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CIGRE 2018

B4-00

SPECIAL REPORT FOR SC B4
(DC and Power Electronics)

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Special Reporters

Cigre study committee B4 is responsible for DC and Power electronics for AC systems. The recent increase in generating power from renewable resource and changes in the power transmission patterns has increased the need for DC and FACTS devices. A growing interest is also evident in utilizing DC at lower voltages for distribution purposes. At the same time the recent advances in semiconductor devices and in circuit topologies opens up new possibilities for planning and operation of AC systems. The study committee B4 plays an important role in this process by providing a forum for the experts to exchange their thoughts and experiences.

For the 2018 session a total of 45 papers were selected, based on the preferential subjects listed below. These papers represent the latest information on DC and FACTS schemes at various stages of planning, construction and operation. The new advancements in manufacturing semiconductors for DC and power electronic applications and in novel topologies for power electronic devices are also reported in a number of interesting papers. The experience with upgrading the aging HVDC and FACTS devices is shared in a number of other papers.

The Preferential Subjects chosen by the Study Committee for the 2018 session are as follows.

PS1 HVDC systems and their applications

- Planning and implementation of new HVDC projects (including, need, justification, design, integration of wind generation, environmental and economic assessment)
- Application of new technologies in HVDC, HVDC Grids / Multi-Terminal HVDC
- Refurbishment and upgrade of existing HVDC systems
- Service and operating experience

PS2 DC and other Power Electronic (PE) systems for distribution systems

- Medium voltage HVDC and its applications in distribution systems
- Planning and implementation of new distribution projects
- New concepts, designs

PS3 FACTS and other Power Electronic (PE) systems for transmission systems

- Planning and implementation of new projects (including, need, justification, FACTS devices for renewables, environmental and economic assessment)
- Application of new technologies in FACTS and other PE equipment
- Refurbishment and upgrade of existing FACTS and other PE systems
- Service and operating experience

PS1 - HVDC systems and their applications

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- *(PS1-1) Planning and implementation of new HVDC projects (including, need, justification, design, integration of wind generation, environmental and economic assessment).*

Paper B4-101 "An 800 kV HVDC bipole to reinforce a regional interconnection and integrate a large amount of variable renewable generation"
This paper describes the need for network reinforcement North-South corridor in Brazil due to the rapid expansion of the renewable generation in the North-East region. Alternative HVAC and HVDC solutions were compared and an 800kV 4000 MW HVDC link was selected due to lower cost. Studies show the HVDC solution and the existing parallel AC transmission system improve the performance of each other. This will be the first HVDC system in Brazil not associated with large generation.

Paper B4-102 "HVDC Ground Electrodes and Tectonic Setting"
For three basic tectonic settings geoelectric models are suggested and described in this paper. These models enable the evaluation of how the tectonic setting of the region interferes with the geoelectric modelling for HVDC ground electrode design. In addition to the minimum depth of the geoelectric model a second parametric study presents an evaluation of the electrode dimension x resistance. Finally, it shares some observations regarding the ground electrode site selection for HVDC projects with different tectonic settings**.**

Paper B4-132 "The Construction of the New Hokkaido-Honshu HVDC Link Project"
This paper describes the need for a second link between Hokkaido and Honshu islands and the studies that led to the selection of the VSC-HVDC option. The paper also describes the DC transmission line and cable and high level converter design and its control and protection.

Paper B4-133 "The construction of the Hida-Shinano HVDC link"
The paper provides an overview of a new HVDC system to be installed between the 50Hz and 60Hz regions in Japan to facilitate power trade between these regions. The need for power transmission between the two regions has been increased as a result of increased renewable energy resources. The paper also discusses the issues related to the low order harmonic resonances and the stray DC current in the nearby AC system. Multi-vendor design considerations are also discussed.

Question 1.1:

- How does the integration of large amount of variable renewable wind / solar generation impact the technical design requirements of the HVDC transmission schemes?
- Considering the experience of previous (successfully) HVDC installations provided by different manufacturers are there multi-vendor requirements established / considered in new specifications?
- How do the other DC projects installed by different manufacturers in close proximity impact the new HVDC projects?

