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

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The Mission and Scope of Study Committee C4

The mission of Study Committee (SC) C4 is to facilitate and promote the progress of engineering and the international exchange of information and knowledge in the field of system technical performance, and to add value to this information and knowledge by means of synthesizing state-of-the-art practices and developing recommendations.

The scope of SC C4 is the development and review of 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, operation and control, apart from those cases in which a component, apparatus, or subsystem behaviour depends on, or significantly interacts with, the performance of the nearby power system.

The SC C4 scope covers system technical performance phenomena that range from nanoseconds to many hours, this includes: Power Quality, Electromagnetic Compatibility and Electromagnetic Interference (EMC/EMI), Insulation Coordination, Lightning, and Power systems performance models and numerical analysis. SC C4 has also been engaged in the development of new tools, models, methods and techniques for assessing and analysing the power systems. Figure 1 shows the range of phenomena that are investigated by SC C4.

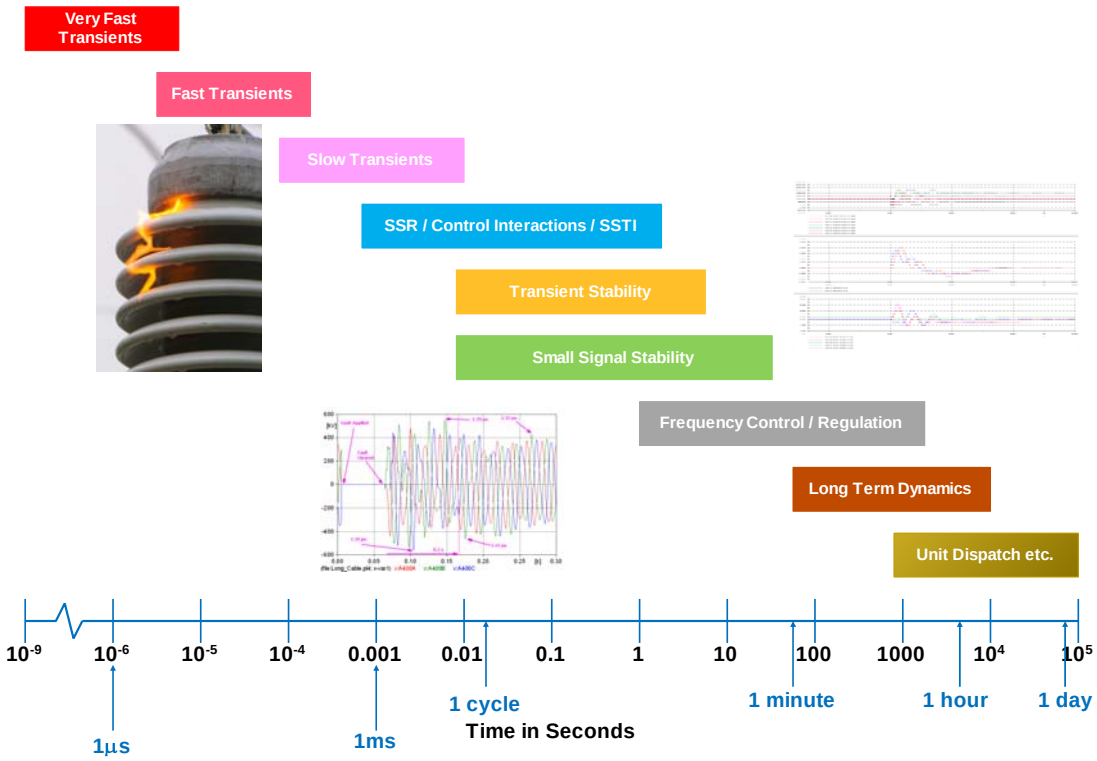

Figure 1: Range of phenomena that are investigated by SC C4.

Clearly, the scope of SC C4 is quite broad and spans all aspects of the technical performance of large electric systems. That is, SC C4 is concerned with the technical performance issues of the power system and how the various electrical components and equipment interact 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. Thus, there is always close cooperation between SC C4 and the other CIGRE study committees that deal with equipment, system planning and operations, distribution networks, materials and testing, and environmental aspects of the power system. This is evident by the fact that there are a few joint working groups that are currently active between SC C4 and several other SCs. There are presently four joint working groups with SCs A2, A3, B4, B5 and C6 (one of these is a joint working group amongst three SCs). Furthermore, SC C4 has two joint working groups with CIRED on issues related to distribution networks. SC C4 also has formal liaisons with the IEC TC 77 (on EMC) and the International Special Committee on Radio Interference (CISPR).

