For the SC A3 Session 2012 three Preferential Subjects have been selected and a total of 22 Reports were submitted.

**Preferential Subject 1: Equipment design to facilitate network developments**
- Design and testing of equipment for HVDC networks
- Role of intelligence within equipment
- UHV
- Impact of changes in AC network design and operation.

Ten Reports will be discussed for Preferential Subject 1, (Report A3-105 has been withdrawn).

**Preferential Subject 2: Reliability and lifetime of HV equipment**
- Experience and trends in reliability of HV equipment
- Prediction and management of end of life due to age and/or potential overstressing
- Role of condition monitoring and assessment.

Six Reports will be discussed for Preferential Subject 2.

**Preferential Subject 3: Environmental suitability of HV equipment**
- Design to minimise environmental impact
- Design and testing for extreme ambient conditions (temperature, seismic levels, pollution, …)
- Design for offshore/marine environments.

Six Reports will be discussed for Preferential Subject 3.

This Special Report has been prepared by the Special Reporters with contributions from members of Study Committee A3.

anton.janssen@alliander.com
Preferential Subject 1

Equipment design to facilitate network developments

Equipment design for Ultra High Voltage (UHV) applications is addressed in four Reports, two for UHV DC applications (A3-104 and A3-111), two for UHV AC applications (A3-106 and A3-110). Further reference to UHV is made in A3-303, composite hollow insulators, and in A3-203, a simulation tool to design arcing chambers. In A3-109 the design of a tool to investigate the arc model parameters required to simulate current interruption by HVDC circuit-breakers is explained. Transformer limited faults (TLF) are the topic of the Reports A3-107 and A3-108.

In Report A3-101, the design of a vacuum circuit-breaker (VCB) for HV networks is described: VCB’s applied for shunt capacitor bank switching are discussed in Report A3-201, whereas another alternative for HV SF₆-gas technology is elaborated in A3-302. The environmental aspects are covered under Preferential Subject 3.

In the remaining Reports for Preferential Subject 1 a new method to test oil insulated equipment for explosion safety (A3-102) and the development of short-circuit currents in the Netherlands (A3-103) are given.

UHV

In China the developments in UHV AC and DC networks are considerable. The authors of Report A3-104 pay attention to the investigations of switching impulse flashover voltages across long air gaps at high altitudes. They apply their findings to phase to earth clearances in ± 800 kV OH-lines. Test results from test stations at an altitude of 4,300 m, of 2,254 m and of 50 m are compared. The 50% flashover voltages across the gaps in a typical tower head with clearances ranging from 4 m to 11 m are collected. The results are plotted against 50% flashover voltages calculated to several standards, including IEC 60071-2. They conclude that the approach detailed in IEC 60071-2 gives too conservative an outcome.

The results may give a contribution to the discussions on the IEC procedures of altitude and atmospheric correction but no exact conclusions for any further standardizing work can be figured out from the description of the results and the proposed approach. Test results with more details should be given to the relevant IEC or CIGRE committees for an in-depth discussion. For such details and procedures the authors refer to Chinese references and standards which unfortunately are not very accessible to the interested readers from abroad.

Q. 1-1 The authors put their investigations against a background of designing UHV DC OH-line towers. Are the results more widely applicable and can they be related to insulation coordination in general, including SI (switching impulse) flashover characteristics for UHV AC applications? Is there a difference in the specification of SI and LI (lightning impulse) between DC and AC; maybe due to the bias voltage? Can the proposed approach be transferred to other configurations beside the tested tower model?

Q.1-2 The results are interpreted mainly in respect of the altitude correction. Do the results fit to the atmospheric correction according IEC 60060-1 which form the base for altitude correction in insulation coordination as described in IEC 60071-2? Have the measurement uncertainties been taken into account as well as the assumptions of the standard deviation for the rough calculation of withstand voltages to get a commonly acceptable approach?

EHV and UHV applications of composite insulators used as busbar supports or the insulators of disconnectors are described in Report A3-111. The emphasis is on a hollow type support insulator designed for UHV DC in China. The specifications for the mechanical and dielectric behaviour of the
UHVDC disconnectors and their dimensions are given. The insulators are filled with \( \text{N}_2/\text{SF}_6 \)-gas, at the higher voltage classes, or with foam, at lower voltages to limit the water vapour accumulation inside the hollow space. Tests have been performed to study the dielectric effect of inadequate adhesion of the foam to the interior of the composite tube, the effect of defective sealing between flange and tube and the effect of long term water vapour permeation. Flashovers only occurred at the outside of the insulators, none at the inside.

In Report A3-106 the authors from India show the design, manufacturing and type testing of a 1,200 kV AC capacitive voltage transformer (CVT). The CVT has been installed at the national 1,200 kV test station. The specification is for an air insulated 1,200 kV substation. The authors pay special attention to ferro-resonance stability, temperature stability of the internal insulation as required for the measurement accuracy, the dielectric stresses due to SI and LI, and the electrostatic field distribution along the impressively tall structure. They refer to dry SI (1,800 kV), dry LI (2,400 kV) and chopped LI. They obviously applied porcelain type insulators.