Paper B4-104 "Parallel operation of multivendor VSC-HVDC schemes feeding a large islanded offshore Oil and Gas grid"
This paper presents the simulation study results for two parallel VSC-HVDC links supplying a gas and oil platform. The two HVDC systems are from two manufacturers and the model from one manufacturer was not available for this study, therefore a generic model was used. The proposed controller can successfully distribute the load between the converters in proportion to their ratings while maintaining the platform frequency constant.

Paper B4-111 "Design considerations for parallel HVDC links feeding offshore platforms"
Another application to supply a cluster of offshore oil platforms using two parallel VSC schemes is presented in Paper 111. Detailed studies have been carried out to identify possible interoperability

issues, to design and parametrize the control schemes in order to share the active and reactive power demands of the offshore grid simultaneously and collaboratively during start-up, steady state conditions as well as during and after a disturbance.

Question 1.2:

- When planning the power supply for an offshore platform two parallel HVDC schemes seem to be a high investment to ensure highest power supply availability and reliability. What are the cost implications here, considering two complete symmetrical monopoles, with full cables and converters?

Paper B4-108 "Support of VSC-HVDC to the restoration of weakly connected systems: the Sardinia case"

This paper illustrates the potential benefits of a VSC-HVDC scheme to support the restoration of a weak AC network following a blackout. Investigations include scenarios where the VSC acts either as a black start unit or as a STATCOM. In both modes the VSC enhances the voltage controllability along the nodes of the restoration path. The frequency controls enables connecting loads or can act as a "ballast" load and thus reduces frequency deviations to levels far away from limiting frequencies for rotating machines.

Question 1.3:

- How should the Black start / System Recovery Ancillary Service (SRAS) capability specified for new VSC projects considering the necessary detailed knowledge of the AC system / restoration procedures of the AC networks as well as all regulatory requirements?
- How should the Black start / System Recovery Ancillary Service (SRAS) capability be proved by off- and on-site tests, may be by using generic network models adequately representing typical black start scenarios?
- Any other experiences related to Black start scenarios?

Paper B4-110 "Application of converter transformer controlled switching in Nelson River Bipole III HVDC system"

Large transient inrush currents resulting in severely depressed AC voltages can be caused by the energization of HVDC converter transformers. In addition to power quality concerns such voltage depression may cause commutation failures resulting in large temporary power losses, especially for bipolar schemes or in cases where other HVDC schemes are impacted. To mitigate such adverse impact the point-on-wave (POW) switching used for Bipole III project calculates remanence to determine optimal closing instants taking also protection trips and different tap-changer positions into account.

Question 1.4:

- The choice between POW and pre-insertion resistors (PIR) is always based on economics. Proposed POW method seems effective. Considering the higher cost, why should PIR even be considered?

Paper B4-113 "Lessons Learnt from the BEST PATHS Project for the Integration of Offshore Wind Power Plants using Multi-Terminal HVDC Grids"

A further step from parallel HVDC schemes and concepts as described in Paper 104 and 111 is the development of MTDC grids including the integration of offshore wind power plants. Paper 113 summarizes the investigations of BEST PATH project (a European project initiative), including the electrical interactions between HVDC and wind turbine converters in offshore wind farms, definition of KPIs to assess the operational performance, the development of open access models and simulation tools with control algorithms as well as the results of studies verified with real-time simulations.

Paper B4-115 "DC Grid Control Concept for Expandable Multi-terminal HVDC Transmission Systems"

As discussed in Paper 113 the development of MTDC grids emerges by the interconnection of additional converters to existing schemes. Paper 115 proposes a control algorithm for MTDC Grid consisting of a primary control algorithm which is the original or typical converter control, and a secondary Algorithm which is the proposed MT type control.

Paper B4-134 "Assessment of interoperability in multi-vendor VSC-HVDC systems: interim results of the BEST PATHS DEMO #2"
Best Paths Demo #2 is a European project to investigate the interoperability in multi-vendor VSC HVCD systems. The assessment at the first stage used detailed EMT models from multiple VSC suppliers. In the second stage (in future) the real time simulators will be connected to the actual control cubicles from multiple vendors to test the interoperability of the real systems in more detail.

Question 1.5:

- Detailed study and planning is the basis of success of complex projects and proper information and models are the key. Would it be possible to fully explore the benefits of HVDC control features by using generic – open access models without the consideration of vendor specific developments?
- What technical challenges have been identified when a new converter is added into the existing HVDC / MTDC system or when a different control strategy is adopted by the DC grid (secondary) control?
- What are the key factors to be considered in today's HVDC schemes to allow their expansion to multi-terminal multi-vendor systems in the future?