The Structure of SC C4 and its Strategic Direction

A copy of the SC C4 strategic plan can be found on the SC website (http://c4.cigre.org/Technical-activities/Strategic-Plan), which presents in detail the current structure and strategic direction of SC C4. Briefly, SC C4 presently consists of some 24 working groups (WGs) performing highly technical work in the fields of power quality, EMC/EMI, insulation coordination, lighting, and power system dynamic performance models and numerical analysis. These WGs are composed of an estimated five hundred, or more, technical experts from forty countries around the world. In addition, SC C4 itself is composed of 24 regular members and 14 observer members, together with a chairman and a secretary, from 38 countries around the world who monitor and manage these working groups and the efforts of the study committee and plan its future activities. These members are experts from 16 Research Organizations and Universities, 15 Utilities, and 9 Regulators, Manufacturers or other entities. There are also three advisory groups (AGs) under SC C4. AG C4.1 on Strategic Directions, which is a group of experts, together with the chairman and secretary that consult on the overall technical direction of the study committee. AG C4.2 on Institutional Liaisons, which coordinated liaison activities between SC C4 and other organizations such as IEC, IEEE, etc. AG C4.3 on Tutorials and Conferences, which coordinates SC C4's activities with respect to colloquia and tutorials. As evident from the WG activities of SC C4, the main strategic direction of SC C4 is looks at the electrical power system of the future. Below a brief summary is given of the main activities in the various subject areas of SC C4.

Main Technical Areas of Activity in SC C4

Here a very brief account is provided of the current areas of activity within SC C4. A complete list of all active SC C4 working groups is provided on the C4 website (http://c4.cigre.org/WG-Area).

Power Quality

There are presently four WGs looking at various power quality related issues of the present and future power systems. A recently formed group is looking at modelling and model requirements for the study of harmonics in power system studies (JWG C4/B4.38). With the advent of new high-efficiency lighting systems and many inverter based technologies on the distribution system there is an increasing proliferation of nonlinear loads and devices connected to the power system. There is presently a lack of guidance on treating existing, and coming, nonlinear loads and converter based generation embedded into the network. Devices particularly on the low voltage networks are usually not part of the larger transmission models and hence it is desirable to know the most suitable voltage level these should be connected to as an equivalent and how that equivalent should be represented when performing harmonic voltage distortion analysis.

Another recent working group (JWG C4/C6.29) is dealing with the challenges with power quality issues on the distribution system due to the proliferation of photovoltaic (PV) systems. 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 PV systems in the distribution system.

Electromagnetic Compatibility and Electromagnetic Interference (EMC/EMI)

Electromagnetic Compatibility (EMC) 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 electromagnetic field (EMF) are excluded, whilst intentional electromagnetic interference (IEMI) is instead included.

There are several active WGs within SC C4 looking at issues related to EMC including a group on power quality and EMC issues associated with future electricity networks (this is a joint WG with CIRED; JWG C4.24/CIRED), a WG looking at the extrapolation of measured values of power frequency magnetic fields in the vicinity of power links (WG C4.28), a WG soon to complete its task which has been investigating the protection of the high voltage power network control electronics against intentional electromagnetic interference (WG C4.206), and two newly established working groups, one looking at EMC in Wind Generation Systems (WG C4.30) and one looking at EMC between communication circuits and power systems (WG C4.31).

Another important WG recently created is WG C4.32 on understanding of the geomagnetic storm environment for high voltage power grids. Geomagnetic storms created by solar activity have caused problems for the operation of high voltage power grids in the past such as in Quebec, Canada in March 1989 and in South Africa in November 2003. Variations of the Earth's magnetic field due to the injection of charged particle streams, created by solar storms, into the magnetosphere of the Earth result in the creation of quasi-dc currents that flow in high voltage transmission lines, thereby causing AC transformers to saturate, leading to increased reactive power demand and transformer heating. These geomagnetically induced currents (GICs) can lead to many undesirable effects such as damage of high-voltage transformers. While there has been some improvement in the understanding of how power grids are affected, there is a need to understand the variations in the different types of geomagnetic storm waveforms. This WG is thus performing an in-depth study of the available historic data and literature to characterize the different types of geomagnetic storms and how they can affect high voltage power grids.

