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General Report of SC A3 Colloquium, September 8th 2011, Vienna

Anton Janssen, Ankur Maheshwari, Paulo Fernandez

Introduction

In the week from September 5th to September 9th, 2011, the Austrian NC CIGRÉ hosted SC A3 for its odd year events, such as the SC A3 Colloquium, Meeting and Tutorials. Besides, the Austrian NC CIGRÉ facilitated meetings for five SC A3 WGs.

The Technical Programme consisted of one day for the Tutorials (Sep 7th), one day for the Colloquium (Sep 8th) and one day for the SC A3 Meeting (Sep 9th). Tutorials and Colloquium were attended by 109 registered participants. The Tutorials covered the following topics:

- Fault Current Limiters (WG A3-23), by Heino Schmidt
- Reliability of High Voltage Equipment (WG A3-06), by Magne Runde
- Surge Arresters (WGA3-17), by Bernard Richter
- High Voltage Vacuum Switchgear (WG A3-27), by Rene Smeets.

In the next day Colloquium 23 papers were presented and lively discussed. The authors of this General Report acted as Special Reporters for each of the Preferential Subjects. The Palais Eschenbach with its dignified Beletage offered an excellent accommodation for the Colloquium, as well as for the Tutorials and the SC A3 Meeting. Located in the centre of Vienna, the attendees could enjoy the historical wealth and the vivid culture of the Habsburg empire.

Although some papers have not been submitted to the organizing committee[1], the programme of the Colloquium had most of the initial submitted papers, with many interesting Reports and Technical Contributions. As all authors kept their presentations within the 15 minutes allowed for, it was possible to run the Colloquium programme all day long by the strict time schedule planned on beforehand. The three Preferential Subjects attracted respectively 9, 10 and 4 Reports for the following topics:

1. HV Equipment for New Network Conditions
2. Life-management of HV Equipment
3. Sustainable Technologies: Impact of/on Environment.

The Reports A3-109 and A3-210 have been presented under Preferential Subject 3, and will be discussed under PS 3.

[1] Organizing committee: Ankur Maheshwari (AUS), Wolfgang Widl (AUT), Brian Cheung (UK), Paulo Fernandez (BR) and Anton Janssen (NL)

PS 1 HV Equipment for New Network Conditions

- *UHV*
- *HVDC*
- *Mixed cable-overhead lines*
- *Series capacitor banks*
- *Built-in intelligence*

There is an ever increasing demand for electricity in nearly all countries in the world, leading to new networks, extended networks and working networks harder. These developments require investigations into new network conditions, such as the application of UHV, HVDC, increased short-circuit currents and series compensation.

Three Reports addressed UHV (AC) related items. In Report A3-101 an overview has been given
of the findings of CIGRÉ WG A3.22, "Technical Requirements for Substation Equipment exceeding 800 kV", that published recently two Technical Brochures (362 and 456). While at the TC Symposium on Smart and Super Grids in Bologna, September 2011, in Report 296 more general aspects are treated, in Report A3-101 more specific items for networks with a rated voltage of 800 kV and above are outlined. An overview is given of system solutions with respect to single and double circuit OH-lines, transposition of lines, shunt- and series compensation, single/multi/three pole auto-reclosure, applied secondary arc extinction technology, induced voltages during single and multi-phase faults and consequent requirements for earthing switches and high-speed grounding switches. Surge impedances of heavy bundle conductors and its effect on switching transients, the application of opening resistors and MOSA in relation to switching transients and TRV amplitudes are summarized. But also the TRV wave-form for de-energizing UHV OH-lines with/without earth fault. And for GIS disconnectors: VFTO (very fast transient overvoltages), bus transfer and bus charging duties. For UHV circuit-breaker testing: the test duty parameters for the TRV envelopes. The work of WG A3.22 will be continued by the new WG A3.28, that will focus on specific questions from IEC SC 17A, such as for multipliers for the second and last clearing pole under out-of-phase conditions, and TRV characteristics for transformer limited fault switching. Further by means of network models, typical for bulk power transmission, the influence of tower configurations, compensation, MOSA characteristics, short-circuit power, line length, opening resistors on the switching duties for circuit-breakers and high speed grounding switches will be investigated for 800 kV and above, but also for 420/550 kV networks.