Paper B4-114 "Need, design and business case for building the North Sea Link"
In many parts of the world, especially in Europa, changes of the power systems are expected over the next decade. With large thermal power plants decommissioned, lower seasonal demand in some regions and increasing amount of wind and solar generation has led to a generation mix that is increasingly volatile. Due to the increasing proportion of non-synchronous generation the power systems have reduced short circuit capacity, lower inertia and less controllability. Paper 114 addresses some of the benefits and challenges of building a new HVDC VSC interconnector from the perspective of the changes in the AC power systems. The North Sea Link (NSL) will use VSC technology in a 515 kV DC bipolar configuration without a neutral cable or sea electrodes to transfer 1400 MW. The NSL will, when completed, the longest subsea cable HVDC interconnector in the world, with a total route length of approx. 722 km.

Question1.6:

- The NSL project uses MIND cable for better reliability, proven technology and ease of manufacturing. However is the cost comparable? What is the experience from other projects regarding the chosen cable technology?
- The rigid bipole configuration is selected for this long cable project to save on the third cable and electrode. Are there any comments from other projects with respect to this configuration?

Paper B4-125 "Studies for Upcoming +/- 320 kV, 2000 MW Pugalur – Trichur VSC HVDC link with +/- 800 kV, 6000 MW Raigarh – Pugalur LCC HVDC link - Indian Approach"
This paper presents the results of initial studies for the Pugalur-Trichur VSC HVDC and Raigarh-Pugalur LCC HVDC systems. The Pugalur 400 kV AC bus is common between the LCC and VSC terminals. The study considered various AC and DC faults in both HVDC systems and concluded that the presence of the VSC terminal improves the commutation performance and fault recovery for the LCC link. Pole to ground faults in VSC system have no significant impact on the LCC system.

Question 1.7:

- How would a pole to pole fault in the VSC scheme impact the LCC system?
- Are there other similar experiences with adjacent VSC and HVDC terminals?
- How does the LCC system, e.g. TOV in case of load rejection, impacts the VSC scheme?

Paper B4-129 "Kriegers Flak Combined Grid Solution – Combination of Interconnector and Wind Power Collector using a Back-to-Back and a Master Controller"
This paper describes the unique arrangement of the KF CGS system that allows any desired portion of the power produced by three offshore windfarms in Denmark and Germany to be directed into either country according to the market requirements. Additionally, if any portion of the transmission capacity is not fully utilized due to the low wind, it can be used as an interconnector for power trade purposes.

Question 1.8:

- KF CGS presents the application of a BtB HVDC regulating the power flow on an AC interconnector both for trade purposes and wind power transmission. Are there other similar applications of HVDC? What are the challenges arising from the error in the wind power prediction?

- ***(PS1-2)*** *Application of new technologies in HVDC, HVDC Grids / Multi-Terminal HVDC.*

Paper B4-103 "Linking DC Macrogrids to Underlying AC Systems"
Large HVDC grids as overlays to AC systems will require efficient forms of DC-to-DC power transformation. Paper 103 explores the prospects of capacitor-based power transformation (DCT) between DC lines of differing voltage while simultaneously providing a means for power interchange between those lines and the underlying AC systems. The DCT offers a solution which minimizes the impact of major macrogrid (DC) disturbances on the underlying AC network (N-1).

Question 1.9:

- What minimum technical requirements shall be determined and considered for the development of DC-to-DC power transformation devices (reliability aspects, losses etc.) ?

Paper B4-106 "Power Semiconductors for Energy Transmission"
This paper explains how best performance, i.e. loss reduction or protection optimization, can be achieved with an optimal design of different semiconductors in certain topologies. In addition to the development of higher voltage and current ratings, new power semiconductors for high power applications, i.e. SiC IGBTs and SiC-MOSFETS (SiC - Silicon Carbide), are now available. Adopting recent developments in power semiconductors, a further reduction of conversion losses for VSC systems can be expected.

Paper B4-305 "Power Semiconductor Technology Advancements for Enabling Next Generation Grid Systems"
The paper describes performance improvements in several semiconductor devices including Phase Controlled Thyristors, Bimode Insulated Gate Transistor (BIGBT) and Insulated Gate Commutated Thyristor. The third generation PCT has current rating up to 6.25 kA and reduced on state voltage. The new stack pack BIGT reach 4.5kV 3kA ratings. The new 94mm IGCT reach 4.5kV and 3kA.

