

TECHNICAL BROCHURES

B4 - HVDC and Power Electronics

REF. 000 **1994 SC 14 WG 14.02** *A summary of the report on survey of controls and control performance in HVDC schemes.*
A survey questionnaire on HVDC controls and control performance was formulated and copies submitted for completion to DC schemes. This report serves as a data collection and summary of general control arrangements, strategies and parameters used in the schemes for which questionnaires were returned. For some schemes having significant and relevant operational experience, control performance was reported on and a summary analysis is contained. **Member Price: 21 Euros Non member Price: 42 Euros 198 pages , file: 8,47 MB**

REF. 003 **1987 SC 14 WG 14.04** *Compendium of HVDC schemes throughout the world.* The Compendium wants to give a survey of the HVDC systems all over the world in detailed fashion. Many datas are required for these descriptions and they have not been obtained from many systems. Those systems, for which not all data is available are described as far as possible. The compendium can only be updated if all recipients support the work and send information on latest available data. **Member Price: 26 Euros Non member Price: 52 Euros 232 pages , file: 3,52 MB**

REF. 025 **1986 SC 38 TF 38.01.02** *Static var compensators.* The rapid development of semiconductor devices and control techniques within the last two decades have enabled the development of controllable shunt reactive compensation devices with rapid response for electric power system applications. In recognition of the potential applications and the impact of such a flexible system design tool on future electric power systems CIGRE decided to form an Ad-Hoc Group to review the progress on the subject. **Member Price: 40 Euros Non member Price: 80 Euros 125 pages , file: 9,36 MB**

REF. 034 **1989 SC 33/14 JWG 33/14.05** *Guidelines for the applications of metal oxide arresters without gaps for HVDC converter stations.* This guide for metal oxide arresters without gaps for HVDC converter stations is a supplement to the application guide for insulation coordination and arrester protection of HVDC converter stations published in Electra No.96 (Oct. 1984). It gives basic information about metal oxide material and basic arrester characteristics which will be of value when designing and specifying an arrester protective scheme and specifying the arresters. **Member Price: 20 Euros Non member Price: 40 Euros 38 pages**

REF. 051 **1996 SC 38 WG 38.01.06** *Load flow control in high voltage systems using FACTS controllers.* The brochure gives an overview on the impact of different FACTS controllers on the system and presents examples of the use of such equipment in the system. It is written for engineers to understand the basic interactions between the FACTS equipment and the system when solving system problems. **Member Price: 15 Euros Non member Price: 30 Euros 90 pages , file: 2,4 MB**

REF. 065 **1992 SC 14 WG 14.03 AC harmonic filters and reactive compensation for HVDC with particular reference to non-characteristic harmonics.** This paper summarises a report prepared by WG14-03 (Filtering and reactive compensation for HVDC) and is a complement to the paper published in Electra No. 63 (1979). The brochure included details on : Importance of non-characteristic harmonics, Generation of non-characteristic harmonics, Impact on AC and DC networks, Disturbance criteria, Transient operating modes, Solutions selected for recent links etc. **Member Price: 37 Euros Non member Price: 74 Euros**
60 pages , file: 3,37 MB

REF. 068 **1992 SC 14 WG 14.07 Guide for planning DC links terminating at AC locations having low short-circuit capacities. Part 1. AC/DC interaction phenomena.** Part I of the Guide AC/DC system interaction phenomena, discusses the effects of various aspects of interactions between AC and DC systems on the design and performance of DC schemes connected at locations where the AC system appears as high impedance. Part II : Planning guidelines, considers the impact of the interactions and their mitigation on economics and overall system performance. **Member Price: 37 Euros Non member Price: 74 Euros** **110 pages , file: 8,25 MB**

REF. 077 **1993 SC 38 WG 38.05.04 Analysis and optimisation of SVC use in transmission systems.** The thyristor controlled static var compensator is in widespread use in power transmission systems, although it is a relatively new shunt reactive power compensation device. With the aim to enlighten the possibilities and limitations of employing SVC's for voltage control and stability improvement a study has been performed on the subject. **Member Price: 26 Euros Non member Price: 52 Euros** **53 pages , file: 4,23 MB**