Insulation Coordination

SC C4 continues to be active in this important subject of insulation coordination, such as in the activities of WG C4.305 dealing with practices in Insulation coordination of modern electric power systems aimed at the reduction of the insulation level.

Many of the other WGs on this subject have recently completed their tasks successfully and thus produced valuable reports on subjects such as insulation coordination of ultra-high voltage AC systems, on resonance and ferroresonance in power networks and transformer energization studies, and on electrical transient interaction between transformers and the power system – this latter WG was a joint effort between A2 and C4.

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. There are presently six WGs investigating main aspects of lightning. A newly formed group, WG C4.37, is looking at the application of finite-difference time-domain (FDTD) techniques to the study of lightning surges. Interest in using FDTD methods continues to grow in the industry, particularly due to availability of commercial code and increased computer capabilities. Thus, this WG was formed to make an in-depth review of the technique and its application. Another recently formed, and important WG, is WG C4.36, which is looking at winter lightning phenomena and its consequences for wind turbines.

Winter lightning has attracted significant attention since the damage to wind turbine blades experienced along the Japanese west coast linked to this phenomenon.

Power systems dynamic performance models and numerical analysis

Under this technical subject there are numerous WGs looking at many important issues of present and future concern for power system analysis. These include subjects such as:

- Modelling and dynamic performance of inverter based generation in power system stability studies (JWG C4/C6.35/CIRED)
- High-frequency transformer and reactor models for network studies (JWG A2/C4.52)
- System conditions for and probability of Out-of-Phase (JWG A3/B5/C4.37)
- Application of Phasor Measurement Units for monitoring power system dynamic performance (WG C4.34)
- Numerical techniques for the computation of power systems, from steady-state to switching transients (WG C4.503)
- Analytical Techniques and Tools for Power Balancing Assessments (WG C4.603)

These WGs, and several more that recently completed their tasks, are looking at many of the challenging technical issues around modeling, simulation and dynamic performance assessment of the power systems around the world.

Tutorials and Conferences

In the past two years SC C4 has actively participated in, and helped organize, several colloquia. These include:

- The CIGRE International Colloquium on Lightning & Power Systems, May 12-14, 2014, Lyon, France, organized by SC C4
- CIGRE 3rd International Colloquium on Electric and Magnetic Fields at Extremely Low Frequencies, October 15-16, 2013 Nara, Japan, organized by SC C3, with participation from SC C4 and several other SCs.
- Joint Colloquium of CIGRE SC A2/C4, Zurich, Switzerland September 9-11, 2013

In addition, SC C4 working groups delivered several recent tutorials, including:

- Tutorial on WG C4.502 Power System Technical Performance Issues Related to the Application of Long HVAC Cables, given at the Paris 2014 Session
- Tutorial on WG C4.307 Resonance & Ferroresonance in Power Networks, given at the Zurich Colloquium
- Tutorial on JWG A2/C4.39 Electrical Transient Interaction between Transformers and the Power System, given at the Zurich Colloquium

Presently, SC C4 is planning on several other colloquia in 2015, as well as delivering additional tutorials at various conferences. SC C4 will also participate in the Lund Symposium in 2015.

Recent Publications

The following technical brochures have been published in 2014 as a result of work done by SC C4 working groups and joint working groups:

- JWG C4.112/CIRED, Technical Brochure on Guidelines for Power Quality Monitoring – Measurement locations, processing and presentation of data (CIGRE Technical Brochure No. 596)
- JWG C4.207/CIRED, Technical Brochure on Guide for assessment of transferred Earth Potential Rise (EPR) on Telecommunication Systems due to faults in ac Power System (CIGRE Technical Brochure No. 592)
- WG C4.409, Technical Brochure on Lightning Protection of Wind Turbine Blades (CIGRE Technical Brochure No. 578)

- JWG A2/C4.309, Technical Brochure on Electrical Transient Interaction between Transformers and the Power System – Part 1 – Expertise / Part 2 – Case Studies (CIGRE Technical Brochure No. 577A/577B)
- WG C4.307, Technical Brochure on Resonance and Ferroresonance in Power Networks (CIGRE Technical Brochure No. 569)
- WG C4.307, Technical Brochure on Transformer Energization in Power Systems: A Study Guide (CIGRE Technical Brochure No. 568)
- WG C4.605, Technical Brochure on Modelling and aggregation of loads in flexible power networks (CIGRE Technical Brochure No. 566)