Paper B4-107 "Innovative mitigation measures for electrostatic charge build-up on surfaces of dry-type air-core reactors for HVDC application"
Paper B4-107 introduces a new method to prevent discharges across the surface and through the encapsulation of the winding packages of HVDC air core reactors. Applying a dissipative plastic film

or a dissipative coating directly to the reactor surface by using a sprayable varnish enables to drain off the charges to the winding ends of the reactor.

Paper B4-118 "Next generation of Line and Cable fault Locator for HVDC transmissions"
The paper presents the next generation of on-line fault locators for HVDC systems. With such high speed recordings available it is possible to detect incoming travelling waves also in DC cable and overhead line combinations and to provide accurate fault location estimates within a few seconds. Fast fault location enables to reduce the outage time and thus improves the overall availability of the HVDC transmission system. With more DC cables being installed including land cables with a large number of joints, the fast detection of the fault location using such on-line fault locators is getting more and more important.

Paper B4-126 "Introduction of a new level of HVDC to UHVAC linked systems with respect to main component transformer technology and design"
This paper reports about the introduction of a new level of HVDC to UHVAC linked systems and how novel design solutions have been considered in the design of the converter transformers. Besides the combination of ±200 / ±400 kV DC and 1050 kV AC in one transformer another particular challenge was the arrangement of the valve and regulation winding.

Question 1.10:

- Are there other innovations applied in HVDC schemes to improve the performance of HVDC systems?
- What measures can/shall be applied, particularly for novel solutions and new developments such as the SiC-power semiconductors or converter transformers combining DC voltage levels with UHVAC levels of 1050 kV, to ensure highest reliability performance in HVDC and FACTS schemes. Any examples?

Paper B4-109 "Hybrid multi-terminal HVDC - LCC with VSC converter taps: A Manitoba case study"
The paper examines the application of tapping a long distance LCC HVDC system with two 500 kV VSC DC converters. Full-bridge VSC has a number of features to enable such hybrid multi-terminal link. Special attention is paid to high level controls and strategies considering different operational scenarios including the start-up of the taps. A two time step model which combines LCC and VSC transient stability models has been used to evaluate transient stability (validation with detailed PSCAD models). EMT type model demonstrates adequate performance of the hybrid multi-terminal scheme in case of both AC and DC faults.

Paper B4-112 "Single arm MMC VSC converter: a novel design for high voltage-low power terminals (taps)"
This paper presents a new topology for a MMC VSC called Single Arm (SA) converter suitable for low power converters (taps) connected to high voltage DC. The proposed converter topology utilizes only one chain of submodules between the DC terminals, as opposed to three chains (for the three phases) in standard MMC VSC. Considering the substantial reduction in the number of submodules the converter is expected to be more economical and takes less space.

Question 1.11:

- Feasibility of tapping an LCC line utilizing VSC has been discussed in many instances, yet it does not seem there are any actual plans to do this. What are the technical and economic issues that discourage this?

Are there other possible configurations to add a VSC tap to an existing HVDC scheme?

Paper B4-116 "Challenges in bringing UHVDC from ±800 kV to higher voltages"

Paper 116 identifies the various challenges in increasing the DC voltage from 800 kV to 1100 kV. The paper demonstrates that many technical challenges of the development of 1100 kV UHVDC systems have been solved and converter station equipment is available today.

Question 1.12:

- It seems in addition to the technical challenges, mechanical, and transportation challenges are just as important. What are the possible solutions?
- With DC voltages of 1100 kV the increased power transfer capacity above 10 GW will cause additional challenges to integrate such large converter terminals into the AC systems and to ensure secure operation of the connected AC networks (load rejection caused by pole faults etc.). Taking into account additional measures to secure AC system stability as well as availability, reliability aspects, what are the cost implications in comparison with two bipolar systems with lower DC voltages?

Paper B4-117 "A cost effective hybrid HVDC transmission system with high performance in DC line fault handling"

Paper 117 introduces a hybrid HVDC scheme for unidirectional power transfer consisting of an LCC converter at the sending terminal and a half-bridge (HB) MMC at the receiving end. Utilizing a diode valve in series with the HB MMC enables to block the DC fault current contribution from the VSC converter and thus, ensures fast DC line fault recovery without the loss of the reactive power control during the DC fault clearing.