REF. 078 **1994 SC 14 WG 14.01.02 Voltage and current stresses on thyristor valves for static var compensators.** The application of SVC employing thyristor valves in power transmission systems has been rapidly increasing in the past decade. Nevertheless there is no International Standard for testing of the valves. As an essential step in developing a guideline the TF undertook a thorough review of the electric stresses experienced by the thyristor valves in operation. **Member Price: 18 Euros Non member Price: 36 Euros** **25 pages , file: 2,64 MB**

REF. 082 **1994 SC 38 WG 38.01.05 Use of DC converters for VAR control.** This brochure is intended as an application guide for system planners and operators as well as equipment engineers who want to evaluate control strategies for DC converters. It starts with an explanation of DC converter capabilities and how this can be evaluated for var control. **Member Price: 29 Euros Non member Price: 58 Euros** **90 pages**

REF. 086 **1994 SC 33 /21/14 JWG 33/21/14.16 Overvoltages on HVDC cables. Final Report.** The number of HVDC projects using long DC cables is increasing, mostly for submarine power transmission. A larger number of such HVDC schemes are already in operation or in planning stage. The economic design of DC cables is very important, because the cost of DC cables is high in proportion to the total cost of HVDC submarine cable transmission. **Member Price: 9 Euros Non member Price: 18 Euros** **55 pages , file: 5,51 MB**

REF. 092 **1995 SC 14 WG 14.03.02 DC side harmonics and filtering in HVDC transmission systems** The report deals with the harmonic voltages and currents of concern on the DC side of HVDC transmission systems. Its aim is to provide some guidance to both users and suppliers of HVDC links in such a way that a common understanding could be established in the area of DC side harmonics and filtering. **Member Price: 18 Euros Non member Price: 36 Euros** **94 pages , file: 3 MB**

REF. 093 **1995 SC 14 WG 14.01.02 Guidelines for testing of thyristor valves for static var compensators.** The application of static var compensators using thyristor valves in power transmission systems has been rapidly increasing in the past decade. Nevertheless there is no international standard for testing of thyristor valves for SVC. The scope of the work was limited to SVCs for power transmission systems. SVC for industrial applications (e.g. flicker control, control of voltage fluctuations caused by motor starting) are not in the scope. **Member Price: 14 Euros Non member Price: 28 Euros** **61 pages**

REF. 097 **1995 SC 14 WG 14.12 System tests for HVDC installations.** This guide is structured in eight parts and should give potential users guidance, regarding which course of action should be taken in planning commissioning activities. Structure of the tests and a brief statement of the purpose of the individual group of tests is presented. Commissioning an HVDC system is a very complex task which may affect more than the actual contract parties. **Member Price: 23 Euros Non member Price: 46 Euros** **145 pages , file: 4,92 MB**

REF. 103 **1996 SC 14 WG 14.05 Commutation failures. Causes and consequences.** Many aspects of the impact and role of the HVDC system on the rest of the power system can be studied and analysed without a detailed knowledge of the actual design and behaviour of the conversion process taking place in the HVDC convertors, but a more detailed scrutiny of a number of phenomena requires a more detailed knowledge and modelling of the HVDC system and of the DC conversion process. **Member Price: 18 Euros Non member Price: 36 Euros** **75 pages , file: 2,63 MB**

REF. 112 **1997 SC 14 WG 14.17 Semiconductor power devices for use in HVDC and FACTS controllers.** During the recent years there has been a growing need for better utilisation of high voltage transmission systems. Power electronic equipment, having an inherent fast controllability, offers solutions to transmission system problems such as load flow and stability. Therefore, engineers are increasingly studying the potential of such equipment to make transmission systems more flexible and adaptive to changing requirements. **Member Price: 17 Euros Non member Price: 34 Euros** **75 pages , file: 5,04 MB**

