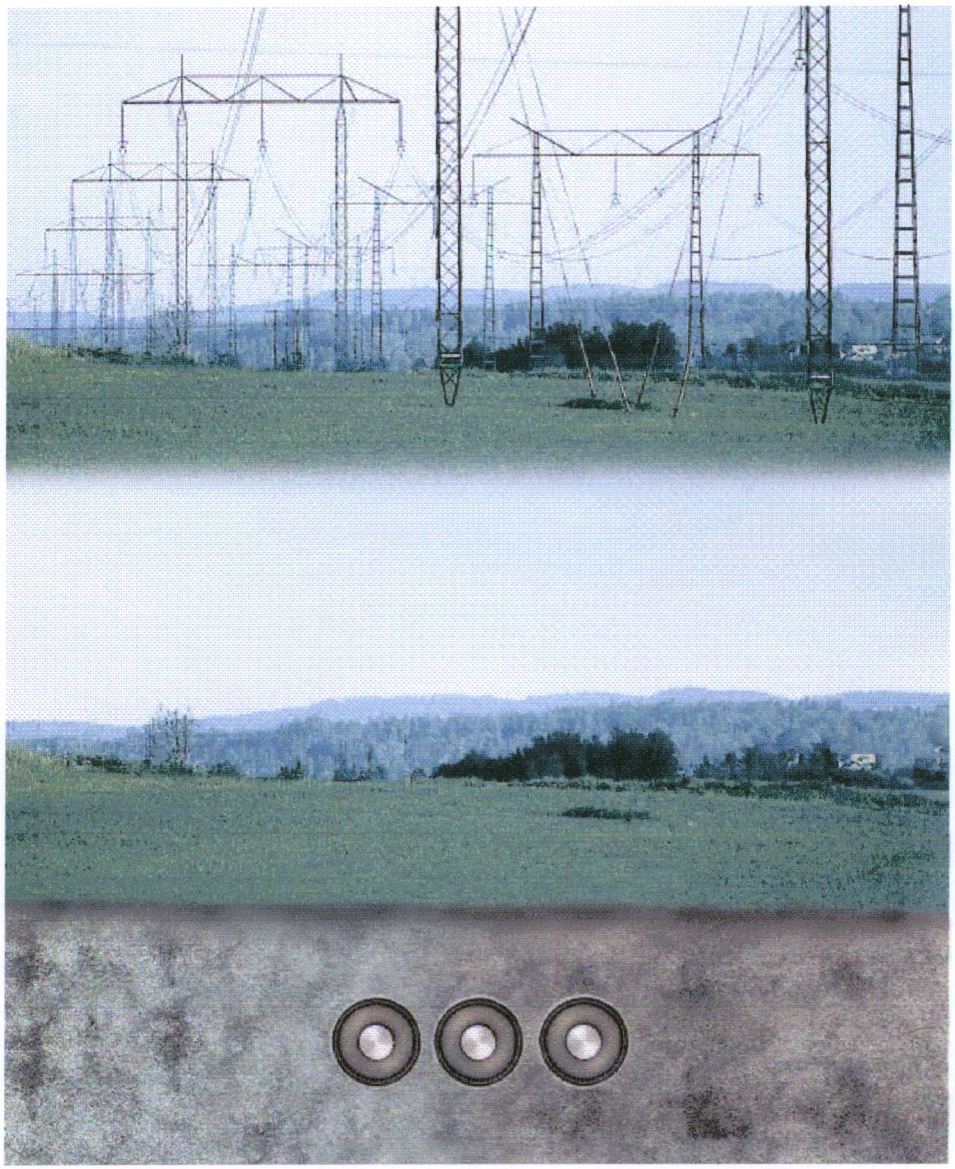
Invisible Power



ABB

Actions for a better environment

Tomorrow's technology is here – ABB Cable System Solutions. By selecting an effective Cable System Solution numerous drawbacks related to traditional overhead transmission technology can be eliminated, not least the esthetic ones. Overhead lines can now be replaced by underground cables at comparatively low cost, in some cases only a few times higher than for an overhead transmission system. The difference is reduced if one takes into account such factors as maintenance costs, system losses and renovations. Furthermore, congested areas benefit from an ABB Cable System Solution as land formerly occupied by an above ground system can now be utilised for other things.