Q.1-3 At the SC A3 Session in 2010 in Report A3-304 an extensive study on composite hollow insulators has been presented. One of the remaining questions was on cyclic mechanical stresses, as a high number of mechanical cycles could harm the strength and tightness of the composite insulators, especially at the junction between insulator and flange. For which endurance stresses are these post and disconnector insulators designed and tested, especially with respect to the torsional (rotating) movement of the contacts? Please, clarify the double break disconnector swinging and rotating movement, as mentioned in A3-111. What is the field experience at the highest voltage levels, so far, with composite versus ceramic insulators (A3-106), and what determines a manufacturer’s or user’s choice? Aren’t wet tests, pollution, humidity, fog an issue for the Indian specifications (A3-106)?

Q.1-4 The authors of A3-106 do not refer to very fast phenomena, such as VFTO (very fast transient overvoltages), despite the fact that at the SC A3 Session 2010 attention has been asked for VFTO in air insulated substations (AIS). Maybe the large capacitance, 2,000 pF, eliminates the onerous effects of VFTO, caused by disconnector switching? What is the position of the authors and other experts with respect to VFTO requirements for air insulated equipment applied for 800 kV and above?

VFTO are a potentially serious problem for UHV GIS, where frequencies a factor ten or more higher than 1 MHz as generated in AIS may be present. A number of CIGRÉ WG’s are dealing with VFTO and the authors of A3-110 are involved in these investigations. Now, they present various methods to reduce the amplitude of VFTO, among which are the adaptation of the GIS configuration, of the disconnector design including its speed and of the substation technology (AIS, GIS, Hybrid). A possible solution to damp VFTO amplitudes is formed by a high frequency electromagnetic cavity resonator, arranged around a GIS conductor. Potentially by adding an external resistor VFTO’s can be damped, but further investigations are needed to optimize the resonator and to see its overall effects and applicability. Another solution to damp VFTO is installing ferrite rings around the GIS conductors. Several types and configurations have been implemented in an experimental test set-up, but the effectiveness is shown to be limited due to the fast saturation of the ferrite material.

Q.1-5 Despite the fact that high amplitude VFTO can be mitigated by a reduced speed of the disconnector or by adding damping resistors, experts are looking for alternative mitigations. Can the authors and other manufacturers highlight the rationale behind the quest for such alternatives? What technical and economical damping methods are of potential interest? Is it possible to adapt the lay-out of GIS in such a sense that disconnectors, that have to (dis)charge short bus sections, are avoided?

**Arc model parameters**

Report A3-109 addresses the development of HVDC circuit-breakers as a combination of very fast acting power-electronic devices and low loss mechanical devices. DC current interruption by the mechanical circuit-breaker requires a forced current zero, for instance by a resonant circuit. As the current amplitude and current gradient will be completely different from that with AC circuit-breakers, and to a certain extent can be freely chosen, the parameters for the arc models show different
interrelationships. The authors’ aim is to determine arc parameters that enable modelling of arcs in DC breakers. A novel unipolar arbitrary current source is proposed, consisting of a three-level inverter with special controllers to shape arbitrary current waveforms. The proposed system has been simulated, showing good results, and a prototype of such a current source has been designed. The authors should be complemented for the design (though not yet proven) of this innovative solution.

Q.1-6 In comparison to some decades ago, the need for HVDC circuit-breakers seems to be more urgent. At the same time the requirements for such devices have become very stringent with respect to the fault clearing time. Conventional circuit-breakers alone cannot fulfil these requirements and very expensive solutions come in place. It is difficult to understand all these developments that influence each other: less expensive converter technologies force more expensive circuit-breakers in meshed HVDC networks; the design of a meshed HVDC network depends on the type of converter and breaker; HVDC circuit-breaker requirements depend on type of converter and the design of the HVDC network. Can experts shed light on this Gordian knot? According to them which path should be followed? Is there a difference in requirements for a circuit-breaker applied at the converter ends of a HVDC network or somewhere in the middle? What kind of configuration do the authors or other experts imagine for a complete HVDC circuit-breaker?

Q.1-7 Do the authors take account of the inherent statistical behaviour of arcs, especially in the low-current region, due to thermal and electro-dynamical impact on the arc? Is there any experience with attempts to derive arc parameters of AC arcs in standard transmission breakers? Do black-box arc models sufficiently take into account parameters from e.g. SF6 decomposition, nozzle ablation, turbulence etc.? Is the present experimental apparatus envisaged to study the interruption characteristics as well, as this should be the final aim of the circuit breaker? Is the relatively short duration of the test current (few ms) realistic against the expected duration of the arc in a DC circuit breaker? What is the proposed mechanism for excitation of the arc instability at levels of several tens of kA, where the arc characteristic can be considered as rather flat? Are alternative extinction media (different from SF6) under consideration?

