Annual Report for Study Committee C4 (SC C4) – System Technical Performance

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The mission of Study Committee C4

The mission of Study Committee C4 is as follows: "SC C4 deals with methods and tools for analysis related to power systems, with particular reference to dynamic and transient conditions and to the interaction between the power system and its apparatus/sub-systems, between the power system and external causes of stress and between the power system and other installations. Specific issues related to the design and manufacturing of components and apparatus are not in the scopes of SC C4, as well as those specifically related to planning and operation and control, apart from those cases in which component/apparatus/subsystem behaviour depends on, or significantly interacts with, the performance of the nearby power system. The fields on which the activity is carried out are: Power Quality, Electromagnetic Compatibility (EMC), Insulation co-ordination, Lightning, Advanced tools for the analysis of power system performance, Power systems dynamic performance models and analysis."

With this mission in mind SC C4 presently consists of some 24 working groups (WGs) performing highly technical work in the fields of power quality, EMC, insulation coordination, lighting, advanced power system modelling and analysis tools and power system dynamic performance models and analysis. These WGs are composed of an estimated three to four hundred technical experts from more than forty countries around the world. In addition, SC C4 itself is composed of 24 regular members and 13 observer members, together with a chairman and a secretary, from 37 countries around the world who monitor and manage these working groups and efforts of the study committee and plan its future activities. These members are experts from 17 Research Organizations and Universities, 16 Utilities, and 6 Regulators, Manufacturers or other entities.

It is clear from the scope of SC C4 that this study committee is focused on the system perspective of large electric systems. That is, we are concerned with the technical performance issues of the power system and how the various electrical components and equipment interaction with each other, the system and sub-systems. However, it is also evident that one cannot investigate the system technical performance issues without a solid understanding of the equipment, the performance of the equipment, system planning and operational issues and environmental factors that may play a role in system performance. Therefore, there is always much close cooperation between SC C4 and the other CIGRE study committees that deal with equipment (e.g. SC B1, SC B4), system planning and operations (i.e. SC C1, SC C2), distribution networks (SC C6) and environmental aspects of the power system (SC C3).Let us now consider in more detail the six major technical areas of study within SC C4.

Power Quality

While guidance exists regarding on the possible new compatibility flicker levels based only on lighting, the effects of voltage fluctuations on other user equipment is not known. Thus, there is a need to review susceptibility levels for user equipment other than lighting in order to consider if there is a need to revise compatibility levels. This is the focus of a joint WG with CIRED, established under SC C4, then WG C4.111 on the review of low-voltage and medium-voltage compatibility levels for voltage fluctuation.

There has been noticeable increase in the amount of power quality monitoring that is presently taking place in electric power systems. While many network operators are installing monitoring equipment, and while more and more manufacturers have monitors available, there is a lack of knowledge and agreement on many aspects of the monitoring process, and in particular on processing the recorded data. The end users of the data, such as network operators, are increasingly

asking for useful information rather than just large amounts of data to be provided by installed monitors and supporting software. In order to resolve some of the issues SC C4 established the WG C4.112 on power Quality monitoring in flexible power networks.

With the many renewable portfolio standards being established around the world in many different regions, there is presently much activity in the deployment of both wind and solar energy systems. In recent years, there has been a strong push in the deployment of residential and commercial installation of solar photo-voltaic (PV) systems in the distribution system. This proliferation of PV systems raises new challenges with power quality issues on the power system. As such, very recently SC C4, in collaboration with SC C6, established the joint WG C4/C6.29 on power quality aspects of solar power.

These are some of the issues being presently investigated by SC C4 in the area of power quality.

Electromagnetic Compatibility

Electromagnetic Compatibility issues addressed by SC C4 cover emission and immunity problems resulting from disturbances that are not addressed under the subject of power quality. These include disturbances produced by the electrical power system as well as disturbances of external origin able to interfere with the electrical power system. Such disturbances can affect the integrated system performance by electrical conduction (electrical contact), induction (electric or magnetic fields) or radiation (high frequency electromagnetic field). Health effects related to low frequency EMF are excluded, whilst intentional electromagnetic interference is instead included.

Interference on communication systems (including damage, danger and disturbances) resulting from an induced voltage caused by high voltage and medium voltage power lines under steady state and fault conditions is an issue that needs to be addressed taking into account the on going development of sensitive electronic and electric devices. The joint CIGRE-CIRED WG C4. 207, dealing with "Methods of analysis and mitigation of the influence of HV power systems on telecommunication circuits, radio communication, low voltage systems and metallic structures" has within its scope the goal to support ITU-T in the maintenance of the ITU K series Recommendations and Directives on this topic.