Reliable systems on a deregulated market

The deregulation of the electricity market has changed the parameters for the electrical trade. This has led to a different approach regarding operational and maintenance costs for generation, transmission and distribution systems.

Future grids have to be reliable, environmentally friendly, cost efficient and have a low visual impact. Due to deregulation it is very likely that operational margins in the industry will increase.

ABB's Cable System Solutions are based on our XLPE, cross-linked polyethylene, cable which meets the comprehensive requirements of International standards and specifications as well as those of our customers.

We offer our customers:

- Cost and technically efficient cable system solutions
- Environmentally friendly cable system solutions

Power XLPE cables versus Power Lines; a comparison

A comparison between Power XLPE cables and Power lines is a valuable one to make before a permit application is submitted for upgrading an existing system or planning a new one. Such an analysis should immediately reflect the differences and similarities between the systems and it is very likely that the new infrastructure will gain from an underground cable system.

Advantages of an underground XLPE cable transmission system

Environment

- Little or no visual impact
- No electrical fields and low magnetic fields
- High safety - no risk of fallen overhead lines
- No external corona discharges

Grid Security

- Not effected by rain, ice, snow, fog or dust

Economy

- No maintenance requirements
- Lower power losses
- Less land used
- Higher value for buildings and the surrounding land

Operation

- Higher reliability, fewer faults
- Higher short term overload capacity

Due to improved production process, material cleanliness and handling systems, the manufacturing of XLPE cables of today has been optimised both regarding quality as well as cost.

XLPE Cable Systems - an improved technology

The product development of extruded cables has accelerated during the last decade. The combination of new product technology and advanced material technology already yield cable system solutions for a new infrastructure.

Triple extrusion (inner conducting shield, insulation and outer conducting shield processed in one sealed operation) and dry vulcanisation (no water or steam during vulcanisation) together with improved material cleanliness and handling systems are the key success factors for the extruded cable performance of today.

The result of this development is that extruded insulation can withstand much higher stresses than was believed possible at the start in the early 70s when the design criterion was established.

Extruded transmission cables can be made with thinner insulation than before without jeopardising the performance of the cables.

These so called lean extruded cables enable installations of longer cable lengths with fewer joints. Therefore more cost efficient and simpler installation methods can be used with this type of cable.

World class system solutions

ABB has manufactured cables with polymeric insulation since the early 70s and is today a leading supplier of efficient, environmentally friendly high quality cable system solutions at all voltage levels.

Our products and systems can be found all over the world (over 85% of our turnover is exported).

Demands for environmentally friendly transmission/distribution system solutions are stronger today than ever before. In cooperation with other ABB companies with differing electrical specialities we are well prepared to meet the challenges of future demands.

A complete system

ABB does not only manufacture cables. We can supply turnkey solutions for the new deregulated market. Our environmentally friendly cable based systems have created new solutions for transformers, switchgear and compensation equipment whether they be installed indoors or underground. In all cases it means more land being made available and easier planning of city infrastructures.