TLF
With respect to transient overvoltages, transformer experts are mainly interested in the high frequency voltage distribution across the coils and windings inside the transformer, whereas circuit-breaker specialists have a main focus on the transformer response at its terminals. Usually the transformer experts, as those of WG A2/C4.39, consider transformer models for the highest frequencies, as excited by lightning impulses or VFTO (some to tens of MHz). Circuit-breaker experts, though, look for transformer models to simulate switching over-voltages with frequencies from some tens of kHz to hundreds of kHz. Besides the much simpler transformer model they have to include the electrical environment as well: connections between circuit-breaker and transformer, attached equipment as CTs, MOSAs, post insulators, maybe CVTs or PTs.

Transformer limited faults (TLF) occur when a transformer feeds a short-circuit current to a fault behind the circuit-breaker, that has to clear the fault current, or when a circuit-breaker has to clear a fault current for a fault behind a transformer (at the other side of the transformer). In both cases, the transformer impedance will be the dominant factor in determining the short-circuit current’s amplitude and the TRV (transient recovery voltage across the breaker terminals) will be determined by the transformer’s characteristics. The authors of the Reports A3-107 and A3-108 use several methods to extract the dominant parameters that represent the transformer transient response. Among others they use an FRA-measurement of the transformer under investigation.

By means of representative RLC-circuits as well as by a pure mathematical approach, called vector fitting, the authors of Report A3-107 demonstrate that it is possible to get a reasonable good fit for the multiple resonance responses measured by FRA (in the frequency band of interest). The TRV calculated with a simplified single or double frequency model however deviates considerable from that calculated by inverse Fourier transform from the FRA-measurement. With these transformer
models the authors simulated the clearing of faults at several locations in an actual substation and show that for the three models the TRVs calculated in the time domain differ more than expected. The authors of Report A3-108 took several very large three winding transformers of different designs and makes: 525/275/63 kV, 1500 MVA. 3-Phase faults at each side have been simulated, based on FRA-measurements performed at each side and also on a manufacturer model of one of the transformers. Reasonably good agreement has been found between rather simple single and double frequency response models and the FRA-measurements and TRV-measurements (by the capacitor current injection method), although the amplitude factor for the double frequency response is less accurate. The authors explain how the interaction between the two frequencies have a large influence on the amplitude factor. Similar effects can be seen with the manufacturer’s multi mesh model versus the lumped transformer model. Without considering any physical losses, with a double frequency model or multi-mesh model the amplitude factor is reduced to about 1.7 (instead of 2.0).

Q.1-8 The Reports are important for WG A3.28, Switching and Testing of UHV & EHV equipment, that is studying the TRV requirements for TLF between 100 and 1200 kV. Large power transformers and transformers designed for the highest operating voltages, say 500 kV and above, seem to show a better fit to the more simple transient transformer models (single/double/triple frequency models). Is this because of the more advanced dielectric design in comparison to smaller transformers or is it because of the considered bandwidth (0.1 or 0.5 or 1.0 MHz?) or because of the influence of other substation equipment? The authors applied reverse FFT: how did they deal with the highest frequencies above, say, 1 MHz and what precautions have to be taken to get a realistic time domain response (TRV)? What is the required accuracy of the transformer model, taking into consideration the influence of the substation configuration on the TRV? How detailed is the meshed (manufacturer’s) model of the transformer in Report A3-108, with respect to each coil? What progress has been made in the Standards, such as IEC and IEEE? Test frequency, first pole to clear factor and amplitude factor?

VCB technology
During former SC A3 Sessions the development and application of VCBs for sub-transmission voltages have been discussed. Based on such publications, SC A3 has established WG A3.27, Vacuum Switchgear, to study the impact of HV VCB applications on the network and circuit-breaker specifications. The authors of Report A3-101 describe the development of a live tank 3-phase operated VCB with a rated voltage of 72.5 kV. It is equipped with a common drive system and a single break per phase. In closed position, the operating mechanism has to give enough contact pressure in order to prevent overheating. As the dielectric strength outside a VCB is less than the inner strength, due to the relatively small dimensions, the outer porcelain (!) insulator contains nitrogen. For many users, as is clear from an enquiry of WG A3.27, the (claimed) very high electrical and mechanical endurance of vacuum breakers is seen as a clear driver for application of vacuum for sub-transmission voltages in frequent switching applications, such as for shunt capacitor-bank and/or shunt reactor switching.