In Report A3-102 the transformer limited fault is dealt with, one of the topics to be studied by WG A3.28. The authors claim that a transformer, which is, for transformer limited faults, the dominant component that determines both the short-circuit current and the TRV wave shape, cannot be represented by a simple topology of the short-circuit inductance in parallel to a capacitance and a damping resistor. This would lead to too high amplitude factors. Based on measurements on relatively small transformers they found that the inductance is frequency dependent because of the iron core permeability is frequency dependent. The frequency dependence leads to lower amplitude factors and this phenomenon may be expected to exist also for the large 550, 800 kV and UHV transformers. Some experts doubted whether the frequency dependence of the permeability is a relevant phenomenon for large power transformers, that show a much lower natural frequency than small transformers. Further investigations are necessary.

Within PT48 (project team 48, meanwhile renamed to WG-48) of IEC SC 17A, experts are defining the requirements for high speed grounding (or earthing) switches, used to eliminate the secondary arc in 550, 800 kV and UHV OH-lines (A3-103). After clearance of a single or multi-phase fault, the healthy phases will induce a voltage into the electrically floating faulty conductor(s) large enough to sustain the arc to ground. By means of single pole operated high speed earthing switches at both ends of the line the faulty conductor is earthed and the arc by-passed. It will extinguish with a few power frequency cycles. As the high speed earthing switches may open within, say, half a second, the circuit-breaker poles can auto-reclose within one second. The earthing switches are devices rather similar to circuit-breakers, as the closing/opening requirements and the making/breaking requirements are severe. PT 48 tries to harmonise the service conditions that have to be considered, including the occurrence of multiple lightning strokes during the operating cycle of the device. An IEC Standard for high speed earthing switches is foreseen to be published in 2013 or 2014.

Within PS 1 three Reports from Brazilian experts addressed the development of short-circuit currents (A3-105), the limitation of short-circuit currents (A3-106) and the experience with series compensation of OH-lines (A3-104). In the last Report a nice overview of the installed and planned (under construction) series capacitor-banks is given, most of them at 550 kV-level, others at 765 and 230 kV. Failure statistics are reported with some interesting figures, such as about 3 unplanned outages per series capacitor-bank per year, resulting into an unavailability of about 75 hours. In addition planned outages count for about 25 hours of unavailability. The cause of ⅔ internal failures is not known, but this part corresponds to ⅓ outage time only. 1% of the internal failures are caused by the capacitor units, but account for half the outage time. 7% of the failures (4% of the outage time) are with MOVs; 5% of which originate from external faults that cause overheating of the MOVs. When asked for, the authors explained that the MOV performance is good, but to prevent overheating of the MOV series capacitor banks are switched off when energy limits are reached, for instance during multiple faults. No information is yet available on the failure rate of capacitor units versus age.

Series capacitor-banks reduce the overall reactance of an OH-line, thus lead to higher short-circuit current levels. Also the increasing demand for electric energy and therefore more power plants cause an increase in the amplitude of short-circuit currents. The authors of Report A3-106 point at IPP's, which due to unbundling of utilities are not foreseen in the long-term planning forecasts. As many TSOs and DSOs today face the problem of limited information, they have to introduce certain margins in the prediction of short-circuit current levels, that consequently lead to increased values for the specified short-circuit withstand and breaking requirements. The authors pay attention to the application of current limiting (series) reactors, installed in incoming or outgoing feeders or, even better, in the coupling bays of busbars. Particular aspects of the implementation of current limiting reactors are treated (Ohmic value, thermal rating, losses, magnetic fields), but special attention is been given to the influence of the series reactors on the TRV wave-shape, especially the RRRV (rate of rise of recovery voltage). Mitigations to reduce the RRRV are discussed. Experience with EHV series reactors in Brazil is given; with an emphasis on the application in busbars.