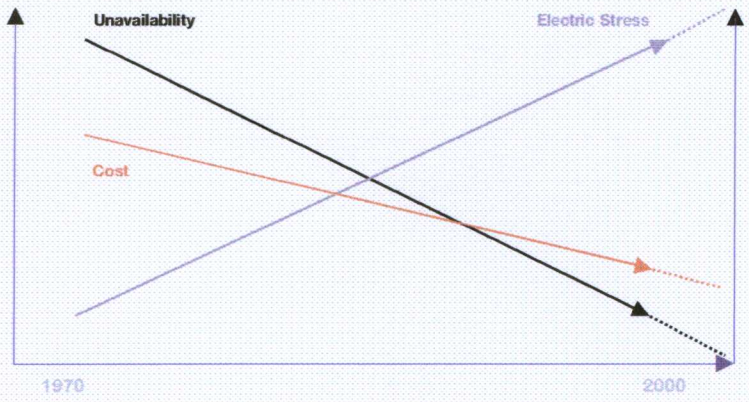
The right solution for you

We would like to assist you in finding the most optimal cable system solution. Not only complying with your requirements from a technical and environmental point of view but also supplying it at a reasonable cost.

We offer:

- System studies
- System optimisation
- Project management
- Guidance on permit application
- Civil works
- Installation, supervision and erection
- Testing and start-up operations
- Documentation
- Monitoring
- Financing (leasing, etc.)

XLPE Performance



1.2.6 MurrayLink, Australia

- Client need
Environmentally-friendly power link for power trading between two states in Australia.

- ABB response
200 MW HVDC Light® converters and 360 km (2x180 km) ±150kV HVDC Light® land cables.

- Summary – MurrayLink
MurrayLink is a 180 km underground 200 MW transmission between Red Cliffs, Victoria and Berry, South Australia. It links regional electricity markets and uses the ability of HVDC Light® technology to control power flow over the facility. The voltage source converter terminals can act independently of each other to provide ancillary services (such as var support and voltage control) in the weak networks to which it is connected. Operating experience is that its AC voltage control considerably improves voltage stability and power quality in the connected networks. In addition, shunt reactors in neighboring networks can normally be disconnected when the link's AC voltage control is on.

On loss of an AC line there is a runback from 200 MW to zero.

The project has won the Case EARTH Award for Environmental Excellence.

Cable transport for Murray Link project

Cable laying for MurrayLink project

2 Applications

2.1 General

A power system depends on stable and reliable control of active and reactive power to keep its integrity. Losing this control may lead to a system collapse. Voltage source converter (VSC) transmission system technology such as HVDC Light® has the advantage of being able to almost instantly change its working point within its capability and control active and reactive power independently. This can be used to support the grid with the best mixture of active and reactive power during stressed conditions. In many cases a mix of active and reactive power is the best solution compared to active or reactive power only. VSC transmission systems can therefore give added support to the grid.

As an example, simulations done at ABB have shown that for a parallel case (AC line and DC transmission) where the VSC transmission system is connected in parallel with an AC system, the VSC transmission system can damp oscillations 2-3 times better than reactive shunt compensation. The benefits with a VSC transmission system during a grid restoration can be considerable since it can control voltage and stabilize frequency when active power is available in the remote end. The frequency control is then not limited in the same way as a conventional power plant where boiler dynamics may limit the operation during grid restoration.

With the above benefits HVDC Light® is the preferred to be used for a variety of transmission applications, using Submarine cables, Land cables and back-to-back.

2.2 Cable transmission Systems

2.2.1 Submarine Cables

- Power supply to islands

The power supply to small islands is often provided by expensive local generation e.g. diesel generation. By installing an HVDC Light® transmission electricity from the main-land grid can be imported. Another issue is the environmental benefits to the island by reducing emission from local generation.

Since HVDC Light® is based on VSC technique the converter can operate without any other voltage source on the island i.e. no local generation on the island is needed for proper operation of the system.

- Remote small-scale generation

Many times remote small-scale generating facilities are located on islands that will not need all the generated power at all situations, which can then be transmitted by HVDC Light® to a consumer area on the mainland or an adjacent island.

- Interconnecting power systems

The advantages of HVDC Light® are of high value when connecting between individual power systems, especially when they are asynchronous. This refers to the possibilities to control the transmitted power to an undertaken value as well as being able to provide and control reactive power and voltage in both the connected networks.