Q.1-9 The dielectric strength at clearing currents and in the open position are critical design limitations of VCB technology, as can be seen with capacitive current interruption; see also Report A3-201. For that reason in some designs multiple breaks are applied. The authors state “in this initial test phase critical application like capacitor banks and shunt reactors switching were avoided”. Can the authors explain the challenge (regarding cap bank switching), in spite of having passed the IEC 62271-100 C2 class of capacitive switching? Can manufacturers or users give background information on VCB’s capacitive current interruption, out-of-phase clearing, dielectric withstand stress in open position? Experience in service and during pilots? What about pre-conditioning? And the external dielectric withstand strength of VCBs? In the case of utility B, 1,800 CO operations were performed in 14 months, so several CO operations daily. What was the switching function of the breaker, given its location in a connection between two double busbar substations. Was it load transfer? And if so, was the loss of contact material monitored?

Explosion safety
In Report A3-102 Russian experts explain an alternative method to test the explosion safety of oil filled equipment, in this case CTs. Instead of destructive tests in a high power laboratory, they have developed a type test technique by using explosives. The problem is to find a method to control the chemical reaction in such a way that the relatively slow pressure build-up coming from an electrical arc will be followed. The authors apply an impulse jet of powder gas (JPG) as an arcless source of the pulse pressure. In order to prove the behaviour of the paper/oil containment and its relief device during the pressure rise, sometimes water instead of oil is used. In the Report the explosion safety test on several types of CTs (110 to 330 kV) is described. Prototypes of protection devices are discussed.

Q.1-10 Can other research institutes or manufacturers contribute with their experience with the application of explosives to test for internal arcs? Is it a method considered by WG A3.24, Simulating internal arcs and current withstand tests? What is the utility’s policy and experience with respect to explosion safety of ITs? Apart from proving that the enclosure does not rupture, the exhaust gases may be important for safety reasons. How representative are the exhaust gases ejected at a test with a JPG?

Short-circuit currents
At earlier CIGRE Sessions publications and contributions dealing with an increase of the short-circuit current levels and DC-time constants have been presented. There is a wide interest in fault current limiters (WG A3.23 will publish its Technical Brochure soon), although the application at higher voltages is still very premature. In Report A3-103 the development of short-circuit currents in the Netherlands are addressed. The authors pay attention to the developments in the transmission network (420 kV), in sub-transmission systems (170 kV) and in distribution systems (12 kV). Also, the trend of increasing short-circuit current amplitudes during type testing at KEMA’s laboratories is shown. The new WG A3.30 pays attention to overstressing of existing equipment, including overstressing due to higher short-circuit currents, higher DC-time constants and more severe TRV requirements.

Sustainable energy and integrated markets lead to more electricity, more power generation capacity, more interconnections and more transformers. In Report A3-103 the development of the statistical distribution of prospective short-circuit currents over the years (420 kV) is given, as well as the development of the number of interconnecting transformers. As a larger part of the short-circuit current is fed through interconnecting and/or step-up transformers, the trend in DC time constants is also upwards. Counter measures are discussed: split networks, split busbars, operate transformers in hot stand-by mode. A special case described is the modification of circuit-breakers to withstand the higher DC-time constants, proven by limited type tests. At the distribution level the impact of larger transformers, the (over)loading of transformers and the influence of DG are highlighted. The fault current contribution by power-electronic devices (HVDC converters, DFIG and windmill generators with full converters) is usually limited as illustrated by some examples.

Q.1-11 One of the factors that play a role in the increasing level of prospective short-circuit currents is the increased uncertainty around power generation developments. TSOs and DSOs apply extra margins to cover future developments, and in addition they apply mutually margins as well. The uncertainty influences the RMS-value as well as the DC time constant. How do other utilities deal with the uncertainty and what developments do they see? Which factors are dominant and what margins are applied? Can information be given on how non-conventional generators (wind) and converter stations are dealt with? What policy is followed by other utilities, as not all information on type, rating, operation and control setting of such generators will be available? Are other disturbances to be considered, such as voltage dips due to energization of large transformers at peripheral locations?

Q.1-12 Modifying or customizing circuit-breaker designs, without full repeat of all type tests might endanger the reliability of these specials. Being a special is already risky from the point of reliability and availability, despite the fact that the extreme short-circuit current switching performance requirements are fulfilled. How do users and/or manufacturers proceed in such cases? What is their policy?
### Preferential Subject 2

#### Reliability and lifetime of HV equipment

Reliability and life time management of HV Equipment has been covered in six Reports.

- **One Report (A3-203)** discusses computer simulation tool for the design and optimisation for UHV SF₆ circuit breakers.
- **Two Reports** discuss condition assessment of circuit breakers. Report **A3-205** discusses EHV circuit breaker condition assessment using Dynamic Contact Resistance Measurement (DCRM) techniques and the Report **A3-204** discusses the application of protective relays for the purpose of circuit breaker condition monitoring.
- **Three Reports** discuss life time management including impact of stresses, reliability and maintenance optimisation techniques. Report **A3-201** discusses stresses on circuit breakers due to switching capacitor banks with very high in-rush current, Report **A3-202** discusses techniques for end of life estimation and optimisation of maintenance of HV switchgear and Gas Insulated Substations (GIS) and the Report **A3-206** discusses reliability analysis of generator circuit breakers (GCB’s).

