

Progress Report of Study Committee 13

Switching Equipment

by E. Kynast, Secretary of SC 13

Field of activities

Study Committee 13 is dealing with switching equipment as apparatus as well as with its interactions with networks as complex systems and their components. The components serving as generating, transmission and load equipment have to be considered concerning their reactions to the switching processes. The activities concerning the switching equipment as component as well as its interactions cover the study of:

- Trends of development and their impact on transient behavior of network and other equipment considering new technologies and possible alternatives to switching devices as used presently
- Reliability and availability of switchgear in service, in particular of high-voltage circuit-breakers
- Diagnostic and monitoring techniques for switching equipment, to reduce life-cycle costs and to extend its life expectancy
- Applications of controlled switching strategies and their impact on networks operation and stress on other system components
- Testing requirements and methods for high-voltage switchgear in view of the stresses from networks and the characteristic behavior of the various types of switching equipment

The future situation of energy transport and distribution will lead to an increased utilization of the equipment capabilities and therefore to higher equipment stresses. This means that a more detailed knowledge on severity and number of stresses switching equipment might be exposed to in the system is required to propose adequate test procedures with the aim to improve equipment reliability.

The trends in the energy market will lead to requirements for higher flexibility of system controls. The demand of advanced equipment control such as monitoring and diagnostic techniques and application of controlled switching is already covered by the Study Committee activities. The future trends of application of digital control systems in substations as well as in switching equipment itself lead to an increased activity concerning the reliability of control systems and their possibilities of implementing advanced features.

Activities of the Study Committee

Contribution to general CIGRE activities

The annual meeting of the Study Committee was held in September 1999 in Washington D.C. (United States).

A Joint Working Group under the leadership of Study Committee 38 concerning the topic "Fault current limitation" will be supported on the base of the work of Working Group 13.10 "Specifications for short current limiters".

A cooperation with the Joint Task Force "Withstand test requirements for substation secondary circuits subjected to EMI" under the leadership of Study Committee 23 was arranged.

A Coordination Committee on electronic control systems has been established with SC 23 and 34. A first draft of an action plan has been prepared. It has been clarified where are overlaps and where are possibilities of coordination between the Study Committees. Common activities have been identified under the topics: Substation control and automation, substation concepts, maintenance issues and non-conventional sensors.

A Joint Working Group titled "Electrical environment of transformers" has been established under the leadership of SC 12. The contribution of SC 13 comes out of the fact that most of transformer problems came from the interaction with switching devices producing very fast transients.

The Study Committee will contribute to the CIGRE Symposium "Behavior of electrical equipment and components in tropical environment" planned to be held in Cairns (Australia) in September 2001.

Cooperation SC 13 / IEEE Switchgear Committee

During SC 13 meeting in Washington a presentation of the standardizing bodies of the United States was arranged. D. Sigmon, Chair of IEEE Switchgear Committee presented the structure and bodies of the IEEE and PES in the USA.

Cooperation SC 13 / IEC TC 17 and SC 17A

The exchange of information between SC 13 and IEC TC 17/17A is practiced continuously due to some personal engagement in both committees. Main items which has been discussed during the IEC-General meeting at the end of October 1999 in Kyoto are:

- A Draft Amendment for IEC 60694 covering the EMC requirements for auxiliary and control circuits of high voltage switching devices has been discussed.
- The CDV of the revised IEC 60056 was decided to go into the FDIS stage so that the revised standard can be published end of 2000 or beginning of 2001. Especially matters of insulation testing have been discussed and extended acceptance criteria of impulse testing across the open circuit breaker has been introduced.
- To establish a test standard for grading capacitors is under consideration

The efforts of harmonization between IEC and IEEE/ANSI are still going on.

Activities of Working Groups and Task Forces

WG 13.04: Switching Test Methods

Convener: I. Bonfanti (Italy)

Taking into account the capabilities of the switching devices the Working Group is establishing laboratory circuits and testing procedures which are suitable to simulate switching conditions in service.

The Working Group held two meetings in 1999, one in April in Arnhem (Netherlands) and the second one in September in London (United Kingdom).

The work concerning capacitive current switching has been completed by publication of the report "Shunt capacitor bank switching; Stresses and test methods" in Electra in February and April 1999 (No. 182 and 183). To finalize the work all reports prepared by WG 13.04 on "Capacitive current switching" were targeted for publication in a CIGRE Technical brochure.

Beside this WG 13.04 gave support to the revision of IEC 60056 concerning the subject "Switching of asymmetrical currents". The results has been incorporated into the Annex of the Draft IEC 60056 (CDV). In continuation of this work the Working Group is preparing a report which will cover the following topics:

- Field needs - including time constants, frequency of the system, practices within utilities, duration of short circuit
- Switching devices – technology dependency including time spread, pre-strike characteristic, controlled switching
- Impact on various standards – considerations and impact to IEC 60694 and specific standards affecting various devices
- Testing aspects for various devices – one- and three-phase, combination of tests, device and test circuit layout, effect of test circuit time constants

WG 13.07: Controlled Switching

Convener: K. Fröhlich (Switzerland)

The Working Group is covering the field of conditions for controlled switching for various possible applications, systems and circuit-breaker requirements as well as system and load response. The characteristics of the circuit-breakers has to be considered by these investigations.