- Power to/from/between Offshore platforms

HVDC Light® made it possible with its small footprint and its possibilities to operate at low short-circuit power levels or even to operate with "black" network to bring electricity:

- from the shore to the platform
- from platform to shore
- between platforms

The most important and desirable characteristics for offshore platform installation are the low weight and volume of the HVDC Light® converter. Offshore, the converter is located inside a module with controlled environment, which makes it possible to design the converter even smaller for an offshore installation than for a normal onshore converter station.

2.2.2 Underground cables

- Interconnections

The environmental advantages of HVDC Light® are of high value when connecting between two power systems. This refers to the possibilities to control the transmitted power to the desired value as well as being able to provide and control reactive power and voltage support in the connected networks to improve AC network stability. Other important factors are: avoiding loop flows, sharing of spinning reserve, emergency power etc.

The fast AC voltage control by HVDC Light® converters can also be used to operate the connected AC networks close to its maximum permitted AC voltage and by that reduce the line losses in the connected AC networks.

- Bottlenecks

In addition to the power transmitted by the HVDC Light® system, an HVDC Light® transmission in parallel with an existing AC line will increase the transmitting capacity of the AC line by the inherent voltage support and power stabilizing capability of the HVDC Light® system.

- Infeed to cities

Adding new transmission capacity by AC lines into city centers is costly and in many cases the permits for new ROW are difficult get. An HVDC Light® cable needs less space than an AC overhead line and can carry more power than an AC cable and is therefore many times the only practical solution, should the city centre need more power. Also the small footprint of the HVDC Light® converter is of importance for realizing city infeed. Another benefit of HVDC Light® is that it does not increase the short-circuit current in the connected AC networks.

2.2.3 Aerial Cables.

Since HVDC Light® Land Cables have low weight/m it is possible to install the land cables hanging in poles if found better than burying the cables.

2.3 Back-to-back

A back-to-back station consists of two HVDC Light® converters located close to each other i.e. with no DC cables in between.

2.3.1 Asynchronous Connection

If the AC network is divided into different asynchronous areas connection between the areas can easily be done with HVDC back-to-back converters. This gives a number of advantages:

- Sharing of spinning reserve.
- Emergency power exchange between the networks
- Better utilization of installed generation in both networks
- Voltage support
- Etc

In many cases the connection between two asynchronous areas is made at a weak connection point in AC systems on the borders of the areas. HVDC Light® is very suitable with its possibilities of operating at low short-circuit ratios for this type of connection.

2.3.2 Connection of important loads

For sensitive loads an HVDC Light® back-to-back system is of importance for keeping the AC voltage and AC frequency on proper levels if the quality of those properties of the connected AC network is not sufficient for the connected load. The fast reactice power control properties of HVDC Light®, can be used for flicker mitigation.

2.4 HVDC Light® and wind power generation

HVDC Light® is a transmission system which has characteristics suitable for connecting large amounts of wind power to networks, even at weak points in a network and without having to improve the short-circuit ratio.

This is contrary to conventional AC transmission systems, which normally require a high SCR compared to the power to be entered. With big wind power farms coming along and becoming a considerable share of the total power generation in a network, wind power farms will have to be as robust as conventional power plants and stay online at various contingencies in the AC network. Various types of compensation will then be needed to preserve power quality and/or even the stability of the network.

HVDC Light® does not require any additional compensation, as this is inherent in the converters. It will therefore be an excellent tool for bringing wind power into a network

2.5 Comparison of AC, conventional HVDC and HVDC Light®

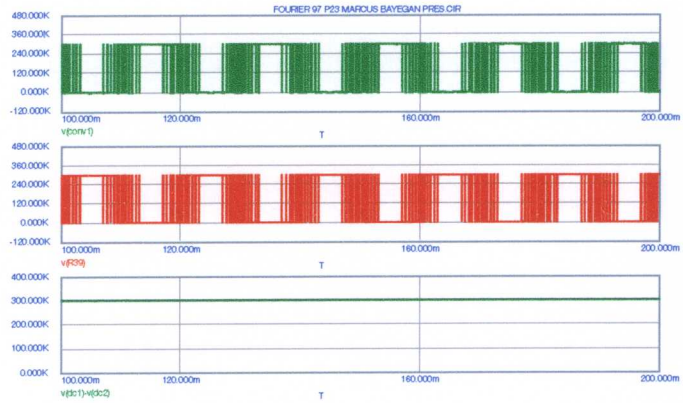
- Comparison DC Cable system and AC Cable system