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**Computer simulation tools and methods for design and optimisation of UHV circuit breakers**

Report **A3-203** details the development of a very effective computer simulation method for predicting arc interruption performance although neither the details of the model nor the evidence of accurate prediction of arc interruption characteristics are explicitly presented.

**Q.2-1** Can the authors confirm if their model is generally valid for all designs of SF₆ CB’s and at all voltages or whether there are limitations? Can the authors explain the difference between experimental and model results and what further work do they propose to address these differences? Can the authors confirm, what G200-value they consider as a suitable criteria for (un)successful clearing and if this G200 parameter is adequate to distinguish between successful and unsuccessful interruption or are other criteria required as well.

**Q.2-2** The authors indicate that the simulation gives the advantage of a faster development process and reduction of testing time. Could they give some quantified estimates of the reduction in testing time for the specific application for the 550kV CB specified in the paper? Were there any areas where test results differed significantly from the predictions of the simulation; did the application CB fail any of the tests? Can users and manufacturers provide examples of similar benefits (related to optimisation and time savings) realised from such simulation approaches in practice for UHV, EHV and HV voltage levels?

**Q.2-3** Can the CIGRE WG A3.24 confirm their views on the findings from the paper in relation to the work undertaken by CIGRE WG A3.20 and WG A3.24?

**Note** : CIGRE has undertaken research through WG A3.20 (see publication Simulations and Calculations as verification tools for design and performance of high voltage equipment – CIGRE 2008) and more recently by WG A3.24 to further evaluate simulation techniques in specific areas where significant benefits can be foreseen, namely, for internal arc testing of SF6 filled equipment.

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**Condition assessment of circuit breakers**

Report **A3-205** discusses application of “Dynamic Contact Resistance Measurement” (DCRM) as a condition monitoring technique (in addition to other condition assessment tests), to assess healthiness of contact assemblies including arcing contacts and other components of the circuit breaker from 132kV to 765kV. The method has been applied by this Indian utility since 1998 and the authors
report that they have successfully avoided the failure of at least 80 circuit breakers (CB’s) through these tests. The authors mention that the time based CB overhaul (detailed internal inspection) is now undertaken based on the evaluation of the DCRM signature and the DCRM signature is required from their suppliers for all circuit breakers procured by the utility. They report that manufacturing defects can be identified using this technique.

Q.2-4 Can the authors, or other users of the technique, indicate the order of magnitude cost savings realised by its implementation and deferral of planned overhaul compared with manufacturers’ recommendations? Is there experience available regarding CB reliability as a result of deferral of these overhauls, i.e. have they experienced a failure of a CB whose overhaul was deferred? And if so, what was the feedback from this failure? Are there reasons why the manufacturing errors mentioned in the Report were not detected by other routine methods and tests at manufacturing?

Q.2-5 How reproducible are the measurements, especially the contact speed, as it is depending on the attachment of the sensors? Can DCRM be applied in such a way that the “first shot” can be caught?

Q.2-6 Can other participants (and manufacturers) confirm whether DCRM is used as a standard by them and if so, can they elaborate on benefits from its application?

The Report A3-204 discusses application of protection relays for the purpose of condition monitoring and their integration in the maintenance program of a US utility as a means to defer maintenance. The Report also brings out the benefit of monitoring CB performance in-service as it brings out the issues that are picked up by slow first trips that would otherwise not be evident during controlled testing. The Report also elaborates the benefits of utilising the information from these intelligent devices as a move towards a condition based maintenance and replacement program.

Q.2-7 The authors mention the benefit of the proposed strategy for newer breakers. Do they see any impediment in applying this approach to older breakers or breakers of various designs where protection equipment is retrofitted as a part of protection replacement program? The authors mention a particular supplier of relay that was used for this purpose. Can they confirm if devices from other suppliers have been considered and found suitable for similar application? Are there any specific performance reports that should be specified for this application?

Q.2-8 Can the participants confirm their experiences in utilisation of the proposed approach for CB monitoring, maintenance optimisation and replacement decision making? Can they also confirm if they have faced similar operational impediments in implementation, as the authors have, in terms of organisational restrictions to apply protection equipment to these additional functions and/or access protection equipment? Do the authors and the other participants see IEC 61850 and its integration in the smart substation as a means of overcoming this restriction and therefore greater application of the proposed methods?

Q.2-9 The authors question the benefits realised from specialist CB monitoring devices being supplied by CB manufacturers in the past decade. Can the manufacturers and participants share their experience in deployment of specialist CB monitoring devices, their application (as a standard) and how they compare to the protection integrated concept presented in the Report?

Q.2-10 The authors mention that they are working with their suppliers with an objective to integrate condition based maintenance as discussed in the Report. Can the manufacturers and participants mention similar initiatives (and their progress) in this area?

