2010 General Report of Group B1
(Insulated Cables)

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0. Introduction

The Group Discussion Meeting of Study Committee B1 took place on August 26th, 2010 from 08.45 to 18.00.and was attended by an audience of around 300 people with a peak of 350 and a minimum of 250.
49 prepared and above 60 spontaneous contributions were presented, referring to 13 questions as proposed by the Special Reporter Pierre Argaut (FR). The Special Report was based on 27 papers submitted for the 2010 CIGRE Session, addressing three Preferential Subjects.

SC B1 Chairman opened the meeting with a short presentation of the activities of Study Committee B1

The activities of CIGRE Study Committee B1 concern all types of AC and DC insulated cable systems for land and submarine power connections and are focused mainly on high voltage applications. Whenever appropriate, however, lower voltage applications are also considered.
Within this field, the scope of work of the Study Committee covers theory, design, applications, manufacture, installation, testing, operation, maintenance and diagnostic techniques.
The main goals of the SC B1 are the following:

- to contribute effectively to the progress in insulated cable systems technology,
- to facilitate the integration of insulated cable systems in electric power networks and in the environment, covering the complete life cycle of cables,
- to maintain its leading position in the field of power cables by providing unbiased and neutral information on all essential cable aspects,
- to be recognised by the Electric Power Industry as a leading and reliable partner with competence in all engineering issues related to insulated cable systems, i.e. technical, economical, ecological and social,
- to monitor and assess current trends in cable technology,
- to promote advancements in cable technology.

The basic operating structures of the SC are its Working Groups. Their effective performances are based on a clear definition of their terms of reference and on work plans with specific time limits (typically three years).

In order to achieve this, it is the normal practice of SC B1 to set up a Task Force (TF) to define the terms of reference of a new WG prior to its establishment. The duration of this type of TF must not exceed one year.

It was recalled that the annual Study Committee B1 meeting took place on Tuesday 24th of August.

Following this meeting, the SC is composed of 24 Regular Members, 10 Observer Members, a Secretary and a Chairman.

There are 22 Working Bodies: 3 Advisory Groups, 14 Working Groups or Joint Working Groups, and 5 Task Forces or Joint Task Forces

The SC B1 has its web site at the following address: www.cigre-b1.org. The SC Secretary is also the web master.

Then the SC Chairman opened the discussion around the three preferential subjects proposed for this Discussion Group.

This report covers the essence of the submitted papers and prepared contributions and reflects the spontaneous discussions that followed the oral presentations.

1.Technical challenges that have been overcome in newly installed underground and submarine cable systems

- Current state-of-the-art in the design of AC and DC submarine and underground traditional cable systems
- Current state of the art in cable systems installation techniques.
- Experiences of operation of cable systems

17 papers were presented under PS 1

For long distances, in some ranges of power, and in some cases depending on network parameters, DC is known to be the only solution for HV transmission lines. For underground and submarine cables, extruded and Mass Impregnated cables are now competing at higher and higher voltages and recommendations (currently prepared by WG B1.32) for testing extruded DC cables above 250 kV will be much welcome for qualification and evaluation of solutions based on cables. Several examples are given in 3 papers describing DC cable systems from 88 km 200kV DC extruded (Transbay in San Francisco) to nearly 600 km 450 kV MI (NorNed).
On the other hand, it appears that new areas (TB 250 from WG B1.19) are now opened to HV AC transmission over distances around 100 km and for powers ranging from tens to hundreds of MW, for example to supply islands, offshore platforms or vessels. Dynamic cables for high voltage applications become a serious candidate for this kind of electrification and the design of cables has to evolve to take into account the mechanical constraints in dynamic applications while preventing from water ingress. Accurate calculation of the transmission capacity of three-core AC cables is also necessary to optimize their design. As it appears that losses in armour of three-core AC cables can be over-estimated, further work in relevant IEC standards is required for a better rating assessment.