The X/R ratio of series reactors may be very high (for instance 50), meaning that the DC-time constant of the short-circuit current becomes larger. Short-circuit currents with large DC-components and, consequently, missing current zeroes are the topic of Report A3-105. The DC-component of a short-circuit depends not only on the X/R ratio, but also on the type of fault (number of phases involved, earth involved, evolution of the fault, the instants the fault currents in each phase start to flow, the pre-fault conditions of the load currents and generator operations). The most onerous condition is that of a progressive single phase to two-phase to three-phase fault, each instant at voltage zero of the related phase voltage, without fault resistance and with a capacitive pre-loading. Based on real network topologies, simulations of several cases are shown and from the oscillograms it is clear, at current interruption, that a large number of cycles without current zero may occur in one or two phases (up to 7). Although the number of cycles without current zero reduces considerable, if the fault resistance and/or substantial arc resistance in the interrupting chamber of the circuit-breaker is taken into account, the authors warn for the low value of the arc resistance in modern circuit-breakers. Moreover, to handle long arcing times is most probably beyond the capability of self-blast SF_6-gas circuit-breakers. Maybe the re-introduction of opening resistors has to be considered in order to cope with such cases. Other experts confirmed that delayed current zeros can be a problem for modern circuit-breakers. They pointed at the Application Guide for Circuit-Breakers (CIGRÉ Technical Brochure 304), that is converted into an IEC Guide, were the capability of circuit-breakers to deal with large X/R-ratios is explained. Together with KEMA, Siemens has developed a software to calculate the influence of the non-linear arc behaviour on the DC-component. It has been mentioned that for generator circuit-breakers manufacturers are used to deal with large DC-components. Questions have been put forward on the influence of multiple short-circuit current paths (multiple DC-time constants), and the impact of HVDC converters and FACTS. Attention is asked for the peak-value of the short-circuit current. The authors propose that within CIGRÉ the increase in short-circuit current levels and the related aspects of short-circuit-currents are investigated more in detail.

Another Report dealing with short-circuit currents is A3-107. A new very fast earthing switch for voltages up to 40.5 kV and short-circuit currents up to 63 kA/1 s is introduced: UFES, ultra-fast earthing switch. The main purpose is to divert a short-circuit current from the fault location (for instance an internal arc in a metal glad switchgear installation) to a well-defined point. The main contacts are within a vacuum bottle and the moving contact is operated by a an ultra-fast micro gas generator, similar to the type used for airbags. Like with airbags, the device can be used only once and has to be replaced. An electronic device processes all required information to detect an internal arc and releases within 2.5 ms a closing command to the earthing switch that closes within 1.5 ms. Safety is increased drastically and damage is limited considerable, due to the UFES. The UFES can be installed as a withdrawable unit for easy and fast replacement. The need for adaptation of internal arc tests is questioned, considering the possibility for simpler simulation possibilities when applying an UFES (CIGRÉ WG A3.24). The author and other experts warn for too fast conclusions, as first of all service experience has to be gained.

In Report A3-110 the development of an hybrid switchgear, consisting of mechanical switches, thyristors and a controller, is described. The device is used for three-phase (short-circuit) current switching on or off at very precise instants with respect to the voltage waveforms. The control of the triggering of the thyristors and the mechanical switches is rather complicated, due to the large make and break times of the mechanical switch in comparison to those of thyristors, the scattering in the make and break times, the behaviour of thyristors around voltage zero and the proper triggering of the reverse thyristors. The authors show a proto-type of a single phase switch-thyristor assembly and describe both a simulation to verify the concept of the controller and a hardware-in-loop simulation to test a prototype controller by means of an RTDS (real time digital simulation system). In the Report a result of the hardware-in-loop simulation is given. The function of the thyristors is to make the current very precisely and the mechanical switch is needed to reduce the losses, especially as the thyristors can conduct a short-circuit current only for a very limited time period.

PS 2 Life Management of HV Equipment

- *Diagnostics*
- *Condition/End-of-life assessment*
- *Reliability*
- *Maintenance*
- *Overstress*

Report A3-201 has not been presented, but it deals with the statistical analyses of failures versus the age of the circuit-breakers when the failure occurred in order to Bath-tub curves for each type of failure. Individual minor and major failures are addressed, as well as the remaining life, based on each type of failure (for instance leakages).

In Sweden disconnectors are known to be the cause of certain large black-outs and deserve therefore special attention. So, in addition to the application of thermography, new sensors are applied near the hot spots of risk full disconnectors in order to monitor permanent or temporary the temperature pattern. In Report A3-202, the development and application of wireless temperature measuring sensors are described. The report recommends consideration to be given to application of these sensors in addition to thermography (depending on the intended application).

Another diagnostic technique is dielectric response measurement on paper-oil insulated apparatus (A3-206). The dielectric response is the dissipation factor measurement and presentation over a frequency band from mHz to kHz. By analysis of the dissipation factor graph versus frequency the moisture content and oil conductivity can be detected and the condition of the apparatus judged. Especially by comparing the graphs from identical apparatus, suspicious equipment can be selected.