REF. 113 **1997 SC 14 WG 14.01.03 Test circuits for HVDC thyristor valves.** In conformity with the usual classification of the specified tests into two major categories, dielectric tests and operational tests, the report is in two parts : Part 1 - Dielectric tests which deals principally with test circuits for verifying the high voltage characteristics of the valve, and Part 2 - Operational tests, which deals principally with test circuits for verifying the turn-on, turn-off and current related characteristics of the valve. **Member Price: 23 Euros Non member Price: 46 Euros** **99 pages**

REF. 114 **1997 SC 13/14 WG 13/14.08** *Circuit-breakers for meshed multiterminal HVDC system. Final Report.* HVDC multiterminal (MTDC) Systems permit the exchange of energy between a number of HVDC substations. The particular advantage of the meshed system is that this exchange can continue even when one of the interconnecting lines is out of service. Investigations have shown that the performance of MTDC systems can be improved by installing HVDC circuit-breakers at appropriate locations. **Member Price: 15 Euros Non member Price: 30 Euros**
115 pages

REF. 115 **1997 SC 14 WG 14.07** *Guide for planning DC links terminating at AC system locations having low short-circuit capacities. Part II : Planning guidelines.* Guidance on planning and design of DC links terminating at AC system locations having low short-circuit capacities relative to the DC power infeed. The Guide is limited to those aspects of interactions between AC and DC systems which result from the fact that the AC system is 'weak' compared to the power of the DC link (i.e. AC system appears as a high impedance at the AC/DC interface bus). Some more general aspects of the design and planning of HVDC transmission schemes are described only when this adds to the understanding of the interaction phenomena and for the sake of completeness of the guidelines. **Member Price: 15 Euros Non member Price: 30 Euros** **53 pages , file: 3,94 MB**

REF. 116 **1997 SC 11/14 JWG 11/14.09** *Guide for preliminary design and specification of hydro stations with HVDC unit connected generators.* Several technical and economical reasons strongly suggest that in certain HVDC applications it is of great advantage to simplify the rectifier station via a direct connection of hydro generating sets to 12 pulse converter groups. The proposed arrangement is referred to in HVDC literature as "Unit Connection". **Member Price: 30 Euros Non member Price: 60 Euros** **230 pages , file: 12,9 MB**

REF. 119 **1997 SC 14 WG 14.05** *Interaction between HVDC convertors and nearby synchronous machines.Final report.* It is not uncommon that HVDC convertor stations and generators are situated electrically and geographically close to each other. This follows from the fact that HVDC links are often built to transmit power from a generating station to a load centre or another part of the power system. Examples of this are the Itaipu and IPP schemes. In these cases the HVDC and generator stations are designed more or less in parallel which means that overall good design can be achieved by appropriate coordination. **Member Price: 11 Euros Non member Price: 22 Euros** **43 pages , file: 1,42 MB**

REF. 123 **1997 SC 14 WG 14.18** *Thyristor controlled series compensation.* The application of power electronic thyristor valves in HVDC and SVC technologies has enabled the development of controllable series devices with rapid response for use in electric power transmission systems. With growing environmental, regulatory and financial constraints facing the electric utility industry, technical advancements and economic solutions which allow increased utilization and reliable operation of transmission systems have potential benefits for utilities and their customers. **Member Price: 18 Euros Non member Price: 36 Euros** **70 pages , file: 4,77 MB**

REF. 127 **1998 SC 14 WG 14.11** *Guide for upgrading transmission systems with HVDC transmission* Following the installation of the first HVDC transmission scheme between Sweden and the Island of Gotland in 1954, over 60 HVDC schemes throughout the world have been installed. Since their initial installation many of the HVDC schemes have been upgraded in various ways. By reviewing both what has been achieved in terms of upgrading and what potentially is possible to accomplish in an upgrade, this guide provides direction and the latest information on the subject. **Member Price: 15 Euros Non member Price: 30 Euros 60 pages , file: 3,44 MB**