Lifetime management – stresses, reliability and maintenance optimisation

Report A3-202 discusses the utilisation of in-service experience for the end of life estimation and optimisation of maintenance of HV switchgear and GIS substations. It mentions the need to modulate the maintenance practices based on the generation of GIS deployed and the authors’ experience with respect to the reliability of the first and second generation GIS switchgear and how they have been
overcome by the latest generation of GIS equipment. The authors mention that the results from their studies align with the findings of WG A3.06. The paper discusses use of probabilistic data analysis to determine optimal maintenance.

Q.2-11 The author’s do not elaborate on the possible shortcomings of probabilistic analysis, whereby maintenance optimisation may lead to failure of switchgear. Do the authors and the participants believe that in the regulated electricity industry cost reduction (maintenance optimisation) is preferred with possible negative (even slight) impact on reliability?

Q.2-12 Can the authors clarify why 245kV GIS was excluded from the analysis presented in Figure 1? The authors mention that the failure rates of 123kV is half that of 420kV. Is this due to more reliable equipment? or due to sample size? or due to issues specific to a particular make/ type?

Q.2-13 The authors have not been able to clarify the increase in failure rate for 123kV GIS after 30 years. Can the manufacturer’s and other participants share their experience in various phases of life of GIS and HV switchgear and highlight where they experience the predominant failures? Is there a correlation between the probability of failure and: age, number of operations, application duty/stresses or combinations of these factors. Feedback from manufacturers/ participants on any such analysis undertaken on GIS and HV switchgear and other HV equipment is invited. This information will be useful in the context of the CIGRE working group WG A3.29 and WG A3.30 that are evaluating life time management techniques for HV equipment.

Q.2-14 The authors conclude that epoxy resin insulated transformers in GIS should be replaced by SF$_6$ insulated CT’s and SF$_6$ and foil insulated VT’s. Can participants and manufacturers share similar experiences?

Q.2-15 The authors briefly present a methodology to assess maintenance necessity and the order in which the maintenance measures should be performed. Can the authors and the participants share practical examples where this methodology has been put into service – i.e. the maintenance measures are derived based on maintenance necessity. Can they also elaborate the benefits derived from this (please quantify the benefits).

Report A3-206 discusses lifetime experience in reliability of generator circuit breakers (GCB’s) and that of HVCB’s and proposes utilisation of the reliability information to modulate maintenance resulting in higher cost efficiencies and greater availability of GCB’s. The Report details the root cause of failures of the analysed GCB population. Whilst the analysis utilises information on GCB’s of a particular manufacturer, the conclusions are useful and aligned with the outcomes from reliability surveys conducted by A3.06. The Report concludes operating mechanisms as the main cause for most failures of circuit breakers with hydro mechanical spring operating mechanism being the most reliable followed by spring, hydraulic/ pneumatic type and air blast being the least reliable.

Q.2-16 Is it not the authors’ and participants experience that the time frame between GCB maintenance is far greater than the time between the overhaul of the generator and its accessories itself? Do they consider there is really a need to reduce maintenance cycles for GCB’s?

Q.2-17 The Report mentions that the hazard rate of HVCB’s is 1.8 times higher than for SF$_6$ CBs. Whilst this could be related to the operational duty and stresses including maintenance undertaken on HVCBs as compared to GCBs, it is not clear from the Report what the main reason for this difference is. Can the authors explain the reason for this difference? Do other participants have similar experience? Is it fair to compare MV GCBs with HV CBs? A very large proportion of the major failures is characterized by “doesn’t open/close on command” and “locked in open/closed position” caused mainly by the operating mechanism, but also by the interrupting chambers. Can the authors explain these unexpected combinations of failure characteristics and causes?
Q.2-18 The Report concludes that analysis of air blast circuit breakers indicates a typical bath-tub curve, the hazard rate of SF₆ CBs is initially higher and then reducing to a constant value. Can the authors, manufacturers and other participants confirm their experience in this area and explain the reasons for this profile? Can the WG A3.06 confirm if they have similar findings?

The Report A3-201 again brings to fore the known challenges of switching capacitor banks and in specific the transient current whilst making the circuit. The Report specifically highlights the challenges of applying vacuum circuit breakers to capacitive switching duty. This topic was also a point of focus in the Special Report for CIGRE SC A3 Session 2010. The Report highlights that the late self restoring breakdown events (NSDD) occur exclusively in vacuum circuit interrupters and very frequently during back to back switching at rated voltages > 30kV. Whilst highlighting the difference in behaviour of the vacuum and SF₆ circuit breakers capability for switching capacitor banks, the Report highlights the challenges of being able to perform three phase energisation with full inrush currents in test set up. The Report presents a new measurement method to monitor the field electron emission (FEE) current in vacuum gaps. It describes the test circuit developed by KEMA to test performance of CBs for capacitor bank switching as close as practical to the standards.