The experience of four large grid operators including processes they apply to identify potential overstresses of HV equipment are highlighted in paper A3-207. These operators are from Brazil, Spain, France and UK. The utilities typically take into consideration the development of load currents and the development of short-circuit currents, including the development and consequences of the X/R-ratio. In addition in Brazil attention is given to the development of TRVs and of temporary overvoltages. In France the development of the system voltage (too high and too low) is taken into account as well. The way the utilities differentiate between the planning horizon of system planners and that of system operators is addressed, including the influence of the regulator. A question has been raised on the relationship between the actual stresses and the potential overstress model. The authors answered that an important aspect is the uncertainty with respect to developments and future operational conditions of, for instant, IPPs. With less accurate information, more margin is needed. In future the authors plan to write a guide how to handle this matter.

A central monitoring system for all kind of HV equipment is described in Report A3-208. From the information available at substation control centers, in the central dispatch center, from protection relays and from enterprise information systems (e.g. maintenance information), many relevant data to detect non-standard behavior and to assess the condition of individual equipment as well of populations of equipment can be extracted. A system to automatically combine all these data and convert it into information is available at the Czech national TOS (CEPS). The system, the selection of the relevant data and the several levels of providing information are highlighted: operational, tactical and strategic level. Additional intelligence completes the system: recognition of re-strikes, of saturation, of inaccuracies, of inrush currents, of overvoltage stresses, line outages in relation with lightning location, investment decisions in relationship to health and risk indices, importance of equipment ranking, etc. Experience with the system and several examples of achievements are described. Upon a question about the interfaces between the software packages, the authors answered that a common interface has been applied successfully with the remark that only for very special calculations, like the accumulated interrupted short-circuit current, some problems have been faced.

End-of-life decisions based on the investigations of the deterioration of parts and materials is the topic of report A3-209. The authors show examples of the combination of deterioration phenomena, which together lead to failures. For example, the combination of the ageing of grease (evaporation of oil, contamination, abrasion powder, destruction of thickener, oxidation) and the number of operating cycles gives an accelerated wear of the silver plating of contacts in comparison to the wear of new equipment. Weibull analysis of the combines stress (ageing and number of operating cycles) shows a steep increase in failure rate after a reduction of the oil content to less than 50% of the grease. Other deterioration phenomena are mentioned as well in this paper by experts from Japan.

CIGRE WG A3.06 summarized the results of the 2004 to 2007 worldwide survey on the reliability of circuit-breakers, disconnectors, earthing switches, instrument transformers and gas insulated switchgear in report A3-211. The reliability of circuit-breakers has improved with respect tot hat reported from the second international enquiry, with 0.3 major failures per 100 circuit-breaker years. Disconnectors and earthing switches show a major failure rate of 0.2 per 100 equipment years (3-phase) and instrument transformers 0.05 per 100 single phase apparatus years. GIS equipment has generally a better reliability performance than air insulated equipment. The overall major failure rate of GIS-bays is 0.4 per 100 bay years. A number of relevant data and information is given in report A3-211. All results will be published soon in a package of 6 CIGRE Technical Brochures.

A reliability survey on gas circuit-breakers in Japan is reported in paper A3-212. The results with respect to the subdivision of major and minor failures show a same trend as that of the worldwide enquiry, discussed in paper A3-211, although the failure rates are lower. Spring drives have a failure rate which is only 1/3 of that of hydraulic drives, mainly because of the much larger number of parts in hydraulic drives. These results are used by the authors to develop a double break 550 kV gas circuit-breaker with a spring operating mechanism. In comparison to a double break circuit-breaker with an hydraulic operating mechanism, as developed two decades ago, the number of parts is reduced to 42%. Even in comparison with a single break gas circuit-breaker with an hydraulic drive, the number of parts of the spring driven double break circuit-breaker is reduced to 68%. The spring mechanism applied is that of a torsion bar type.

Reliability is also the topic addressed in report A3-113, in this case the reliability and forensic investigation of vacuum interrupters. The author explains the physics of vacuum tubes and the factors that may lead to deterioration. Important failure modes are mechanical damage, corrosion and design issues. Examples of such failures are given, but the overall reliability of vacuum interrupters is very good. Vacuum technology has been introduced 40 years ago and so far experience learns that the sealed for life device scan last for at least this period of time. A question was raised about how to handle vacuum interrupters after 40 years of service. The author honestly answered that most probably after 40 years corrosion and leakages will become an increasing issue, but that is still to be experienced.