Optimization of the transmission capacity of new and existing cables is the topic of several papers. This can be done by uprating (for example by better assessment of losses in three-

core cable as mentioned), or by upgrading in one of the different ways inventoried by WG B1.11.
One way to optimize the transmission capacity can be found in the daily use of Dynamic Thermal Rating systems as mentioned by WG B1.02 (TB 247) and also recalled by B1.11
New Dynamic Thermal Rating Systems are coming into operation in different countries.
DTS systems have already proved in the past to be an efficient way to detect hotspots and to make feasible the upgrading of installed cable systems, either by changing the thermal environment of the cable or by using locally cables of better performance. Upgrading part of an existing cable system may require the use of transition equipment. New types of transition joints are now available up to 400 kV, including Y-Branch transition joint at 275 kV. Their performances will be evaluated starting from the **recommendations issued by WG B1.24 published in Technical Brochure 415**.

New design of cables or cooling systems may be required to retrofit existing structures while increasing performance. High Temperature Superconducting cables may be a solution in some specific cases.
Another way to upgrade an existing system (as mentioned by WG B1.11) is to increase the service voltage when possible. This must be done on a large scale of an existing grid. This solution is under consideration in a distribution network in China.
Extension of the service life of a system is anyway one of the main challenges for a system operator. In the short term, this starts with proper repair in case of failure as reported on a 550 kV system in Canada. For medium and long term, it can result from a well established maintenance policy as proposed by WG B1.04 (TB 279) and B1.09 (TB 358) and continuous improvement of the design based on the failure cause analysis .
Careful consideration of statistics of failures is recommended to better focus on appropriate measures to improve reliability. Third party damages are reported to be the main cause of failure of underground HV power cables in Brazil. This confirms results of the survey carried out by WG B1.10 (TB 243). The work published by WG B1.09 (TB 398) will probably help in finding solutions for improvement.
Very large transmission capacity can be obtained in cables installed in tunnels. Large cross section High Voltage Cables installed in tunnels is the topic of one paper which outlines the thermo-mechanical and thermo-dynamic forces that the system has to withstand in normal operation, in overload conditions and under fault conditions.
Most of the time, such cables are working in N-1 conditions, and can be unavailable for days or weeks without big problems. But a new type of large cross section cables installed in tunnel is coming, to connect big generators to the grid, for example in nuclear plants. These cables will work in N configuration and a very high transmission capacity coupled with very high reliability will be required for them. A completely new approach may be necessary for this kind of systems. This is a new challenge for SC B1.

Five questions were addressed to the audience:

The first question addressed the availability of HVAC solutions for long distance transmission versus power/voltage/length. Four prepared contributions offered some elements to better understand the issues.
The invited contribution “Technical (electrical) issues regarding the integration of a long distance underground or submarine cable in the network” gave a widened view of the challenges to finally conclude:

- Transmitting power over long lengths with HV and EHV cable lines **is feasible**
- Projects including long cables require an **ad hoc system design**

- The longer is the cable length the higher is the expected interaction with the network and therefore **the design horizon has to be extended to the network** (f.i. risk of resonances)
- To ensure the feasibility of a project including a long cable is therefore necessary to focus also on the network and on the expected **system operating conditions**

Five spontaneous contributions completed the discussion. High performance backfilling materials were also discussed. It was mentioned by a user that some difficulties may arise for long routes, as this kind of product is not usually processed by standard concrete providers and the manufacturing process has to be well monitored (checking water and additives contents).

The second question aimed to understand the current state of the art for HVDC extruded cable systems and to identify the trends. Seven prepared contributions presented different recent, current or near future land and submarine projects and tests carried out on prototypes opening a discussion with nine spontaneous contributions. Temperature of operation was discussed including in overload conditions The trend is definitely towards higher voltages (500 kV is announced in operation in a few years) and bigger powers (1.8 GW/bipole) and for increasing lengths. As mentioned before, the final report of WG B1.32 giving recommendations for testing HVDC Extruded cable systems is expected in 2011.

Global behaviour of large cable systems installed in tunnels was the topic of the third question, especially when cable systems connect a large generator to the network. The discussion was opened by five prepared contributions which were followed by five spontaneous ones. The current status of relevant IEC Standard was explained, and several lacks were pointed out, even if in CIGRE TB 403 “Cables in multipurpose or shared structures”, a lot of relevant information on cables installed in a tunnel has been collected
Different issues were listed showing that additional work could be needed. Earlier in the week, the SCB1 had decided to investigate in this area

Question four addressing the areas to be explored to better optimize the sizing and the cost of submarine and land cables was the subject of four prepared contributions regarding mainly the use of finite elements calculations and comparison with tests to better estimate the losses. Some different opinions were expressed including 6 spontaneous presentations.
Further work is expected in this area and the wish to update relevant IEC standard to take into account the new results rather than introduce FE calculations was expressed.