Paper B4-120 "Research and development of Ultra-High-Voltage VSC for the multi-terminal hybrid ±800kV HVDC project in China Southern Power Grid"

Paper 120 describes the research and development of another Hybrid HVDC system, but at UHVDC 800 kV in a multi-terminal configuration. For the WDD project the two inverter stations consist of two series connected VSC-MMC converters per pole to match with the LCC rectifier arrangement. Two topologies, the Full-Bridge (FB) MMC and the hybrid MMC with 80% FB-modules can meet the DC line fault performance requirements.

Question 1.13:

- What other solutions exist for improving the DC fault performance of a long distance VSC HVDC system utilizing an overhead transmission line?
- Has the technology now reached a stage to build 800 kV VSC transmission schemes?

Paper B4-121 "Characteristics of system and parameter design o key equipment for Zhangbei DC grid"

This paper presents the Zhangbei demonstration DC grid. The 500 kV DC grid adopts a four terminal ring configuration in bipolar topology with a dedicated metallic return conductor. Modular hybrid DC breakers and DC reactors have been implemented at both ends of each line to clear DC line faults.

Question 1.14:

- For a DC Grid with terminal loads in the range of 1500 – 3000 MW highest reliability of DC breakers is a stringent requirement to ensure secure and stable operation. This may include features such as multiple auto-reclosures as used in AC systems or back-up breaker functionality. What specific aspects and requirements shall be considered for DC grids or in the design of DC breakers?

Paper B4-124 "Transformer-less VSC-HVDC Transmission"

This paper discusses the advantages and issues related to the elimination of the transformer in a symmetrical monopole VSC HVDC scheme. The advantages include reduced cost, losses and footprint, ease of transportation, possible reduced lead time and increased reliability and availability. The simulation study shows that all identified issues such as flow of DC current into the AC system, flow of zero sequence harmonics into the AC system can be addressed through proper control and modulation techniques, an increase in the number of submodules and arm reactance.

Question 1.15:

- In a VSC converter utilizing half bridge converter and without the interface transformer the DC voltage and AC current cannot be selected in an optimal manner. For a full bridge VSC the DC voltage can be selected independent of the AC voltage and further optimization is possible. Is there any experience in consideration of a transformer-less VSC (either half bridge or full bridge) for a real world project?

Paper B4-127 "A Novel DC Fault Blocking Concept for Full Bridge Based MMC Systems with Uninterrupted Reactive Power Supply to the AC Grid"

Paper B4-127 describes a novel method of suppressing DC fault current in a full bridge VSC. The new method allows the converter to continue providing reactive power support to the AC system while blocking the DC short circuit current. This is achieved by blocking only the upper (or lower) arm submodules.

Question 1.16:

- What are the available fault current suppression methods in a VSC and what are their relative advantages?

Paper B4-130 "Advances in DC neutral breaker performances for bipolar HVDC schemes"

The paper presents the challenges and advancements in developing conventional (resonance based) MRTS (metallic return transfer switch) for the bipolar HVDC systems with rated currents above 6 kA. Challenges and innovative techniques in testing the high current MRTS are discussed.

Question 1.17:

- With the continued increase in DC current ratings in HVDC systems what are the challenges in developing suitable DC switches? How does the increased utilization of dedicated metallic return conductors impact the design of DC switches?

Paper B4-131 "Design Aspects of MTDC Grids with Integration of Renewable Energy Sources"

This paper explains the critical role of the DC breakers in a DC grid and the need for bidirectional breaking capability. Simulation results for energization of the DC grid and primary and backup fault clearing are presented. The need for DC choppers to assist with wind farms fault ride through is discussed.

Question 1.18:

- When a fault occurs in a DC grid the power flow in the entire grid is interrupted until the fault is cleared. What are the possible techniques to allow the windfarms supplying the DC grid terminals ride through a DC grid fault?

Paper B4-135 "Virtual capacitor for DC grid stability enhancement"

The paper presents the novel concept of virtual capacitor for a VSC connected to a DC grid. The energy storage capability of the MMC can be used to mitigate the fluctuations of the DC voltage. The virtual capacitance is achieved by controlling the power exchanged between the DC grid and the converter during a disturbance. The size of the virtual capacitance can be adjusted through controller parameters. The virtual capacitor can improve the DC grid voltage stability. A small scale prototype is made to prove the concept.

