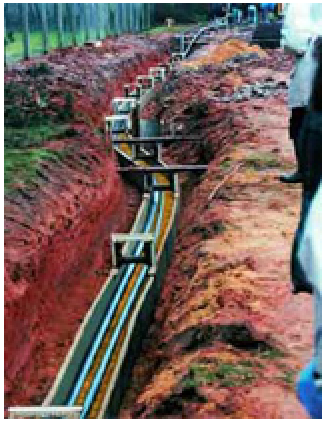
Issues related to long lenght HVAC cables Implementation and practical experience



RELIABILITY of SUPPLY

WG B1.47

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WETS'15 Workshop

Organization: Jicable and Prospective 21OO
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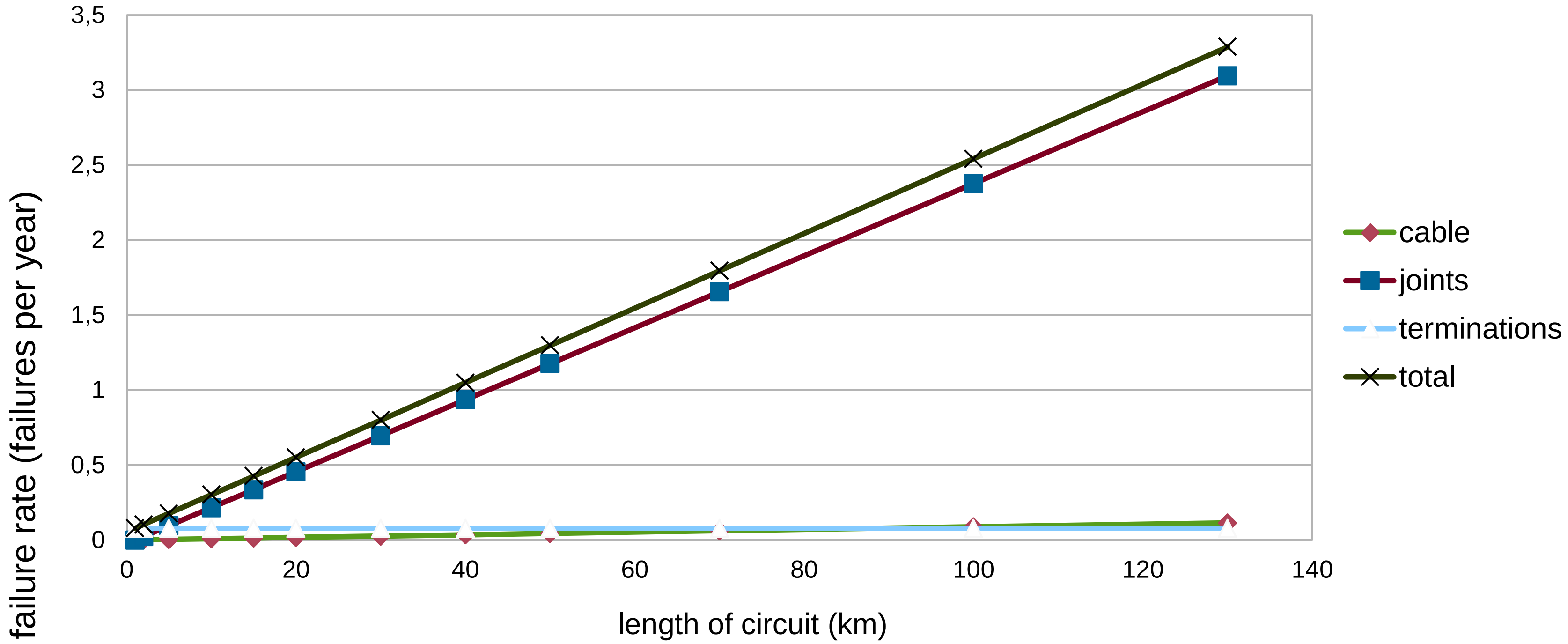
Long AC Cable links - Circuit Reliability

- **Reliability is a mixture failure / defect and length of outage**
  - **Causes extra costs to fix**
  - **Can cause blackouts**
- **Failure (some effect reliability more than others):**
  - **Some cause forced trip, others require outages**
  - **Some cause safety concerns that lead to outages on other circuits for checks**
  - **Generally single circuit, but can be double circuit, or worse**
- **Defects, generally less problematic than failures but:**
  - **Design defects may require widespread system outages to fix**
  - **Hidden defects can be worse than a failure (some become a failure only when the system is already depleted e.g. London blackout, Auckland blackout...)**
- **time of outage**
  - **Length of outage following failure or to repair defect**

Published failure rates CIGRE TB 379

- **No universal failure (or defect) definition. Can be system focused (causes outages), function focused (system stops performing function), or other (requires replacement)**
- **CIGRE TB 370 Text:**
  - **1. Instantaneous failure leading to automatic disconnection**
  - **2. Occurrence requiring subsequent unplanned outage**
- **CIGRE TB 370 questionnaire:**
  - **TB 370 did not publish the questionnaire so it is not clear what the actual definition used was**
- **CIGRE TB 370 results**
  - **Internal faults**
  - **External faults**
- **For the next slide just used overall reported failure rate for XLPE land cables with voltage 60 kV to 500 kV (but what does the rate really means?)**

