Implementation of long AC HV and EHV cable systems

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Introduction

The aim of this Technical Brochure is to provide a comprehensive document which it is hoped will be a valuable reference by any Utility, Government agency or Investor looking to put in an underground system in lieu of an overhead line, or a long length of submarine cable, particularly in terms of appreciating what can be done or has been done.

Basically, due to economics, the power transmission network has been developed during the last decades based on the use of overhead lines (OHL). EHV underground cables systems have been available since a long time, but their use has mainly been to provide interconnections from these transmission lines where they are needed to connect to cities, urban and industrial areas or where there are other constraints due to environmental aspects.

In many countries, there are many thousands of kilometers of underground HV & EHV cables but the nominal length of these underground circuits is usually between 2 and 20 km. Today however, we are seeing many underground or sub-sea cable circuits being established which are 50 – 150 km in length. This TB explains the reasons for this dramatic change and have provides guidance in terms of the special factors that must be considered when designing such links compared with the normal considerations given to shorter links.

Scope

The first task was to come up with a definition of what could be classified as a long length of HVAC cables and the following was chosen:

> "A long length of insulated cable is one where the load due to the capacitive current needs to be considered in the system design. Typically, this would be 40 km for voltages less than 220 kV and 20 km for 220 kV or greater".

Given the scope of work, this definition is slightly different to that of TB 556 "Power System Technical Performance Issues Related to the Application of Long HVAC Cables" which covers many of the technical aspects relating long AC cable links. This document however, addresses some of the other aspects, with the emphasis on implementation issues and so the above definition was selected to be able to draw on the experience gained from approximately one hundred current and future projects worldwide.

The document has six chapters which address the following:

1. Current state of development
2. Challenges for Implementation
3. System Design
4. Installation
5. Monitoring
6. Maintenance

Then there is a seventh chapter providing examples of practical experience from 11 different countries and an eighth chapter giving statistics on world experience.

Finally, there is a very short conclusion, some reference documents and 4 Appendix's. The first of these lists 81 projects from all over the world and then 3 giving mathematical examples of load flow and efficiency of long length cable systems. •••

Period	Number of years in the period	Number of Projects	Links length	Cables Length	Average project /year	Average cable km/year
1967-1997	30 years	13	398 km	458 km	0,43	15 km/year
1997-2007	10 years	12	538 km	682 km	1,20	68 km/year
2007-2012	5 years	20	1122 km	1343 km	4,00	269 km/year
2012-2015	3 years	22	1349 km	1947 km	7,33	649 km/year
2015-2018+	-	14	703 km	1216 km	-	-
TOTAL	48 years	81	4111 km	5645 km		

Description of the technical brochure

Chapter 1 - Current State of Development discusses the reasons for this rapid growth which is very much related to the use of new materials, processing technology, ancillary equipment and installation techniques being used today. These factors have overcome some of the problems of capacitance, dielectric losses and the relatively low current rating compared to overhead lines, such that the constraints on maximum length and power transfer have largely been overcome.

The difficulties in installing new overhead lines are making it essential to consider the use of longer underground cable links, at the same time the development of off-shore facilities has created a demand for long submarine cables.

As such it is interesting to note that for 30 years between 1967 - 1997 there are only 13 projects involving less than 400 km of total circuit length being reported.

Now in the 3 years 2012 - 2015 there were at least 22 projects involving more than 5 times as much cable and this trend is continuing because of the demand to have rapid interconnections to the grid. The TB discusses cable and accessory design trends, reactive compensation to offset the cable capacitance, the need for harmonic filtering and most importantly the key factors to consider in terms of reliability of supply.

Chapter 2 - Challenges for Implementation - there are very significant technical challenges to be considered whilst planning such cable installations, the impact on the transmission grid, protection systems and life time expectancy and installation. The matching of ratings for overhead lines to underground cable systems are discussed along with the need to consider the effect of auto re-closures on the protection system and the voltage rise due to the Ferranti effect. Switching and Harmonic resonance along with Mitigation of magnetic fields are discussed. Finally, the life time expectancy and the real importance of testing during commissioning to demonstrate reliability of the circuit is clearly much more important for these long length systems.