Q.2-19 Can the authors confirm how they expect their discovery in relation to vacuum circuit breakers effect the development of these circuit breakers for high voltage application? Do other participants have any solution or a solution in development to address the challenges that are presented in the Report with respect to vacuum circuit breaker application for capacitor switching for voltages > 30 kV? What can the participants contribute regarding the performance of HV VCBs with respect to capacitor bank switching? Does the industry in-service experience agree to the conclusions drawn in the Report with respect to VCB performance whilst switching capacitor banks? Can experts show the impact of NSDD’s on the network? Can the existing protection systems or dielectric coordination accept its occurrence? Could it affect safety during maintenance work? How is the state-of-the-art technology to reduce NSDD probability?

Q.2-20 As FEE(field electron emission) current does not show clear relation to probability of NSDD, the authors conclude that high probability of NSDD during Back-to-Back switching may be explained by an impaired dielectric integrity due to pre-arcing and subsequent welding. Can other experts accept the conclusion? Is there any other data showing a relation between FEE current and NSDDs or re-strike probabilities?

Note: Stresses imposed by capacitor switching have been studies by CIGRE WG 13.04 and more recently by CIGRE working group A3.26 (Capacitor bank switching and impact on equipment).
**Preferential Subject 3**

**Environmental suitability of HV equipment**

The six papers for Preferential Subject 3 cover the effects of pollution on insulators (A3-301 and A3-303) and on substation connectors (A3-305), the effects of seismic perturbations on equipment (A3-306) and alternatives for SF₆-gas applications (A3-302 and A3-304).

**Pollution**

Salt and desert dust in combination with high humidity and fog cause flashovers across the insulators to earth of 500 kV CTs in Egypt. Investigations in both the dielectric performance of the CTs and the methods of cleaning and live line washing are addressed. The authors conclude that for unknown reasons the best procedure is to wash the CTs, that are equipped with special sheds and an extended arcing distance, from bottom to top, and, opposite to the other equipment, under dead condition only.

Whereas in Report A3-111 hollow composite insulators for supports are described in Report A3-303 advantages of hollow composite insulators for electrical equipment (housings) are denominated: weight, strength, flexibility in production, extruded sheds, lining to protect against SF₆ by products, etc. A prototype 1100 kV DC bushing is shown. The pollution performance of helical profile to IEC 60815 is claimed to be better than that of conventional porcelain and that of Spirelec insulators. Good pollution withstand performance is reported from test stations in heavy marine and very industrially polluted areas, without any washing of the insulators. The authors repeat that for DC applications the insulation and creeping distance requirements are more demanding than for AC applications, certainly under circumstances with high pollution severity values.

**Q.3-1** Reading both Reports a question comes up as whether the composite insulator wouldn’t be a solution to the Egyptian problem. Can the authors and other experts give their view, preferably based on service experience? What is the audience experience with a helical shed profile? The authors of A3-303 claim a better explosion safety with composite insulators? Is that confirmed by service experience and experience from high power test stations? For instance with their own auxiliary breakers?

**Q.3-2** In Report A3-303, design optimizations of composite insulators for DC applications with a consideration of a partial loss of hydrophobicity is described. Isn’t a positive effect of hydrophobicity to be expected from the design of composite insulators for both of AC and DC applications? Can experts show field experience of composite insulator for DC applications, especially from the viewpoint of long term reliability and is there a difference between AC and DC applications?

A marine or an off-shore environment is very harsh from the point of view of corrosiveness and dielectric stress. As shown in Report A3-305 it is the surface roughness caused by corrosion and the thin conductive saline moisture layer that disturb the electric field at the perimeter of conductors and connectors. By 3D FEM analysis of the electric field around 765 kV AC connectors the weakest points have been detected and redesigned. Good agreement between simulation and corona onset tests has been found.

**Q.3-2** Doesn’t the saline layer smooth the surface and doesn’t the conductive humidity layer compensate for the surface roughness, thus reducing the local electric field? What about the conductor surface? Is it included in the simulation? Do other manufacturers and users experience similar problems in a marine and off-shore environment? How do they cope with the corrosion effects of EHV conductors and fittings? The authors assumed certain parameters, such as air conductivity, the saline water layer conductivity and the dielectric constant for the simulations. How can the parameters be selected corresponding to the conditions of environment? Can manufacturers give any other reliable design methods for conductors in coastal areas?
Seismic perturbations

Large and long structures, like several hundred metres of GIS-busbar, may face earthquake waves of different acceleration patterns. By simulations the authors of Report A3-306 show that mechanical stresses are possible, that are much higher than 0.3 G, as applied during type tests. Similar calculations are used to determine the resonant frequencies of sections of a GIS. For example the circuit-breaker section, being a part that could be tested at a platform for seismic tests. The support structure of the breaker section under test is adapted in such a way that the same resonance frequencies are obtained as with the complete GIS. So, an accurate and practical test method has been obtained. The authors show another example of their simulation techniques, where the augmented response of equipment installed at a floor upstairs is predicted.