Failure rate of a cable circuit



Impact of long lengths

- **As cable circuits increase in length they will be more unreliable as they have more cable and joints**
- **CIGRE statistics suggest that the joints are more problematic than cable**
  - **For submarine cables with longer cable sections this will be less of a problem**
- **Safety will not be a greater concern for buried cables (same number of terminations as short routes)**
- **Tunnel installations suffer**
  - **Potential for multiple circuit failures (e.g. fire)**
  - **Failure of one component leading to limited access due to safety**

CIGRE TB 379 Repair Times

Table 15d Average repair time – mode of land installation

Average Repair time in Days per Mode of Installation		
>1day and <6months	Direct Burial	Ducts/Troughs/Tunnel
60 to 219 kV	14	15
220 to 500 kV	25	45

Introduction to Long length AC Cable systems

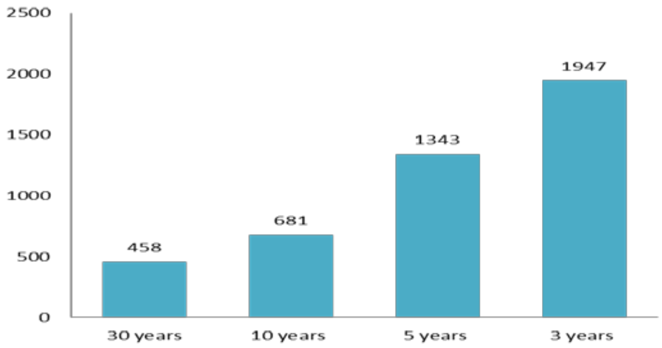
Why is there now such a significant interest in Long Length AC transmission Power Transmission by insulated cables. Some of the reasons being:-

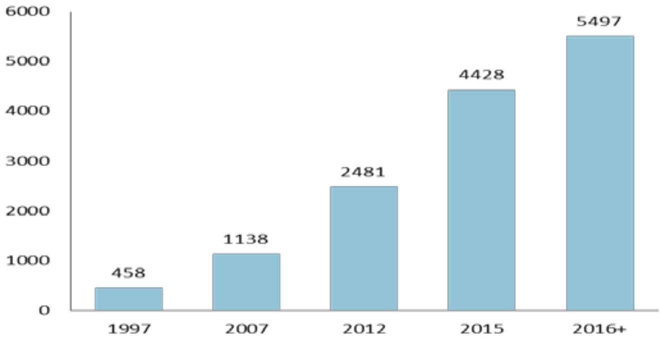
- **Now very possible with new cable designs and materials**
- **Need to transfer power from renewable energy sources to the grid in the most economical manner**
- **Need to provide electric power to remotely located plants**
- **Often there are difficulties in obtaining approvals for OHL**
- **Offers quicker implementation time than using OHL**
- **Now lower cost differential between Underground and OHL**
- **Need for lower system/network – power losses**
- **Environmental issues and community support**
- **IMPROVED RELIABILITY**

Progress with the introduction of long length AC cable links

- The definition of **A long length of insulated cable:-**
  - is one where the load due to the capacitive current needs to be taken into account in the system design.
  - typically this would be 40 km for voltages less than 220 kV and 20 km for voltages above 220 kV.

Years		Period	Projects	Links km	Cable km
1967	1997	30 years	13	398	458
1997	2007	10 years	12	537	681
2007	2012	5 years	20	1122	1343
2012	2015	3 years	22	1349	1947
2015	2016+	From 2015	13	556	1069
Total			**80**	**3962**	**5497**





Cable circuit km – 50 years from 1967 – 2017

CURRENT STATE of DEVELOPMENT
Reasons for Growth in demand

- **Possible 50 years ago but now more practical with new cable designs, materials, accessories & installation methods**
  - **Improved overall performance of cables and accessories**
  - **Cost of supply and installation significantly lower**
  - **Availability of Monitoring systems**
  - **Net effect is improved reliability of supply**
- **Transfer power from renewable energy sources to the grid**
  - **Demand for offshore wind farms**
  - **Limited space on Offshore platforms for other options**
- **Need to provide electric power to remotely located plants**
  - **New Mine sites, Desalination plants**
  - **Need for lower network losses – net effect on energy cost**
- **Difficulties in obtaining approvals for Overhead Lines (OHL)**
  - **Quicker implementation time than using OHL**
- **Environmental factors**
  - **Climatic conditions and security of supply**