REF. 130 **1998 SC 14 WG 14.23** *Operational guidelines and monitoring of HVDC systems* Major advances in technology for controlling HVDC systems has led to greater efficiency in operation and maintenance, as well as providing a reduction in staff. The quality and reliability of an HVDC system is directly dependent on the type of monitoring implemented. Recent developments now allow implementation of computer based information systems with significant improvements in the delivery and presentation of data necessary for supporting the operation. **Member Price: 10 Euros Non member Price: 20 Euros 30 pages , file: 0,251 MB**

REF. 136 **1999 SC 14 TF 14.01.04** *Fire aspects of HVDC thyristor valves and valve halls.* Survey of the possible causes of fires in valves and valve halls; assistance to users in the areas of specification, engineering and construction; comparative information on fire detection and protection systems; fire alarm and fire control systems; guidance with fire-fighting, operation and maintenance; guidance to actions after a fire. This is also a reference document for discussion with insurance companies. **Member Price: 23 Euros Non member Price: 46 Euros 100 pages , file: 0,646 MB**

REF. 139 **1999 SC 14 WG 14.30** *Guide to the specification and design evaluation of AC filters for HVDC systems.* The principal purpose of the document is to give guidance to those responsible for : preparing the a.c. filtering aspects of Technical Specifications for HVDC projects ; evaluating the proposed designs, and monitoring the subsequent project. The main objective is to enable informed judgements to be made and future Technical Specifications to be written, such that the resulting a.c. filters are effective yet economical and are non under or over designed. **Member Price: 38 Euros Non member Price: 76 Euros 250 pages , file: 1,23 MB**

REF. 143 **1999 SC 14 WG 14.25** *Cross-modulation of harmonics in HVDC schemes* Harmonic cross-modulation is a term used to describe the variety of frequency interactions around the two converters that comprise an HVDC link and the effect on and interactions with the DC system and both AC systems. Because there are two converters involved, as well as two AC systems and any number of coupled frequencies, the number of interactions to be considered is infinite. Questions to be answered are : which interactions are the strongest, and whether they are likely to cause steady state or transient problems, and how to determine these interactions. **Member Price: 15 Euros Non member Price: 30 Euros 30 pages , file: 1,87 MB**

REF. 144 **1999 SC 14 WG 14.19** *Static synchronous compensator (STATCOM)* Rapid developments of solid state power electronic devices in the last three decades have led to the development and widespread application of static var compensators (SVCs). These shunt connected reactive compensation equipment provided an important means for enhancing electric power transmission system performance. Continued rapid developments in power electronic devices and control techniques led to utilisation of gate turn-off thyristor (GTO) devices to form new power electronic shunt compensation equipment which offered more robust output. **Member Price: 34 Euros Non member Price: 68 Euros 214 pages , file: 7,08 MB**

REF. 149 **1999 SC 14 WG 14.29** *Coordination of controls of multiple FACTS/HVDC links in the same system.* Power electronics applications in high-voltage electric power systems date from the early 1970s when converters for HVDC systems began using thyristors to replace mercury arc valves. Since the mid-1970s all new HVDC systems have employed thyristor valves. Advances in power electronics have extended the application of fast switching currents to AC systems as well, resulting in the technology commonly known as FACTS, Flexible AC Transmission Systems. This document is intended to provide guidelines into the kinds of interactions that can occur and the means of analysis and design that are available to assure that a coordinated response is achieved and adverse interactions are avoided. **Member Price: 30 Euros Non member Price: 60 Euros** **135 pages , file: 19,9 MB**

REF. 160 **2000 SC 14 WG 14.27** *Unified power flow controller (UPFC)* The result of a dialogue between utilities and manufacturers concerning the application of the unified power flow controller (UPFC). its purpose is to provide comprehensive information on the physical nature of such devices, the functions they can provide, the value of these functions for utilities, the way to implement them in the network, the problems to anticipate and the obstacles that may exist regarding cost-effective implementation. **Member Price: 21 Euros Non member Price: 42 Euros** **120 pages , file: 3,21 MB**

