at 1.9 Un and 70°C, as stated in the conclusions? Was this effect taken into consideration by the authors of Report **A3.305**? Do the authors and experts believe that the resistive voltage transformer will be a competitive alternative for EHV and UHV substations? What about the transient response of resistive VT? Would be possible to accurately record switching transients by means of this kind of VT?

Q. 3-4 Report **A3-305** also analyzed optical voltage transformers concluding that electrical field of the neighbor phases influence the VT accuracy might be a problem. On the other hand, optical VT are commercially available since about 20 years and no clear evidence of a long term measurement precision has been reported. What is the experts' view?

Integration of Intelligence into HV Equipment

Since the advent of digital controls systems, its potential application in HV switchgear drives has been investigated and in the mid-nineties some concepts were developed and prototypes installed in the network. However, at that time a well-known barrier for the broader application of digital control systems in HV substation was the lack of international communication bus standardization. This problem was overcome with the publication of IEC Std 61850 in 2005. Report **A3.205** describes the experience with a digital drive solution for HV disconnectors pilot projects for 145 kV, 245 kV and 420 kV network. The potential of the digital technology applied directly to the disconnector drive in terms of condition monitoring, diagnosis and maintenance policies are addressed.

Q.3-5 In spite of the publication of IEC Std 61850, the application of industrial solutions for digital drive technologies in HV switchgear is still quite timid. How is utilities operation experience with digital drive technologies? Could the authors of Report **A3.205** and experts explain the situations and requirements for utilities' wider applications of digital control for CB and disconnector drives? What kind of technical and economical breakthroughs are required to use electrical motors replacing traditional spring or hydraulic drives for CB?

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General information

Within SC A3, dealing with AC & DC transmission & distribution equipment, six Working Groups have published or will publish their Technical Brochures in 2015/2016:

WG A3.24	Simulating internal arcs and current withstand tests (TB 602)
WG A3.25	MO varistors and surge arresters for emerging system conditions
WG A3.26	Capacitor bank switching and impact on equipment (TB 624)
WG A3.27	The impact of the application of vacuum switchgear at transmission Voltages (TB 589)
WG A3.31	Instrument transformers with digital output
JWG A3/B5.34	Technical requirements and capability of state-of-the-art DC switching equipment

Other working Groups are:

WG A3.29	Deterioration and ageing of HV substation equipment
WG A3.30	Overstressing of substation equipment
JWG A3.32	Non-intrusive condition monitoring for MV/HV switchgear
WG A3.33	Experience with equipment for series/shunt compensation
WG A3.35	Guidelines and best practices for commissioning and operation of controlled switching projects
WG A3.36	Application and Benchmark of Multi Physic Simulations and Engineering Tools for Temperature Rise Calculation
JWG A3/B5/C4.37	System conditions for and probability of Out-of-Phase

Important information

Experts who wish to contribute to the SC A3 Session are required to send their draft prepared contribution to the Special Reporters before **August 1st, 2016**, in order to check whether and where the contributions fit into the program: anton.janssen@alliander.com. The draft presentations will also be checked on readability and technical/scientific content (no commercial information is allowed). Prepared contributions in draft, which are received after **August 1st**, will not be accepted and considered. During the Session, for each prepared contribution a time slot of three-four minutes will be available, so that the number of slides essentially has to be less than four. After receiving the draft prepared contributions the Special Reporters will review the size and readability of the power point presentation. They will give recommendations to the experts and inform them whether the prepared contribution will be accepted by August 8th.

The SC A3 Sessions is scheduled for Thursday, August 25th, in the Salle Bordeaux, at the 3rd level. On the day before the Session (i.e. on Wednesday, August 24th) Contributors need to contact the Chairman, the Secretary and Special Reporters of SC A3 in room 362 on level 3 at the Palais de Congrès.

During the Session the Chairman may call for spontaneous contributions. Attendees who provide a spontaneous contribution, are allowed to deliver a text for the General Report. This text is required to be forwarded within a maximum delay of 2 weeks after the Session to anton.janssen@alliander.com .

The authors of the SC A3 Session Reports may present the results of their studies during the Poster Session on Friday morning, August 26th, 2016. If the author(s) cannot attend the Poster Session the National Committee is requested to send a substitute. All SC A3 WGs will present the progress and results so far of the investigations. For each Report (and each SC A3 Working Group) space for a single A0 poster will be available. Before **August 1st**, draft posters have to be sent in digital format to André Giboulet, the Session and Poster Secretary: consulting38@gmail.com. After receiving the draft posters the Session and Poster Secretary will review the readability of the draft posters.

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