Question five was dedicated to HTS cable systems and to updating of the learnings from installed HTS cable systems, including pilot ones. Three prepared contributions gave the information regarding main installed (short) cable systems, with up to four years experience. Six spontaneous contributions completed the discussion. Increased test lengths will be installed soon (6 km). The main concern remains the availability of reliable terminations and joints.

At the end of the morning session, SC D1 gave a short overview about the status of nanocomposites and the possibility to use them in insulated cables.
Promising nanocomposite materials candidate to be used as cable insulation are based on polyethylene (PE), cross-linked polyethylene (XLPE), polypropylene (PP) or ethylene-vinil-acetate (EVA), filled e.g. with layered silicates (LS), nanosilicates (NS), TiO_2 and MgO nanoparticles.

This contribution had the aim to show how the electric properties of such materials can be modified by the addition of nanofillers.
This presentation was very well received by the audience.

This concluded the morning session .
The afternoon session was dedicated to preferential subjects 2 and 3.

2.Key factors in current and foreseen development of cable systems

- Environmental impact
- Balancing capital costs (including costs for Right of Ways) vs operational costs (including costs for operation and maintenance, social costs, losses, dismantling, etc.)
- Prospects of UHV cable systems

Several papers presented under Preferential Subject 1 have already addressed some items listed under PS 2: losses, upgrading, repairing.
Three papers presented under PS2 are more focused on environmental impact and social costs.
It is shown that the design of a cable may influence the environmental impact of a cable system. It is interesting to learn that all major recent design evolutions (lapped to XLPE insulation system, lead to aluminium metal screen, insulated wires) may have led to a reduction of the impacts on Global Warming and on Water. If SC B1 decides to launch a working group on Life Cycle Analysis, the cable industry will be soon able to evaluate the environmental impact of any future change in design, installation, operation and upgrading of a cable system.
When existing links reach their ampacity saturation and additional loads are expected, the decision must be made between build a new line or upgrade the existing one following one of the methods already mentioned under PS 1.
WG 21.17 (TB 194) has pointed out that some installation techniques may better favour future upgrading than other ones. On the other hand, some cable designs may be more suitable to given installation techniques.
Everything has to be taken into account for an optimized solution. Consequently, the whole life cycle of the cable system has to be considered to assess the environmental impact of a solution as well as the capital costs versus the operational costs.

In a similar way, future prospects of cable technology have to be taken into account to prepare the upgrading options (increase of voltage, retrofitting, forced cooling, change from AC to DC…..) and assess their technical and environmental impact.

This subject had attracted 4 papers for the Special Report, and 12 prepared contributions for the Group Discussion Meeting to comment the four questions of the Special Report.

Question one dealt with environmental impact of cable system during the whole service life and aimed to list the existing studies made in the area. Only one prepared contribution was presented followed by one spontaneous contribution. Life Cycle Analysis is under consideration within SC B1 for a possible new WG.

Question two regarding the “events” and faults in underground lines was addressed by four prepared contributions followed by three spontaneous ones. Third party damage is a concern. The use or radial water ingress barrier is recommended. Short-circuit levels are an important criterion for the consequences of fault.

Upgrading existing lines is a solution which is more and more adopted by utilities. It can be the solution of minimum impact on environment. Question three aiming to hear about experiences in upgrading existing lines and process of decision making received four prepared contributions opening a discussion among nine spontaneous contributions. The necessity of preliminary studies and testings before decision was discussed. When increasing the service voltage of an existing line, special care must be given to the condition of metallic shield or sheath and higher failure rate should be expected in the first months and years.

Question four aimed to understand the new considerations between AC and DC transmission lines in terms of System/Network design and transmitted power versus length with the increasing performances of extruded DC cables. Three presenters offered prepared contributions which were discussed in six spontaneous ones. HTS cable Systems solutions were also included in the discussion. The question was raised regarding the maximum length of HTS cable systems. For comparison of AC and DC Extruded cable systems, it was stated that due to possible operating temperature limits for DC cables, emergency ratings should also be taken into consideration. The compared losses of VSC and LCC converters were also mentioned.