Chapter 3 - System Design aspects are addressed. There is brief comparison of AC - DC and then a discussion about the reactive compensation and cable sheath bonding arrangements that are the two essential factors to be considered for AC systems.

Because there is now a need to consider very large conductor cables the important aspects of thermomechanical forces and their compensation is also discussed.

Part of the chapter addresses EMF and the maintenance of circuit ratings which often requires use of different cables and installation arrangements along the route.

Finally, future trends such as reduction in frequency or new materials are discussed.

Chapter 4 - Installation - whilst is acknowledged that installation aspects are very well covered in other CIGRE Technical Brochures it was consider that we needed to address this subject in some detail because it is one of the most expensive part of any long length cable projects and therefore readers of this TB need to understand the importance of this topic.

It is also important to discuss the steps that need to be taken in route planning and then explain the three types of cable installation being:

1. Rigid Constrained
2. Semi Flexible Constrained
3. Flexible constrained

Attention is given to transportation of drums which is one of the most significant factors because to limit the number of joints, very long cable lengths are preferred, which often presents a significant problem in remote areas and in major cities. •••

Then there are examples of the possible testing requirements after installation and quality assurance requirements which again have a greater impact when considering long length circuits

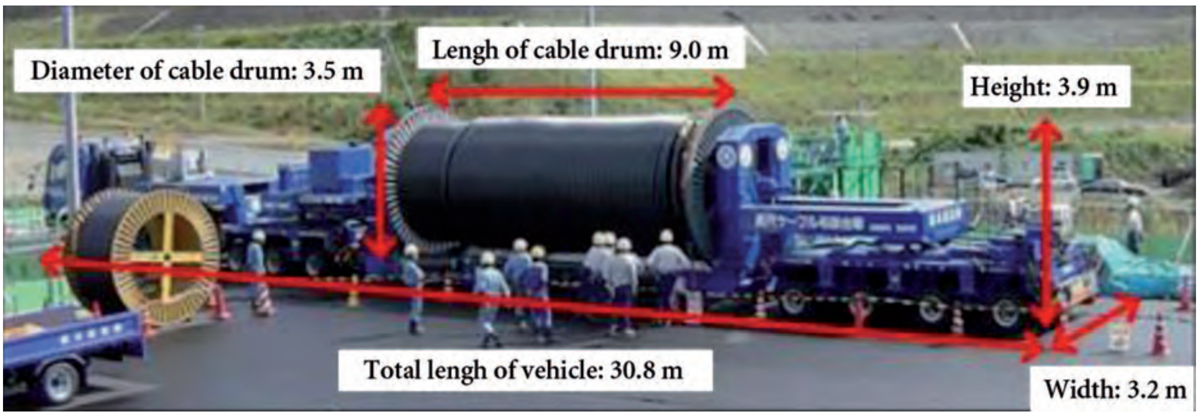
Chapter 5 - Monitoring - significant developments have been made in systems for monitoring the condition of cable circuit both in Underground and subsea cables. Distributed Temperature Sensing (DTS) systems are now available for monitoring of long cable lengths and this technology is considered very important for long length AC cable circuits as it enables "On line" – "Real time" condition assessment as well as very fast and accurate fault location.

We discuss the various systems with references to appropriate CIGRE documents and highlight developments in other monitoring systems, for strain, Sheath Voltage Limiters (SVL's), sheath condition assessment, Partial Discharge (P.D.) and Time Domain Reflectometry (TDR).

Chapter 6 - Maintenance - this is clearly an important topic for both land and submarine cables because if a fault occurs then the circuit needs to be put back in service as quickly as possible. However, the process is slightly different for these two situations so that land and submarine maintenance and fault location are discussed separately.

Chapter 7 - Examples of world experience - includes a short summary of long length HV & EHV cable links in 11 of the countries that were provided by members of this WG. The examples are representative of the 81 that are documented in Chapter 8 and include both land and submarine cable links to show what has been done.