REF. 183 **2001 SC 14/37/38/39 JWG 14/37/38/39.24** *FACTS technology for open access* Summary of the present state of the art on the key technological developments in the FACTS area, addressing in particular the open access aspects of networks and the scope for the application of FACTS devices therein. Contains the approved terms of reference. Definition of FACTS includes conventional devices such as phase shifting transformers, series capacitors and HVDC links for completeness and the possibility of combining them with FACTS devices to improve HVAC transmission system flexibility and control. **Member Price: 27 Euros Non member Price: 54 Euros** **80 pages , file: 14,2 MB**

REF. 186 **2001 SC 14 WG 14.20** *Economic assessment of HVDC links* HVDC has been a viable technique since the 60's and has played a vital part in both long distance transmission and in the interconnection of systems. Its relative economic position has been much discussed over 30 years and this report is both an update of those considerations and a review of the present position. It reviews many aspects of transmission development common to both AC and DC transmission with a concentration on the specific aspects of DC as they give advantage or extra dimension to the long distance transmission of electrical power. **Member Price: 26 Euros Non member Price: 52 Euros** **71 pages , file: 0,787 MB**

REF. 202 **2002 SC 14 WG 14.26** *HVDC stations audible noise* The principle purpose of this guide is to give specific recommendations to those responsible for preparing the audible noise aspects of technical specifications for HVDC projects, evaluating the proposed designs and monitoring the subsequent project. The main objective is to enable future technical specifications to be written and informed judgements made, such that the resulting outdoor audible noise levels fulfil applicable regulations and standards. **Member Price: 25 Euros Non member Price: 50 Euros** **100 pages , file: 0,679 MB**

REF. 205 **2002 SC 14 WG 14.31 Custom power - State of the art.**

Custom power is a concept, based on the use of static controllers in the distribution system or in some instances, rotating machines, for the electric utilities to supply value-added power with the reliability and power quality requested by the customers. It includes consideration of all aspects of power supply that impact individual customers, including harmonics, inter-harmonics, voltage dips, overvoltages, range of steady state voltage and frequency variations and phase unbalance, in addition to the above consideration to reliability. **Member Price: 28 Euros Non member Price: 56 Euros 110 pages , file: 4,05 MB**

REF. 215 **2002 SC 14 WG 14.32 HVDC converter stations for voltages above +/- 600 kV**

The scope of the work is to review the current state of HVDC converter stations up to 600 kV and the problems associated with it and to investigate in detail what needs to be done to expand the technology to voltages above 600 kV and specifically to 800 kV. Parallel operation of converters is not considered in this document. **Member Price: 20 Euros Non member Price: 40 Euros 40 pages , file: 0,776 MB**

REF. 222 **2003 SC B4 WG B4.05 On voltage and power stability in AC/DC systems**

Significant new results concerning the definitions of voltage and power stability on AC/DC systems. **Member Price: 25 Euros Non member Price: 50 Euros 79 pages , file: 0,97 MB**

REF. 223 **2003 SC B4 WG B4.28 Active filters in HVDC applications**

This report presents both DC and AC active filters including the existing installations. The items of the report are nearly arranged in two consecutive parts, the first treating the DC application, while the second covers the AC filters. As active DC and AC filters share many concepts subjects may be dealt with in both parts. **Member Price: 20 Euros Non member Price: 40 Euros 53 pages , file: 0,99 MB**

REF. 237 **2003 SC B4 WG B4.19 Static synchronous compensator (STATCOM) for arc furnace and flicker compensation**

The brochure describes the application of STATCOM for arc furnace and flicker compensation. Starting from the measured flicker of an actual arc furnace, performances of the actual SVC compensation and the calculated STATCOM are compared. An utility application is presented which demonstrates the accuracy of the calculation method. **Member Price: 40 Euros Non member Price: 80 Euros 165 pages , file: 4,56 MB**

REF. 240 **2004 SC B4/A2 JTF B4.04/A2.01 Analysis of HVDC thyristor converter transformer performance**

A presentation of performance summaries with failure areas described and classified as bushings, valve windings, AC windings, static shields, load tap changers, core and magnetic shields or internal connections and leads together with short descriptions of the failures. Present transformer test methods are also evaluated for adequacy. Comparisons with the previous report are included. **Member Price: 15 Euros Non member Price: 30 Euros 30 pages , file: 0,646 MB**