Q.3-3 With last year’s heavy earthquakes in Japan in mind, the question arises of which conclusions can be drawn for the earthquake type tests. Is the information given in the Report based on the latest information, resulting from the 2011 earthquakes? What specific information can be given on the lessons learned? Was it possible to compare actual earthquake stresses with simulation results? Can other manufacturers or users show the experience of evaluation by input of scenario waves, as described in the Report A3-306? If so, how can the scenario waves be obtained?

Q.3-4 It is impressive to see how Japanese engineers are able to design equipment that to a large extent can withstand such huge disasters and how they are capable to restore the infrastructure so fast. Short term restoration after catastrophes, not only with earthquakes, seems to become a requirement for modern society and its utilities. What can be learnt from Japan and what consequences can be put in place for the design, application and operation of HV equipment? Is the topic of HV equipment for emergency situations to be considered by SC A3? For instance the question how on-site tests can be accelerated or simplified in order to save time? To apply or keep in stock prefabricated equipment, plug-in cable connections, AIS and MTS rather than GIS?

Alternatives for SF₆

In Report A3-101 a HV VCB as an alternative for an SF₆-gas circuit-breaker is presented; in A3-302 a gas circuit-breaker based on CO₂ is described. CO₂ is applied at a higher pressure than SF₆, but as liquefaction is not an issue with CO₂, no application problems are foreseen. A live tank 145 kV, 31.5 kA, 3150 A CO₂ circuit-breaker, three-pole single drive has been designed, built and tested with good results. The only drawback mentioned in the Report is the higher temperature during the heat run test, as the heat dissipation of CO₂ is poor in comparison to SF₆-gas. A two-year pilot installation in a substation as capacitor bank breaker and as line breaker is used as a proof of principle.

Arc models are addressed in the Reports A3-109, A3-203 and A3-304. The authors of Report A3-304 pay attention to the effect of local conditions of the arc, where no thermo-chemical equilibrium exists. They use a computer model of an arcing chamber with N₂ as quenching gas, as this gas is less complicated than SF₆. As a conclusion the authors postulate that for nitrogen thermo-chemical non-equilibrium does not occur between the two arcing contacts, and is therefore less important with respect to the thermal interruption capabilities of the design.

Q.3-5 The authors of A3-302 state that the design has been based on SF₆-gas technology, but optimized for CO₂-gas. Is it possible to give some technical details, such as the quality of the gas (pure CO₂), the applied pressure, by-products, arcing times, arc parameters in comparison to SF₆-gas, critical currents to be interrupted, dielectric characteristics of downstream gases, leakage rate, mechanical and electrical endurance, etc.? In Report A3-304 nitrogen has been simulated. Is N₂ a serious alternative for SF₆? Can other experts contribute to the development of alternative gas technologies? What are the prospects, technological, economic, environmental, of alternative gas technologies in comparison to VCBs?

Q.3-6 How far can the results of simulations, as shown by the authors, be considered as representative, knowing the difficulties with predicting even simple dielectric withstand strengths?
Despite the use of advanced arc models type test results are still not completely understandable (A3-304). Still these models and their refinements seem to help designers to get a better feeling for the phenomena and to accelerate the development of circuit-breakers. Can experts show in this respect the progress that has been made during the last decades? Can the authors or other experts explain the reason why there exists a slight but fundamental difference between the simulation results with or without effects such as the abrasion of the nozzle?

**General information**

Within SC A3, High voltage equipment, four WGs are about to publish their Technical Brochures:

- WG A3.06 Reliability of HV equipment (six Technical Brochures)
- WG A3.15 Non-conventional instrument transformers
- WG A3.17 Surge arresters
- WG A3.23 Guidelines and selection of FCL.

Four WGs will publish their study results next year:

- WG A3.24 Simulating internal arcs and current withstand tests
- WG A3.25 MO varistors and surge arresters for emerging system conditions
- WG A3.27 Vacuum switchgear
- WG A3.28 Switching and testing of EHV&UHV equipment.

Three other WGs have just started their activities:

- WG A3.29 Ageing of substation equipment
- WG A3.30 Overstressing of substation equipment
- WG A3.31 NCIT with digital output.

**Important**

Experts who wish to contribute to the SC A3 Session are required to send their prepared contribution to the Special Reporters before **August 15th, 2012**, in order to check whether and where the contributions fit into the program. It will be difficult to accommodate prepared contributions that are received after August 15th.

Contributors will need to contact the Chairman and Special Reporters of SC A3 on the day before the Session (i.e. on Tuesday, August 28th, as the Session will be on Wednesday, August 29th) at a location in the Palais de Congres, to be announced by CIGRÉ Central Office.