PS 3 Sustainable Technologies: Impact of/on Environment

- *Vacuum HV breaking*
- *SIS (solid insulated switchgear)*
- *DAIS (dry air insulated switchgear)*
- *Off-shore/marine applications*

In Report A3-210 it was described which actions have been considered in the last years in order to reduce the risk of SF_6 emissions/leakages to the environment, specially considering end-of-life treatment and SF_6-gas recovering on a large number of 30 years old MV and HV switchgear equipment. The paper states that for many applications SF_6 technology is the best solution, without equivalent substitutes, in terms of compactness, insensitivity to environmental conditions, low maintenance, cost-effectiveness and sustainability.

The authors of Report A3-109 draw attention the effects of surface charge on the electric field intensity near solid insulations in a gaseous environment. They focus at the relatively weak discharge activity (glow mode of corona) that takes place in strongly non-uniform fields. Basic formulas for the drift, diffusion and recombination of charged particles (electrons, ions) in electric fields are implemented in a finite element model. The model is verified by means of the static voltage-current characteristics of the positive DC corona in a rod-plane system of which experimental data are known. Results of the simulation of charge density and electric fields are discussed for the rather simple configuration of a rod above a plane with an insulating barrier at some distance parallel to the plane. The authors show how the charge density changes over time and consequently the total electric field distribution, when a switching impulse voltage is applied.
They mention the optimal position of the barrier to achieve the highest breakdown voltage, and compare experimental results with the simulated optimal conditions for corona charging and field homogenization. By this approach they contribute to the methods needed to design high voltage hybrid insulation systems.

In Report 301 the experience in Japan with SF_6 gas-free switchgear for medium/high voltage range (24 up to 84kV), focusing mainly on vacuum/dry air insulated switchgears and SIS (Solid Insulated Switch-gear) applying vacuum switchgears, is described. About 2,500 SF_6 gas-free VCB units from 24 kV to 84 kV have been produced and delivered until now. It was verified by various tests that the developed material and actual products show high reliability, mechanical strength and good insulating performance.

In Report A3-302 it was described the development of a research by Siemens on dielectric performance (TRV performance) of HV switchgear (GCB) in the presence of liquefied SF_6 (LSF_6) inside the interrupting chambers in very low operating temperatures and at typical in-service conditions. The results of the research showed no reduction in insulation withstand characteristics of HV GCB tested, indicating that the tested full scale high-voltage components can withstand the relevant IEC type test voltages with LSF_6.

In Report A3-303 it was pointed out that for electric industry in general, and for Power System (PS) sector in particular, environmentally accepted solutions will be a key issue, as well as economic and reliable supply of electricity will be required by public opinion and policy frames. High quality of the sealing system and gas compartment housings offers good gas tightness values and very low leakage rates. Besides that, SF_6-handling process, trained staff and the service equipment, like maintenance units or gas quality measurement instruments are important factors to reach the desired aims for minimizing environmental impact. Reuse concepts have to be considered during maintenance and end-of-life-procedures, as well as maintenance strategies might be improved (less openings). Corrosion protection is a big concern in this respect

In Report A3-304 it was shown some experience on the use of VCB as HV switchgear (up 72.5 kV) using glass ceramics as housing replacing GCB as a gas free alternative, mainly in end-of-live assessment for GCB considering mitigation of impacts to the environment.

Concluding remarks

The Austrian National CIGRÉ Committee and the OVE (Östereicher Verband für Elektrotechnik: Austrian Electrotechnical Association) organized excellent accommodations and general infra-structure for the events: Tutorials, Colloquium, SC A3 Meeting and WG-meetings. A large number of attendees from all over the world enjoyed both the technical events and the city of Vienna.

The topics addressed at the Colloquium were chosen by the organizing committee mainly due to the fact that they will be repeated as Preferential Subjects for the 2012 Study Committee A3 Session in Paris, and showed to be very interesting, instigating many fruitful discussions. Three of the four SC A3 WG's that presented themselves at the Tutorial are about to finalize their Technical Brochures, so that the material presented is already mature.: Fault Current Limiters (WG A3.23), Reliability of HV Equipment (WG A3.06) and Surge Arresters (WG A3.17). The program of the Tutorials and the Colloquium, including the list of Reports (see also the Attachment), is available thought the websites of the Austrian National CIGRÉ Committee (http://www.cigre.at/sca3/) and of CIGRE Study Committee A3 (http://www.cigre-a3.org/).