REF. 242 **2004 SC B4 WG B4.35 Thyristor controlled voltage regulators: Parts 1 and 2** A two part report containing three non-conventional methods of voltage regulation by reactive power control : voltage controlled static var compensator, shunt capacitor bank series shorting and special delta star switching. The second part explores the feasibility of static on-load transformer tap changers. **Member Price: 35 Euros Non member Price: 70 Euros** 70 pages , file: 1,06 MB

REF. 269 **2005 SC B4 WG B4.37 VSC Transmission** This Brochure describes VSC Transmission technology, i.e. HVDC transmission using Voltage Sourced Converters. A comparison with Line Commutated HVDC technology is provided. The WG found no technical reason why this technology could not be used at high voltage and power, and concluded that such development would depend solely on the perceived commercial return on the R&D investment. **Member Price: 60 Euros Non member Price: 120 Euros** 82 pages , file: 2,48 MB

REF. 280 **2005 SC B4 WG B4.33 HVDC and FACTS for distribution systems** The development of new high power electronic switches has made it possible to implement Voltage Source Converters (VSCs) and other converters for usage in power systems. These converters offer now applications in distribution systems too, where they can resolve problems of environmental or planning restrictions and, as they are fast acting, they can either eliminate or mitigate frequently appearing power quality problems. **Member Price: 32 Euros Non member Price: 64 Euros** 63 pages , file: 1,42 MB

REF. 337 **2007 JWG B4/A3/B3.43 Increased System Efficiency by Use of New Generations of Power Semiconductors** The TB presents the present developments of power semiconductors, with lower losses, higher switching frequency, converter modularization..., and their new application areas, in order to propose and evaluate new or enhance equipment for increased system efficiency. **Member Price: 120 Euros Non member Price: 45 Euros**

REF. 352 **2008 WG B4.34 Capacitor Commutated Converter (CCC) HVDC Interconnections: Digital modeling and Benchmark Circuit** Capacitor Commutated Converter -CCC- calls for developing models for digital studies. The TB discusses the state of the art in digital studies of HVDC connections with CCC converters and proposes a benchmark circuit. It will serve as a simplified guide for application/specification of this type converter stations. **Member Price: 193 Euros Non member Price: 130 Euros.**

REF. 364 **2008 WG B4.41 Systems with multiple DC Infeed** The TB provides an analytical framework for the understanding of interactions amongst multiple HVDC line commutated inverter stations within a common ac system. The theoretical development is complemented by actual system examples of multi-infeed HVDC planning. **Member Price: 118 Euros Non member Price: 50 Euros**

REF. 370 **2009 WG B4.39 Integration of large Scale Wind Generation using HVDC and Power Electronics** New large wind farms, both onshore and offshore, may face challenges such as, system stability issues, the need for the wind farm to provide system/ancillary services, and difficulties to build overhead lines. The TB shows how HVDC and other types of Power Electronics can help overcome these challenges, thereby helping to integrate large scale wind farms into power systems. **Member Price: 157 Euros Non member Price: 60 Euros.**

REF. 371 **2009 WG B4.40 Static Synchronous Series Compensator (SSSC)** The TB provides the basic principles of the Static Synchronous Series Compensator (SSSC), its functional features, basic characteristics and applications, and gives information on topologies, harmonic generation issues and modeling. It describes existing worldwide SSSC installations and presents a future outlook of SSSC. **Member Price: 177 Euros Non member Price: 60 Euros.**

REF. 388 2009 JWG B2/B4/C1.17 IMPACTS OF HVDC LINES ON THE ECONOMICS OF HVDC PROJECTS The study considers the overall HVDC system economics, capital (lines and stations), losses, operation and maintenance. The most economically favorable voltages and conductor configurations are studied for several HVDC system alternatives. It is shown how the HVDC line and the converter stations selection impact each combination. Directives are presented on the 'best-solutions' for different sets of transmission parameters. **Member Price: 164 Euros Non member Price: 70 Euros** pages , file: **HVDC and Power Electronics MB**