DC Cable system

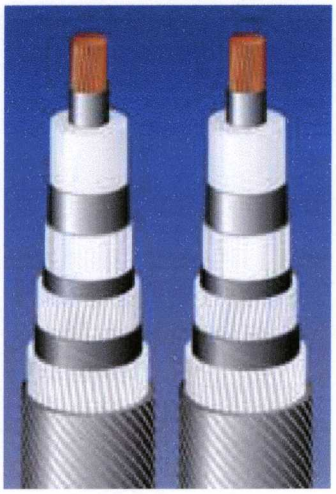
- No limit on cable length
- No intermediate station needed
- No increase of capacitance in the AC network (avoids low order resonances)
- DC voltages mean less aging and longer cable life

AC Cable system

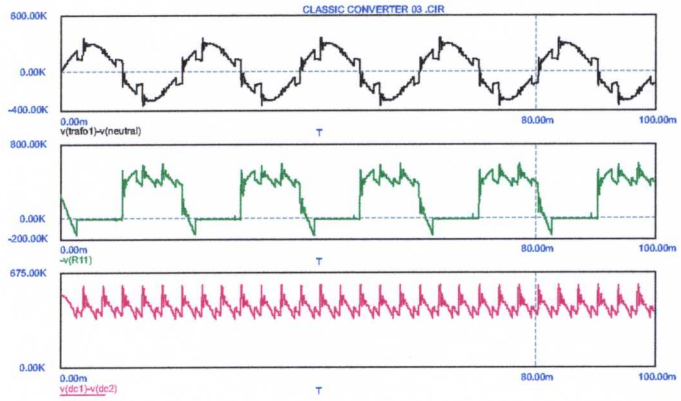
- Cable capacitance limits the practical cable length
- Reactive compensation is needed



- Upper trace: Reactor voltage
- Middle trace: Valve voltage
- Lower trace: DC Voltage