EMC requirements and solutions for high-voltage substations and generating stations is the subject of WG C4.208. This WG is looking at the need for updating, according to the most recent findings, EMC hardening solution for the increasingly sensitive electronic devices in substations.

Another issue dealt with by SC C4 concerns pacemakers and other implants, which are becoming more common. Interferences caused in them by high electric or magnetic fields can be lethal. Issues related to "Extremely Low Frequency (ELF) electromagnetic field exposure and transient contact currents" are being considered the WG C4.25. The recently established WG C4.28 on extrapolation of measured values of power frequency magnetic fields in the vicinity of power links is looking into better and improved methods for measuring magnetic fields created by power lines. .

Insulation Coordination

According to the recent revision of SC C4 scopes, the activity traditionally carried out within SC C4 on "Pollution and Environmental Influence on Electrical Performance of Power Systems", still being carried out by WG C4.303 will be progressively moved to SC D1, as now C4 is dealing mainly with insulation coordination from the perspective of the power system transient interaction with power components and apparatus. The study of switching transients is similarly expected to be progressively moved to SC C4.

In 2010 WG C4.305 dealing with "Practices in Insulation Coordination of Modern Electric Power Systems aimed at the Reduction of the Insulation Level" started its activity, which apart from the aim clearly shown by its title, has also the task of providing a survey on current status of insulation coordination practices worldwide.

There is common agreement that the network of the future will see a progressively increasing deployment of ultra-high voltage (UHV) AC systems. Thus, the WG C4.306 on insulation

coordination of UHV AC systems was established to develop a technical brochure on the latest developments for the study and assessment of this important subject.

In 2010 the WG C4.307 started its activity, which focuses on resonance and ferroresonance in power networks and transformer energization studies. Previous WGs have dealt with this subject only in the context of simple ferroresonant circuits, while now rather complex configurations can be analysed. Thus, this work aims to extend and build on previous work.

The joint WG A2/C4.39 on electrical transient interaction between transformers and the power system was established several years ago to look at the important issue of transformer failures and/or damage caused by switching surge and other electromagnetic transients originating on the power system. This work thus required close collaboration between SC A2 and SC C4 to bring together the experts on transformer design and modeling, and power system modeling and analysis experts.

Lightning

Lightning impacts and interacts with the electric power network through two main mechanisms: direct strokes that hit the line conductors and indirect lightning hitting the soli nearby the line. For both cases the knowledge of lighting current parameters is crucial. For this reason SC C4 started in 2008 the revision of the 'classical' data published in Electra, in the 70s. This work has been extended to include additional parameters, such as continuing current or lightning channel impedance, on the basis of the most recent knowledge, and also adding information relevant on seasonal or geographical variations. The WG C4.407 lightning parameters for engineering applications is addressing this issue, and now that the work of WG C4.407 is close to completion, WG C4.23 addressing the procedures for estimating the lightning performance of transmission lines was recently established to revise the CIGRE brochure 63 on this subject, which has not been reviewed for several decades.

Activity in the lightning protection area relevant to distribution networks is addressed by WG C4.408 "Lightning Protection of Low Voltage Networks" whose final aim is to present specific methods of protecting LV networks and relevant equipment taking into account the above mentioned two mechanisms lightning can reach and damage LV networks and relevant components.

Lightning also represents a threat for wind turbine blades, a topic that is specifically addressed by WG C4.409 on lightning protection of wind turbine blades.

Wind turbines are not the only tall structures present in the modern power system: the growing deployment of UHV systems has motivated SC C4 to investigate the "Lightning Striking Characteristics to Very High Structures" and to assign this task to WG C4.410. Presently, when for the evaluation of lightning performance of transmission lines the electro-geometrical model (EGMmodel) has been used, the observed shielding failure rate of UHV transmission lines, whose average height is about 100 meters, was not in agreement with the results estimated with the conventional EGM model, whose parameters were inferred for lower height overhead lines. Through detailed observation of lightning hits on these UHV lines, difference between the actual phenomena on such tall transmission lines and the conventional EGM predictions has gradually been revealed, a issue that has motivated WG C4.410 to investigate physical characteristics of upward leaders from earthed objects.

The above concerns motivated also the creation of WG C4.26 Evaluation of Lightning Shielding Analysis Methods for EHV and UHV DC and AC Transmission-lines, which are characterized by structures of greater heights.