The Working Group held two meetings in 1999, one in March in Zurich (Switzerland) and the second one in September in Rio (Brazil).

In continuation to the document "Controlled Switching of HVAC Circuit Breakers – Guide for Application", published in Electra in April and August 1999 (No. 183 and 185), the Working Group has finished the draft of a second chapter titled "Controlled Switching of HVAC Circuit Breaker – Studies, Specification and Type Testing". The intention of this chapter is to give guidance to users and manufacturers of controller-breaker systems how to proceed when implementing controlled switching. Also in examples guidance is given what kind of pre-studies should be carried out. These studies are the basis how to specify the controller-breaker system taking into account that controller and breaker may be from different manufacturers. In a third step recommendations are given how to type test such a controller-breaker system again taken into account different manufacturers for controller and breaker. Questions of responsibility for the entire system are covered.

Two further topics will be covered in future work. One is the technical aspects of new controlled switching cases, such as energisation of unloaded transformers taking into account the remanence flux of the transformer and the controlled switching under fault conditions. The other one is the evaluation of the economical impact of controlled switching as a decision factor.

WG 13.08: Life management of circuit breakers
Convener: A.L.J. Janssen (Netherlands)

The conditions for life management are studied within the Working Group and recommendations are elaborated how to extend the residual life expectancy of switchgear in service and under development.

The Working Group held two meetings in 1999, one in March in Zurich (Switzerland) and the second one in September in Montreal (Canada).

The Working Group has prepared a second draft of the report on life management of circuit breakers. The final draft will be presented to SC 13 in 2000.

For this, the Working Group has collected service experience on other than electrical and mechanical stresses and also experience with life management techniques. Up to now there are no final results but in tendency there seems to be less influence on the lifetime of circuit breakers. Management support and risk assessment techniques have been evaluated and possibilities for the life expectancy and circuit breaker life extension are studied. One question during this work is to define the end of life of a circuit breaker because this is influenced by a lot of items. The application of monitoring devices on old circuit breakers for life extension is in most cases very costly.

Furthermore the Working Group supported IEC SC 17A by defining test procedures for electrical endurance tests and the need for these tests.

A paper on advanced maintenance management techniques for HV circuit breakers has been presented at the CIGRE Symposium 1999 in London titled "Working plant and systems harder".

WG 13.09: Monitoring and diagnostic techniques for switching equipment
Convener: C. Jones (United Kingdom)

For the application of monitoring and diagnostic techniques to circuit breakers and other switching equipment the Working Group is gathering recommendations for a guideline under various aspects.

The Working Group held a meetings in April 1999 in Warsaw (Poland).

The work is going on in preparing the report "Monitoring and diagnostics techniques for switching equipment". In small Task Forces the subtopics has been lined out. First of all the terms to be used has been defined. The need for any kind of monitoring has been investigated taking into account the different possible applications and circuit-breaker types. By showing the benefits and costs the justification for monitoring has been evaluated. The following description of sensors and diagnostic techniques will be the main focus of the report. To ensure reliability in service requirements concerning design and testing are being gathered. The use of diagnostic and monitoring techniques could result in excessive false alarms. This problem should be settled by using good and tested sensors, well designed interfaces and by the nowadays usual self-checking opportunities offered by electronic systems. Dependability and architecture of monitoring and diagnostic systems are gathered in two further sections. A view into the future will show possibilities and trends.

The final report is expected to be published as Technical Brochure together with a summary in *Electra* before the CIGRE Session 2000 in Paris.

WG 13.10: Specifications for short current limiters
Convener: A. Greenwood (USA)

The uprating of the load carrying capacity of medium and high voltage distribution systems leads to considerations to use short circuit current limiters. The Working Group is determining the degree of current limiting needed and the operational conditions for current limiters use.

The Working Group held two meetings in 1999, one in March in Rio (Brazil) and the second one in September in Washington D.C. (USA).

The draft of the Working Group report on "Specification for short circuit current limiters" has been finalized. The final version will be published in *Electra* in 2000.

Since other CIGRE SC's are also dealing with similar subjects it was stated that a cooperation with them will be necessary, but the product "current limiter" should be kept within SC 13. SC 38 may deal with the current limiters application. To make this clear the title of the report will be changed in "Function specification for short circuit limiter".

The report points out the critical features that must be addressed for special designs. To give a specific list of requirements is not possible at this time. A great variety of techniques are applied at present which are described in 26 applications, most of them industrial. The results of an inquiry among potential users of fault current limiters out of industry as well as utilities are incorporated.

The future program of work for WG 13.10 will be the exploration of the topics "State of the art", "Testing" and "System demands" related to fault current limiters.

WG 13.11: Application Guide for IEC 60056 and 60694
Convener: H.H. Schramm (Germany)

To support users and to provide them with background information a guide will be worked out upon the requirements of the Standards IEC 60056 "High-voltage alternating-current circuit-breakers" and IEC 60694 "Common specifications for high-voltage switchgear and controlgear standards".