Question 1.19:

- Considerable amount of energy is stored in submodule capacitors of an MMC VSC converter. How can this energy be utilized to improve the performance of the DC and AC systems connected to a VSC HVDC converter?

· ***(PS1-3)*** *Refurbishment and upgrade of existing HVDC systems.*

No papers were submitted for refurbishment and upgrade of the existing HVDC systems.

· ***(PS1-4)*** *Service and operating experience.*

Paper B4-105 "Assessment of Nordic HVDC operation and maintenance practices on reliability and availability of HVDC systems"

This paper presents the results of a study by a joint working group formed by Nordic TSOs to identify measures to improve the reliability and availability of their HVDC systems considering their operation and maintenance methods. The paper presents the current availability level, the impact of different operation and maintenance methods on reliability and availability and the ways to improve them.

Paper B4-119 "Lifecycle Service for HVDC Systems"

This paper presents a life cycle approach for HVDC and FACTS systems. For such assets with typical lifetimes of 30 – 40 years, the development of newer and more advanced components and technologies can improve the performance and security of older systems, adds many years to its lifetime and delivers new functionalities that further increase its availability and reliability. Digital upgrades enable systems to benefit from connection to the Internet of Things (IoT), and integration with modern asset management and data analytics systems.

Paper B4-137 "A Survey of the Reliability of HVDC Systems throughout the World during 2015 – 2016"

CIGRE Advisory Group B4.04 collects data annually on the reliability performance of HVDC systems in operation throughout the world. This report is a summary of the reliability performance of HVDC systems in operation worldwide during 2015 and 2016.

Question 1.20:

- How can the present quality of the HVDC statistics and reporting being improved to provide a level required by detailed analysis of the factors affecting the reliability and availability or its value?
- Are there any suggestions for AG04 to provide more detailed outage and failure as well as scheduled outage related information?
- What is the experience from other HVDC operators?
- What is the experience with outages caused by control and protection considering the duplicated controls are being utilized?

Paper B4-122 "Design, erection and operational aspects of India's first indoor DC yard at Agra converter station"

Paper 122 highlights the design, erection, operational & maintenance aspects of indoor DC yard at the 800 kV Agra converter station. Special consideration is given to insulation coordination and air clearances, the electrical and mechanical design, building requirements / civil design as well as commissioning, O&M.

Paper B4-123 "Commissioning experience and challenges of World's first +/- 800 kV HVDC Link with Dedicated Metallic Return (DMR)"

The paper summarizes major observations experienced during commissioning and operation of Bipole-I of the 3000 MW HVDC Champa-Kurukshetra Link, which is the first ±800 kV system with dedicated metallic return. There are certain constraints in the conventional ground return i.e. non-availability of site having suitable soil resistivity and thermal conductivity. DMR resolves several issues encountered in conventional electrode line, though some of the issues like DMR protection require specific solutions.

Paper B4-308 "Operation experience of back-to-back HVDC station based on voltage source converters for interconnection of non-synchronous power systems with significant voltage distortion"
The paper presents the operating experience of a VSC back-to-back converter station connecting the asynchronous AC systems of East- and Siberia. The AC network is characterized by long AC lines, with generation located far away from the loads. Due to very long AC lines and traction load of the railway system the power quality is characterized by large AC voltage fluctuations and very high harmonic distortion. Modifications implemented in the HVDC control and protection systems improved the power quality and performance, ensuring stable operation under such network conditions.

Paper B4-136 "Operating experience and ways to improve reliability of Vyborg back-to-back HVDC link (in connection with the 35th anniversary of the commissioning of the first converter unit"
The paper describes some of the operating experiences with Vyborg BtB system between Russia and Finland. In particular the sequence of events leading to voltage avalanches were analyzed. Modifications to the control and protection to correct this situation were successfully implemented.

Question 1.21:

- What is the operational experience from other HVDC transmission schemes with respect to DMR fault clearance as well as observations reported in Paper 122, 123, 136 and 308, such as flashover in DC yard, arrester duties under certain operating conditions or AC voltage / RPC issues?