CURRENT STATE of DEVELOPMENT
Modern Cable & Installation Technology

➢ HVAC Cable design

- **Significant improvements made in Fluid Filled cables**
  - **However manufacturing, installation and maintenance costs are now generally higher than for XLPE cable systems.**
- **Modern XLPE cables**
  - **Lower dielectric losses than the older fluid filled cables**
  - **Operating temperature of XLPE cable is higher.**
  - **Net result is ratings much improved**
  - **These cables can be made and installed in long lengths**
  - **No concerns about changes in ground level and oil pumping**
- **Significant experience in manufacture of XLPE cables & accessories.**
  - **There are now more than 100 cable plants worldwide making HV & EHV AC cables**

CURRENT STATE of DEVELOPMENT

Advances in associated equipment and overall reliability of supply

- **Associated Equipment**
  - **Joints & Terminations**
    - **Premoulded i.e. prefabricated**
  - **Surge Arrestors & SVL's**
    - ***Z*nO**
  - **Reactive Compensation**
    - **Reactive power compensation devices – low losses**
  - **Harmonic Filters**
    - **Required for long AC links connected to the grid**
- **Reliability of Supply**
  - **Prequalification test**
    - **Well established requirements**
  - **Site Testing**
    - **New low frequency devices can test long lengths of AC cable**
  - **Monitoring**
    - **Inclusion of Optical fibre in Cable > 30 years experience**

CHALLENGES for IMPLEMENTATION

- **Effect on the grid**
  - **Matching ratings .**
- **Protection systems**
  - **Auto reclosing as used on OHL**
- **Voltage effect**
  - **Ferranti effect - mitigation**
- **Harmonics**
  - **Filters**
- **Mitigation of EMF**
  - **Installation arrangement**
- **Life time expectancy**
  - **Reliability – monitoring .**

Monitoring – ON LINE real time provides reliability of supply

- **Partial Discharge**
  - **P.D, sensors at joint locations**
    - **Normally for commissioning only**
- **Temperature – Distributed Temperature Sensing**
  - **Well established technique using Optical fibres within the cable is now available for very long lengths**
- **Monitoring of Condition of SVL's in Link boxes**
  - **Now being done for some circuits**
- **Monitoring of sheath condition**
  - **Sheath condition monitoring systems beginning to be developed**
- **Monitoring of possible cable disturbance**
  - **New systems using Optical Fibre cables can detect acoustics**
  - **AIS systems for submarine cables in use.**

Maintenance and Impact on Reliability

- **Route information**
  - **Now available in GPS format**
- **Fault location systems**
  - **Land & submarine options**
- **Rapid repair options**
  - **Land & Submarine solutions developed**

Long length AC links by Country

No	Country	Number of Links	Circuit Length km	Cable length km
1	Australia	2	116	116
2	Belgium	2	94	94
3	Canada	2	76	114
4	China	1	32	32
5	Denmark	5	308	355
6	France	6	214	279
7	Germany	4	229	229
8	Italy	2	173	221
9	Japan	9	267	590
10	Korea	1	22	66
11	Netherlands	2	122	244
12	Norway	4	399	399
13	Saudi Arabia	5	246	317
14	Spain	5	296	422
15	Sweden	3	162	162
16	Tanzania	1	75	75
17	Thailand	1	55	55
18	Tunisa	1	25	25
19	Qatar	1	102	203
20	United Emirates	1	42	42
21	U.K.	14	646	1157
22	U.S.A.	7	207	245
23	Vietnam	1	56	56
	Total	**80**	**3964**	**5498**

* Projects commissioned since 1967 or planned to be in commission by 2019

Long Length AC links by Voltage

Cable Voltage	No of Links	Total km	
		Link	Cable
>33 kV <170 kV	35	2299	3075
>170 kV <380 kV	34	1298	1860
>380 kV <525 kV	11	365	562
Total	**80**	**3962**	**5497**

Summary of some of the challenges for Implementation

- **Cable Design**
  - **Choosing the best cable design for a LONG LENGTH AC Link**
- **System design issues**
  - **Selecting the best voltage**
  - **Consider frequency of supply e.g. 60, 50 or 16 Hz.**
  - **Matching the power rating for hybrid circuits**
  - **Acceptance of cyclic ratings – thermal delay for cables**
  - **Protection system arrangements - Cable vs. OHL,**
  - **Controlling EMF - easier for cable than OHL ,**
  - **Controlling future changes in route to ensure circuit rating**
  - **Amount of reactive compensation - location**
  - **Impact on other network components**
  - **Sheath bonding for long lengths – acceptance of voltage levels**
  - **Reliability - repair times for underground cable**

Summary of challenges for Implementation (cont.)

- **Installation**
  - **Rights of way.**
  - **Remote areas – transportation issues**
  - **Inductive coupling with OHL – safety**
  - **Thermal mechanical forces from long straight cable lengths**
  - **Commissioning – Testing- voltage & frequency.**
- **Monitoring**
  - **Long distance Distributed Temperature Sensing with OFC**
  - **Monitoring of Sheath Link box SVL's**
  - **Sheath condition monitoring.**
  - **Control of route condition AIS and Acoustic**
- **Maintenance**
  - **Fault location methods and automation**
  - **Access to route information – GPS data**
  - **Methods to reduce repair times - outage in case of cable damage**