The Working Group held two meetings in 1999, one in March in Rio (Brazil) and the second one in October in Kyoto (Japan).

The Working Group has reviewed the topics to be included in the application guide and got a long list of detailed tasks in this field. The most advanced chapters are:

- Introduction
- Application of high-voltage circuit-breakers
- Short-line fault

Due to new classifications of circuit breakers in the revised IEC 60056 concerning capacitive switching and mechanical application the chapter "Classification of circuit breakers" has to be adapted accordingly. The real-stress data collected from WG 13.08 will be considered as background information.

The next step of the Working Group will be the drafting of the chapters:

- Insulation coordination
- Capacitive current switching
- Rated (operating) frequency 50/60 Hz
- Continuous current and overload

WG CC03: TRV stresses in MV systems - Test circuit topology
Convener: L. van der Sluis (Netherlands)

The Working Group is gathering information on actual TRV stresses in systems with rated voltages below 100 kV and studying the interaction between test circuit topology and the circuit breaker under test.

The whole broad scope was covered by publishing the Technical Brochure No. 134 and a summary was published in Electra in December 1998. The remaining task of the Working Group is to investigate the test circuit topology and the TRV requirements for the first, second and third pole to clear for medium voltage systems. Results on these topics are needed as input for IEC 17A. Not very much information is available up to now due to the nature of the subjects. The work is carried on in a small Task Force with nominated experts out of the Working Group.

TF 13.00.2: Revision of IEC standards relevant to switching devices
Convener: J.F. Reid (United Kingdom)

The Task Force is reviewing standards relevant to switching devices (circuit breakers, switches, disconnectors, fuses) in view of electrical, mechanical and environmental questions where fundamental revisions may be required.

The subject "New switching devices" with the investigation of any need for standardization for devices with a switching capability higher than disconnectors but lower than switches has been finished with the result that there is no real need because no significant market demand has been seen.

Under the heading "System quality" a compilation of existing material on the behavior of switching devices that could degrade power system quality will be developed. The Convener of the TF is establishing a bibliography of papers by means of search initiated in IEEE, Electra and IEE, and by request for relevant bibliographies from authors of recent/active documents.

A report can be expected in the beginning of 2000.

Activity of the Current Zero Club
Chairman: K. Möller (Germany)

The Current Zero Club is a Club of experts specialized on the field of current interruption. There is a continuous exchange of experience with Study Committee 13.

The 20th meeting of the Current Zero Club took place in Arnhem (Netherlands) on September 8-9, 1999 hosted by KEMA and attended by 16 Members and 15 invited guests. As the new chairman of the Current Zero Club M. Barrault (France) has been elected. His duty will start with the next meeting in September 2001.

The subjects of presentations and discussions during the technical sessions were:

SF6 circuit breakers

- Experimental investigations on arc-nozzle interaction, flow fields, post arc phenomena (4 papers)
- Physical arc modeling, radiation, ablation, non-equilibrium phenomena (5 papers)
- CFD (computational fluid dynamics) tools (4 papers)
- Arc model application in design and testing (3 papers)

Vacuum circuit breakers

- Plasma densities, ion energies, droplet formation (3 papers)
- Contact phenomena, material, temperature-measurements (3 papers)
- Application related models, switching of condenser banks small generators (4 papers)

Measuring methods

- Arc temperatures, particles formation, flow fields (2 papers)
- Electrical current zero phenomena (2 papers)

General discussions were focussed on the Circle-activities.

CFD studies for SF6 circuit breakers

Different groups have achieved appreciable progress in distinct fields. So, for example, modeling of the radiative heat transfer in connection with global or local nozzle ablation, gas mixing process in the high current region, non-equilibrium and turbulence phenomena in the post arc region, and recovery behavior can serve as modules to be integrated in CFD (computational fluid dynamics) tools.

Nevertheless there is still doubt or even lack of knowledge concerning many details of switching arc modeling. However even more important is that an approved set of modules to be integrated into a complete CFD program suitable to respect specific features of realistic circuit breakers under operational conditions is not available so far. To overcome this situation the following measures have been decided:

- To continue the development of distinct modules attracting further support from outer groups active in respective fields but not yet integrated in this process.
- In order to make substantial progress the Circle has been reestablished for defining standard interrupter geometries and standard boundary conditions to be used in a benchmarking procedure for different modules of CFD tools. This benchmarking shall be carried out by different CFD tools and to some kind of "approved modules".

Vacuum switching

The scope discussed during the last Circle Meeting in 1998 is still valid. Respective items have been put forward also during the Arnhem Meeting. The next meeting of the Circle Vacuum Switching will take place early next year in Ratingen, Germany.

Diagnostics and Monitoring

Traditionally this Circle met in connection with the Summer School on High Voltage Testing at Newcastle-upon-Tyne in July 1999.

The activity of this Circle is restricted to measurements relevant for circuit breaker research and testing rather than normal circuit-breaker operation.