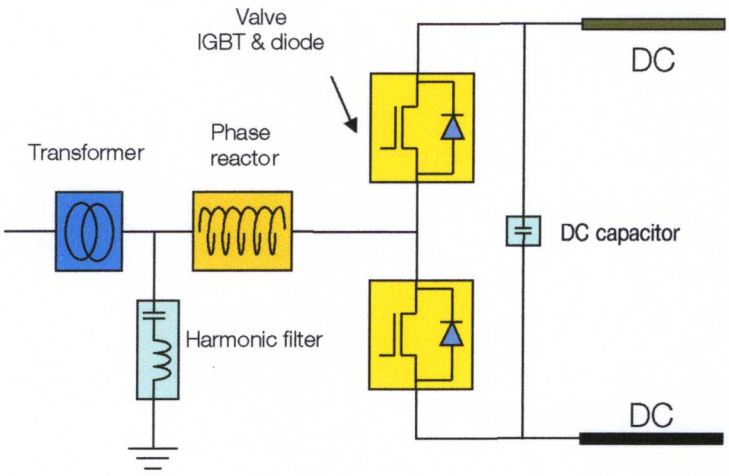
HVDC Light® deep sea cables



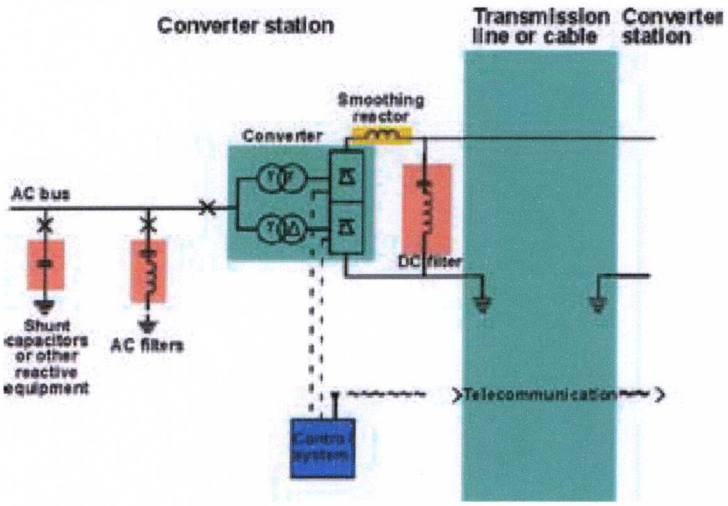
- Upper trace: Transformer voltage
- Middle trace: Valve voltage
- Lower trace: DC voltage

Mass impregnated HVDC cable

- **Simplified single-line diagram for HVDC Light®**



- **Simplified single-line diagram for conventional HVDC**



Moderate climate, submarine cables with copper conductor

Area	Ampacity		80 kV cable bipole				150 kV cable bipole				300 kV cable bipole			
Con-ductor	Close laying	Spaced laying	Close laying	Spaced laying	Weight per cable	Diam. over cable	Close laying	Spaced laying	Weight per cable	Diam. over cable	Close laying	Spaced laying	Weight per cable	Diam. over cable
mm²	Amps	Amps	MW	MW	kg/m	mm	MW	MW	kg/m	mm	MW	MW	kg/m	mm
95	343	404	55	65	4,7	42	103	121	8,5	60	206	242	15	90
120	392	463	63	74	5,5	44	118	139	9,4	61	235	278	16	91
150	441	523	71	84	6,7	47	132	157	10	63	265	314	17	93
185	500	596	80	95	7,4	49	150	179	11	64	300	358	18	95
240	583	697	93	112	8,4	52	175	209	12	67	350	418	20	99
300	662	797	106	128	9,4	56	199	239	13	69	397	478	22	102
400	765	922	122	148	11	61	230	277	16	75	459	553	24	105
500	883	1072	141	172	13	66	265	322	18	78	530	643	26	108
630	1023	1246	164	199	15	71	307	374	21	83	614	748	30	114
800	1175	1438	188	230	17	76	353	431	24	88	705	863	33	118
1000	1335	1644	214	263	21	81	401	493	26	96	801	986	37	122
1200	1458	1791	233	287	24	85	437	537	29	100	875	1 075	40	126
1400	1594	1962	255	314	27	89	478	589	32	103	956	1 177	43	130
1600	1720	2123	275	340	30	92	516	637	35	107	1 032	1 274	47	133
1800	1830	2265	293	362	32	96	549	680	38	110	1 098	1 359	50	137
2000	1953	2407	312	385	35	99	586	722	41	113	1 172	1 444	53	140
2200	2062	2540	330	406	40	103	619	762	45	118	1 237	1 524	58	145
2400	2170	2678	347	428	42	106	651	803	48	121	1 302	1 607	61	148
2600	2275	2814	364	450	45	109	683	844	51	123	1 365	1 688	63	150
2800	2373	2937	380	470	48	111	712	881	54	126	1 424	1 762	67	152
3000	2473	3066	396	491	50	114	742	920	57	128	1 484	1 840	70	155

Sea soil: Temperature 15 deg.C, Burial 1.0 metre, Thermal resistivity 1.0 K x W /m
Cable: Copper conductor, HVDC polymer insulation, Steel wire armour