Advanced Numerical Tools for Electromagnetic-Transients and Dynamic Analysis

The numerical electromagnetic analysis (NEA) method is becoming one of the most promising approaches to solve transient phenomena that are hard to solve by existing circuit-theory based simulation tools such as the Electromagnetic Transient Program (EMTP). EMTP type tools cannot solve problems that incorporate transients involving a sphere-wave propagation, such as a transient

across an archon and a wave-front transient at a transmission tower due to lightning. Also, the circuit-theory based approach has difficulties in dealing with a transient in a complex media, such as a transient on a grounding electrode and that on a semi-conducting layer of a cable. Furthermore, the circuit-theory approach cannot be applied if circuit parameters are not known. The NEA can solve such problems, because it calculates Maxwell's equations directly. WG C4.501 on numerical electromagnetic analysis and its application to surge phenomena, in close collaboration with some of the SC C4 WGs on lightning, is addressing this subject.

Due to the increasing public resistance against erection of new overhead lines, transmission utilities have to consider installation of large number of HV/EHV AC cable lines in their networks. Some of these cable lines are of long length, even in the range of 100 km. Such long cables require installation of reactive power compensating stations along the cable line. Network planners, network operators and equipment suppliers do not have much experience with the performance of transmission systems with a large number of (long) HV/EHV AC cables and for this reason SC C4 has assigned the task of studying this subject to WG C4.502, whose final aim is to prepare a technical brochure that will serve as practical guide for performing studies necessary for assessing the technical performance of HV/EHV systems with a large share of AC cables.

SC C4 traditionally devotes much attention to modelling and simulation tools for power systems performance analysis. Advanced numerical techniques for the computations of steady-state, electromechanical transients, fundamental frequency overvoltages and switching transients and at the same time coping with issues related to the computation of power electronics based components, are nowadays much needed in view of the on-going transformation of the power network. Especially at the distribution level, the network is experiencing a large number of connections of small-size dispersed generation units from renewable (variable generation) sources. The primary scope of WG C4.503 is indeed the critical assessment of existing numerical modelling and computation techniques for the above mentioned types of studies including issues relevant to unsymmetrical conditions of power networks.

Power systems dynamic performance models and analysis

There are increasing challenges related to balancing control and management of fast reserves in power systems around the world, especially in power systems and control areas with a large penetration of wind generation: this issue is presently addressed by WG C4.603, which is focusing on "Analytical techniques and tools for power balancing assessments".

Another important issue in modern power systems is the interaction between HVDC systems and the nearby portion of the power system. This work is being carried out in close cooperation among SCs C4, B4 and C1, and is being investigated by the JWG C4/B4/C1.604 "Influence of Embedded HVDC Transmission on System Security and AC Network Performance".

Although load modeling is an established topic with important research and effort having been applied to this subject, the renewed interest in industry and academia for this important topic has motivated SC C4 to foster the creation of WG C4.605 "Modelling and aggregation of loads in flexible power networks", which started its activity in 2010. The basic motivation for establishing this WG is the appearance of new, non-conventional types of loads (power electronics based or interfaced through power electronics) and requirements to operate modern electric power networks with increased penetration of non-conventional types (mostly stochastic) of generation and power electronic devices in a safe and secure manner and the need of even more on adequate modelling of load components.

Tutorial & workshop capabilities

SC C4 is able to deliver tailored tutorials and workshops in a range of areas including Power Quality, Electromagnetic Compatibility, Insulation Coordination, Lightning Protection, Advanced Numerical Modelling of Power Systems, Power Systems Transients and Dynamics. This capability is constantly developing in line with the activities of the SC.

Publications

The following technical brochures have been published recently or are due to be published by SC C4 within the next several months.

- TB No. 449, Review of Flicker Objectives for HV, MW, LV Systems; WG C4.108 (with CIRED), published February, 2011
- TB No. 467, Economic Framework for Power Quality; JWG CIGRE-CIRED C4.107; June, 2011
- TB 468, Review of Emission Assessment Techniques; JWG CIGRE-CIRED C4.109; June 2011
- Electra Paper by V. Cooray on behalf of WG C4.405, “A review of simulation procedures utilized to study the attachment of lightning flashes to grounded structures”; August 2011
- Electra Paper by V. Cooray on behalf of WG C4.405, “Non conventional lightning protection systems”; October 2011
- WG C4-303, Pollution and environmental influence on the electrical performance of power systems
- WG C4-501, Numerical Electromagnetic Analysis and Its Application to Surge Phenomena
- JWG C4/B4/C1.604, Influence of Embedded HVDC Transmission on System Security and AC Network Performance
- TB on EMC within Power Plants and Substations; WG C4.208; just uploaded to C4 website for review by SC
- WG C4-502, Power system technical performance issues related to the application of long HVAC cables