PS2 - DC and other Power Electronic (PE) systems for distribution systems

- ***(PS2-1)*** *Medium voltage HVDC and its applications in distribution systems*

Paper B4-202 "Developments in the Angle-DC project; conversion of a medium voltage AC cable and overhead line circuit to DC"
The Angle-DC project introduces power conversion technology into the MV distribution business, whilst retaining the existing AC infrastructure operating under DC conditions. This paper describes the latest developments and the detailed engineering considerations in hardware specification, partial discharge monitoring, network level control, and converter operation including energization sequence of this project.

- ***(PS2-2)*** *Planning and implementation of new distribution projects*

Paper B4-201 "Design of the first public distribution DC grid in The Netherlands"
The paper describes the design of a unipolar 750 V DC public distribution system which allows higher or more economical power transfer as well as addresses lower losses, integration of renewable energy, fluctuating load flows etc.. Aspects covered by the paper include the requirements for the DC grid design, the system design, safety and protection concepts. The LV DC distribution system is more complex compared to the traditional LV AC system and the use of converters introduces new fault scenarios and challenges for protection selectivity.

- ***(PS2-3)*** *New concepts, designs*

Paper B4-203 "Performance Evaluation of Different Modulation Strategies Applied to Modular Cascaded Multilevel Inverter based Shunt Hybrid Active Power Filter"
The purpose of this paper is to investigate the performance of the modular cascaded multilevel inverter based shunt hybrid active power filter for reactive power compensation and harmonics elimination.

Different modulation strategies have been analyzed with respect to the effectiveness for both harmonic and dynamic reactive power control.

Question 2.1:

- The projects described in the papers above demonstrate the enhanced functionality which the DC technology / power electronic can bring to the operation of distribution networks. Are there other examples and projects under development which shows benefits and technical features adopting DC technology in distribution systems?
- The concept (Paper B4-201) of using fuses and special reactors to limit the current is unique, but follows distribution philosophies. Are there any other protection concepts?

PS3 - FACTS and other Power Electronic (PE) systems for transmission systems

- ***(PS3-1)*** *Planning and implementation of new projects (including, need, justification, FACTS devices for renewables, environmental and economic assessment)*

B4-307 "Development and Design of ±100Mvar MMC STATCOM at NP Kunta substation in India"
The paper describes the design and commissioning experience of the MMC STATCOM installed at the NP Kunta substation in India near a 1500MW solar power plant. The STATCOM consists of two ±50MVar units to provide higher availability. The design challenges related to the selection of the MV circuit breakers are explained. Dynamic performance, redundancy aspect and harmonic performance of the STATOM are described using the recorded waveforms from commissioning tests.

- ***(PS3-2)*** *Application of new technologies in FACTS and other PE equipment*

No paper was submitted for this topic.

- ***(PS3-3)*** *Refurbishment and upgrade of existing FACTS and other PE systems*

Paper B4-301 "Refurbishment Strategies for Conventional SVC Stations Utilizing Modern Control Cooling and Thyristor Valves and Selective Main Circuit Replacements"
This paper reports the experience with refurbishing two SVCs in Alaska. The main reason for refurbishing is the difficulty in obtaining the spare parts and increased maintenance costs for control and cooling systems as well as the valve electronics. The condition assessment showed little need for replacing the main circuit equipment. The recorded results from factory acceptance and commissioning tests particularly for the newly added power oscillation damping function is presented.

Paper B4-302 "Upgrading of three SVCs in Norway. What is the best action to take for aging SVCs?"
The paper discusses the issues related to the maintenance of the aging SVCs in Norway, particularly the increased outage times, difficulty of obtaining spare parts and finding the knowledge and expertise. The challenges in an upgrade project such as defining the scope of replacement, performing the project in an existing and energized substation are explained. The experience of upgrading three SVCs is shared.

B4-306 "Essex STATCOM upgrade - Engineering, testing and commissioning"
This paper describes the experience with upgrading a STATCOM particularly the challenges caused by the required modifications to the design and the testing of the key components. The limited outage time available for the construction and installation work was another challenge. The experience from commissioning and harmonic performance measurements is presented.

Question 3.1:

- Paper 304 describes the installation of a STATCOM near a major solar power plant. What are the challenges of installing FACTS devices in close vicinity of other power electronic based systems?
- Papers 301, 302 and 306 provide examples of SVC and STATCOM refurbishment projects. What are the main drivers and challenges for refurbishment of FACTS devices?

- ***(PS3-4)*** *Service and operating experience*

No paper was submitted for this topic.