	Resistance	Voltage drop		Losses at 50% load		Losses at 100% load	
Copper Conductor	per phase 20 deg.C	Close laying	Spaced laying	Close laying	Spaced laying	Close laying	Spaced laying
mm²	ohm/km	V/km	V/km	W/m	W/m	W/m	W/m
95	0,193	66	78	6	8	27	38
120	0,153	60	71	6	9	28	39
150	0,124	55	65	6	9	29	41
185	0,0991	50	59	7	9	30	42
240	0,0754	44	53	7	10	31	44
300	0,0601	40	48	7	10	32	46
400	0,0470	36	43	7	10	33	48
500	0,0366	32	39	7	11	34	50
630	0,0283	29	35	8	12	36	53
800	0,0221	26	32	8	12	37	55
1000	0,0176	23	29	8	12	38	57
1200	0,0151	22	27	8	13	39	58
1400	0,0126	20	25	8	13	38	58
1600	0,0113	19	24	9	13	40	61
1800	0,0098	18	22	9	13	39	60
2000	0,0090	18	22	9	14	41	63
2200	0,0080	16	20	9	14	41	62
2400	0,0073	16	20	9	14	41	63
2600	0,0068	15	19	9	14	42	64
2800	0,0063	15	18	9	14	42	65
3000	0,0059	15	18	9	14	43	66

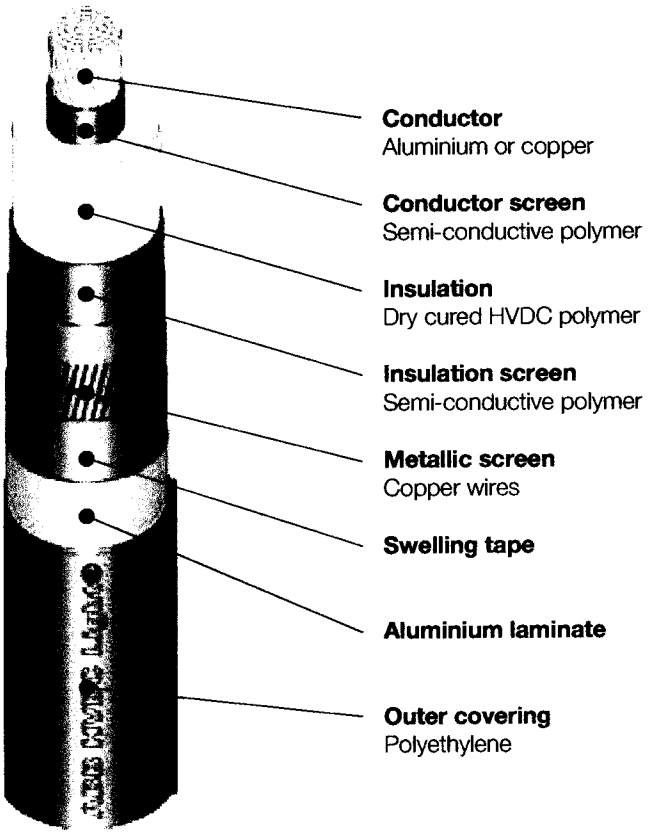
5.4 HVDC Light® Cables

5.4.1 Design

The cables are designed to meet the current and voltage ratings for the specified power transmission capacity and for the specified installation conditions.