Attachment

Reports presented at the 2011 CIGRÉ Study Committee A3 Colloquium in Vienna

PS 1: HV EQUIPMENT FOR NEW NETWORK CONDITIONS

A3-101 Background information and study results for the specification of UHV Substation Equipment
(H. Ito, A. Janssen, D. Dufournet, Y. Yamagata, U. Riechert, P. Fernandez, M. Koskada, D. Peelo)

A3-102 Investigation of TRV after Interrupting Transformer Limited fault
(H. Ikeda, E. Haginomori, H. Toda, M. Hikita, T. Koshizuka)

A3-103 Considerations for the standardization of high speed earthing switches for secondary arc extenction on transmission lines
(M. Toyoda, Y. Yamagata, L-R. Jaenicke, H. Heiermeier, A. Lathouwers, K. Edwards, I. M. Kim, B. Han, G. Marquezin, M. Koskada)

A3-104 Series Capacitor - Brazilian experience with series compensation of transmission lines
(A. C. Carvalho, H. Pessoa Oliveira, A. D'Ajuz, P. Guimarães Peixoto)

A3-105 Determination of requirements for short circuit currents with delayed zeros through digital computer simulations using the ATP program
(J. Amon. F., P. C. Fernandez, R. A. A.Gonçalves)

A3-106 Brazilian successful experience in the Usage of Current Limiting Reactors for Short Circuit Limitation
(J. Amon. F. , P. C. Fernandez, E. H. Rose, A. D´Ajuz, A. Castanheira)

A3-107 Active arc fault protection - Ultra-Fast Earthing Switch Type UFES
(K.-H. Hartung)

A3-109 Charging of solid elements of high-voltage insulation by corona in gas
(U. Kaltenborn, Y.V. Serdyuk, S.M. Gubanski, R.F. Summer)

A3-110 Simulation-based development of a three-phase hybrid switchgear for high-current testing laboratories
(P. Jonke, F. Andren, G. Brauner, W. Hribernik, H. Ertl)

PS 2: LIFE – MANAGEMENT OF HV EQUIPMENT

A3-201 Prediction and Management of 550kV SF6 Circuit Breakers with Multiple Censoring Data
(E. Gockenbach, X. Zhang, Z. Liu, K. Gao)

A3-202 Wireless sensors vs Thermography - Comparing accuracy and applications
(T. Lindquist)

A3-206 Lifetime management using dielectric response with focus on instrument transformers
(S. Rätzke, M. Koch, M. Krüger)

A3-207 Overstress - Criteria for tracking transmission equipment overstress
(A. C. Carvalho, R. Tenorio, M. Waldron, M. Escoto, N. Lemaitre, S. Moroni)

A3-208 Automatic Central Monitoring System for HV Equipment Condition Assessment
(D. Kopejtkova, P. Kopejtko, L. Kocis, J. Chrastek, L. Vranova)

A3-209 End of life assessment for aged switchgear considering age and operation times
(T. Kobayashi, H. Saito, K. Takahashi, M. Kawada, T. Minagawa, H. Ito)

A3-210 Recovery and regeneration of SF6 at switchgear end of life is now a mastered industrial process
(J.-M. Biasse, T. Endre, T. Hoel, N. De Bure)

A3-211 Summary of Results of the 2004 - 2007 International Enquiry on Reliability of High Voltage Equipment
(WG A3.06)

A3-212 Analysis of failure mode of Gas Circuit Breakers
(H. Kohyama, D. Yoshida, I. Ishigaki, T. Yonezawa, H. Ito)

A3-213 The Reliability and the Forensic Investigation of Vacuum Interrupters.
(L. T. Falkingham)

PS 3: SUSTAINABLE TECHNOLOGIES; IMPACT OF/ON ENVIRONMENT

A3-301 Application of SF6 gas free switchgear and its technology in Japan
(N. Inoue, H. Saito, K. Sasage)

A3-302 Basic investigations concerning equipment with liquefied SF6 under extreme low temperatures
(E. Kynast, K. Juhre)

A3-303 Environment concious use and handling of SF6 in Gas Insulated High Voltage Switchgear
(P. Glaubitz)

A3-304 Green solution for using vacuum interrupter and SF6 free insulation for72.5 kV circuit breaker
(R.S. Parashar, P.J. Howard, A. Girodet)