3.State-of-the-art and trends for cable system testing

- Qualification, type testing, routine, sample, after installation testing of cable systems
- Representation of installation and operational stresses in testing of cable systems
- Diagnostic testing of cable systems

When the integration of long HV cable systems in the network is shown to be feasible as presented in several papers under PS1, it is highly important to know the electrical characteristics of these systems and to compare computed values with experimental ones.
SC B1 and SC B4 are working closely on these topics and tests mentioned in paper B1.301 offer a high value contribution to this work.
Ultra Low Frequency after laying testing had been recognized as an interesting way to test HV cables by WG 21.07 in Electra 171. At this time, no equipment was available for HV tests. Today, when this type of test appears to be helpful in distribution voltages, as experienced in the US, it is perhaps time to explore this method in the high voltage range.
Under PS1, one paper has pointed out the need of assessing the behaviour of installation equipment of HV cable in tunnels under short-circuit conditions by appropriate tests. Such tests will be costly and their cost will increase the overall cost of the cable systems.
On the other hand, SC B1 had issued recommendations for preparation of IEC 62067 and more recently WG B1.06 has published TB 303 to introduce the concept of Extension of Qualification and to confirm the ranges of approval of Prequalification Test and Type Test as defined in IEC 62067. Despite this, it appears that costly tests which are not requested in CIGRE recommendations are still required in some contracts and increase the costs of the cable systems most probably without added value.
PD measurement and PD monitoring, especially using sensors located at the link boxes in cross-bonded systems, are proved to be a good way to detect PD activity in joints with a sensitivity of 5 pC in environment showing background noise around 200 pC.

Laboratory tests often lead to new concepts of monitoring of HV equipment. Ten years after the work of B1.02 on use of DTS systems, it is interesting to know how DTS systems and field measurements and tests have opened the way to Dynamic Thermal Rating Systems which would meet the needs of the users.

This subject had attracted 6 papers for the Special Report, and 14 prepared contributions for the Group Discussion Meeting, where four questions had been addressed to the audience.

Question one aimed to update the state of the art of very low frequency testing of installed cable systems. Five prepared contributions were presented, then four spontaneous contributions highlighted the high interest in this topic confirming the decision of SC B1 to investigate in this matter through a new TF. It was noted that IEEE/ICC is also investigating in this field.

Before going to question two, an invited contribution was given about "Full Scale Testing of long AC Cable lines". This presentation of the results of the testing of a very long cable system in Denmark is an interesting contribution to the work of current WG B1.30 (Cable Characteristics). Some of the main learnings are:

- There is an overall good agreement between simulations and measurements but a little less damping in simulations than in reality.
- The voltage rise due to Ferranti effect slightly higher in reality than in simulations; reasons to be to be investigated further.

The central matter of Prequalification Testing and repetition of Long Term testing in some contracts was discussed following question two. Four prepared contributions exposed different points of view. Three spontaneous contributions followed to complete a long discussion. Thermo-mechanical behaviour of cable systems and thermo-mechanical conditions of testing appeared to be a serious issue. The work of WG B1.34 will probably help in the matter.

Question three regarding the use of Dynamic Thermal Rating and need of additional recommendations or standards attracted three prepared and two spontaneous contributions. Different opinions about the need of further standards or recommendations were expressed. SC B1 Working Group on rating calculations (WG B1.35) will investigate in this field to prepare decisions from Study Committee B1.

Question four about PD measurement and assessment of time available for repair before failure was covered by two prepared contributions and commented by two spontaneous ones.
PD measurements are recognised as useful but not able to cover all the types of faults. It is thus impossible for the time being to give a clear answer to the question. Work in this area is carried out by a current SC WG (WG B1.28).

4. Conclusions

As usual, the Group Discussion Meeting of SC B1 was an active and lively forum of international experts(61 spontaneous contributions from 15 countries), who frankly and competently discussed topical issues in the power cable world. Not all questions were answered conclusively, however, this was not the intention and the expectation of the auditorium. Open questions are considered the input for future activities of Study Committee **B1 "Insulated Cables".** They are partly already included in the scopes of the existing **Working Groups and Task Forces** recently decided during last Study Committee Meeting earlier the same week**,** which are indicated in the respective chapters of this General Report. Readers and experts are invited to contribute with their comments and experience to the further progress of these working bodies of SC B1.