Chapter 8 - Statistics of long length HV AC Cable Projects - these are shown graphically in this section •••



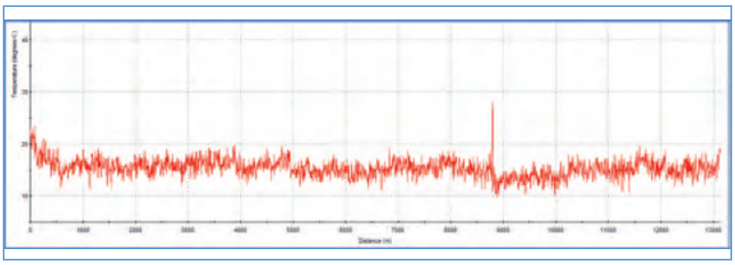
Essais HT sur site par résonance

Voltage Level	Number of System	Cable Length (per circuit)	Total cable length in system
U0 ≤170kV	36	2446 km	3222 km
170kV≤ U0 ≤380kV	34	1298 km	1860 km
U0>380kV	11	367 km	563 km
TOTAL	81	4111 km	5645 km

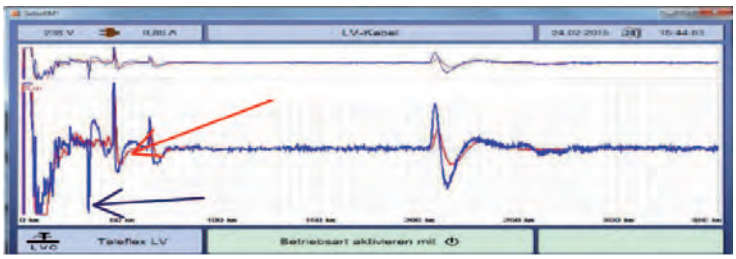
Conclusion

From the information provided in this Technical Brochure it can be seen, that it is practical to build long lengths AC Cable links for a wide range of power transfer requirements. Currently 110 km is the about the longest length installed but we can expect to see longer lengths installed in the future. However, it needs to recognised that each link is unique so that in each case, system design modelling needs to be done to confirm practicality and ensure compatibility with the network.

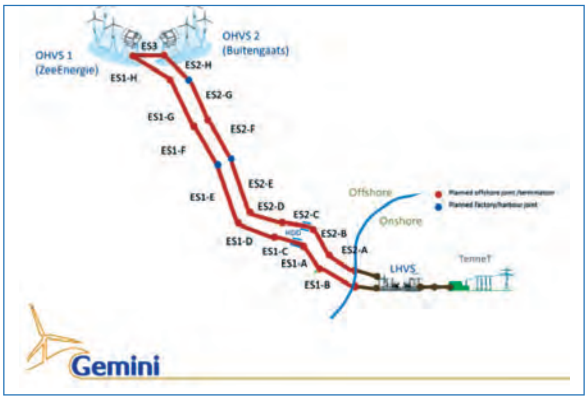
Secondly to reduced risks of failure in service there needs to be a very good quality assurance plan including onsite testing at commissioning where ever possible and at the same time a monitoring system must be implemented. The later, being very important because the link may •••

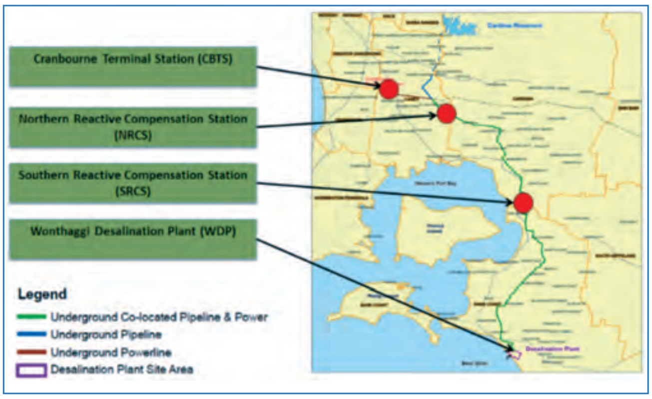


DTS trace showing hotspot



TDR trace showing Fault location





Outside: Country, number of projects
Inside: Continental repartition

include cable and accessories installed in very different environmental conditions and or by different methods. Finally, a fully developed plan for fault location and repair must be prepared which will include supply of cable, accessories, specialised equipment or services and a rapid response team to implement the repair. ■

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