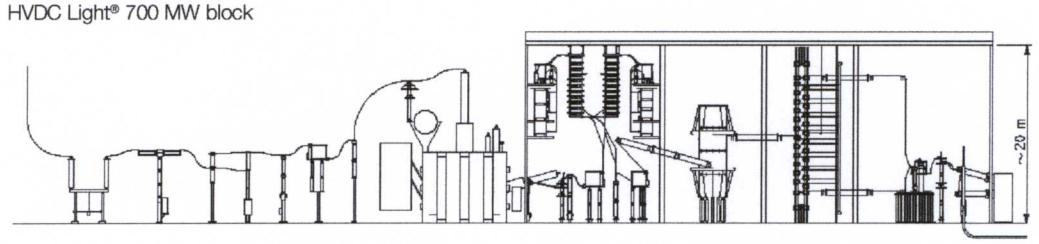
5.4.2 Land cable

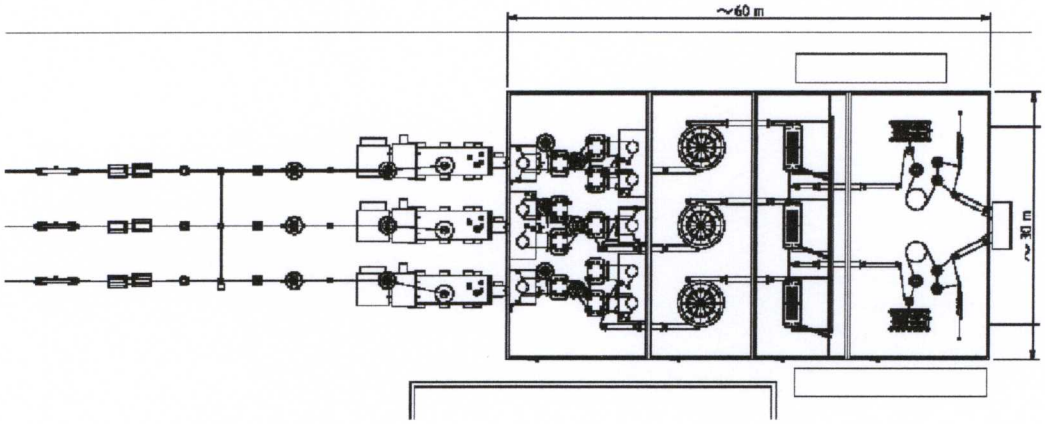
A general cutaway drawing of the land cable design is shown below

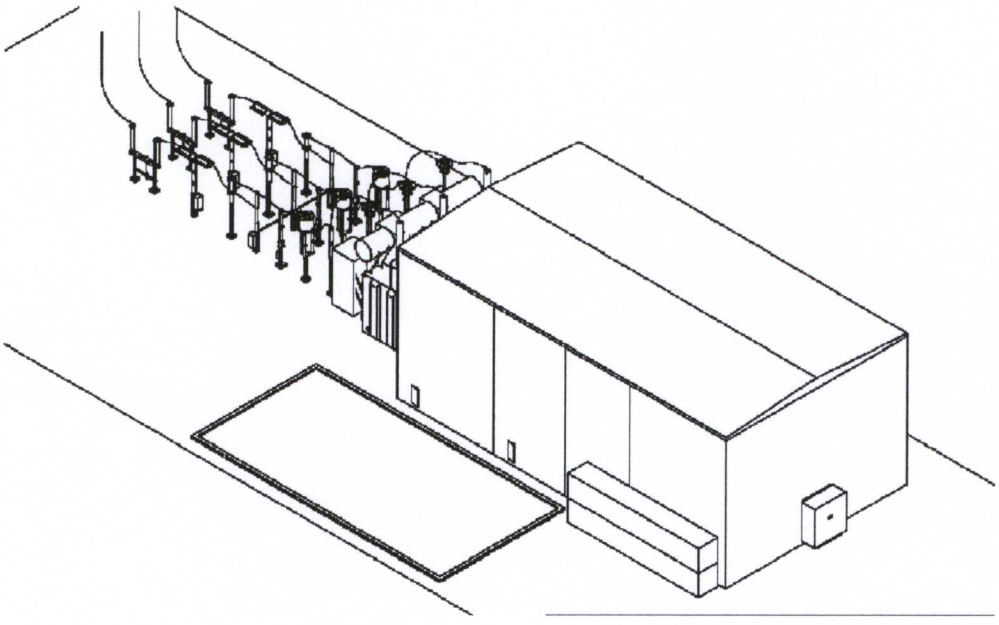


- Typical layout

HVDC Light® 700 MW block







Overhead power line hazards