Light, safe and effective

HVDC Light® cable systems are the future of power transmission

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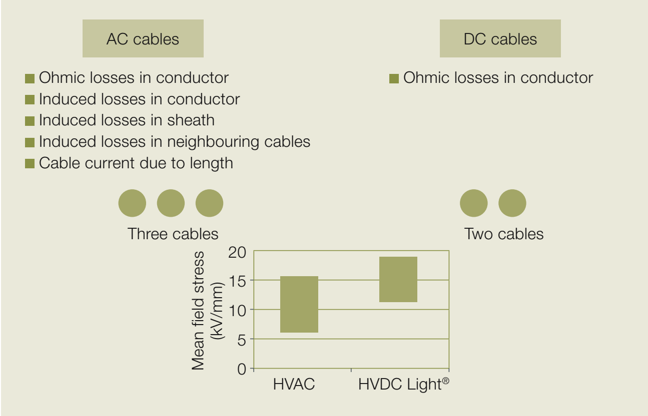
As the global population continues to grow, resources are becoming ever more stretched. Growing populations need more land as well as adequate electrical, water and communication services, and these must be provided in a way that complies with the now compulsory environmental regulations. For its part, the energy sector has been working hard to find safe and innovative ways of increasing power transmission in power corridors while keeping the environmental impact to a minimum.

One company particularly active in this area is ABB. Over the past number of years, the company has developed transmission capabilities that not only bring more power to the people, but it does so in a safe and invisible way. Using HVDC Light® cable, transmission systems are more compact, effective, require low maintenance and are environmentally friendly.

The earth's resources are becoming more and more limited. Building the infrastructure to satisfy growing population demands is fast becoming – if it already isn't – a critical issue. Whether they like it or not, energy, water and communication companies are now, more than ever, compelled to find ways of providing increased services using, in many cases, the same infrastructure in a more compact, effective and environmentally friendly way. The energy sector, for example, has been investigating ways of increasing power transmission in the already existing power corridors. Not only this but in the framework set by the European Commission in 2003 [1], electrical trade between member countries must be increased. Because this is currently underdeveloped compared with other sectors of the economy, a larger number of inter-connectors must be built, either on land or at sea.

1 Comparison between HVAC and HVDC Light® cables



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In any case, to meet the demands of a growing population and tightening regulations, many service providers are faced with three very important questions:

- How can the power per square meter of land usage be increased?
- How can the environmental effects with maintained or improved technology and/or reliability be reduced?
- How can the risks involved be handled?

Power transmission in the energy sector
Today most electrical power is transmitted with conventional alternating current (AC) because it is relatively simple to transform one voltage level to another. In rural areas, overhead lines are normally used for transmission over long distances while power cables are adequate for urban areas. Submarine AC cables are used for limited distances in seas and lakes.

However, AC transmission systems have some technical limitations, such as reactive power generation/consumption and no power flow control. Compensation techniques, such as FACTS devices, are used to limit the effects of reactive power generation/consumption. Additionally, when compared with overhead lines, AC cables have higher capacitive charging currents, thereby limiting their ability to transmit power over long distances. There are also environmental concerns regarding the electrical and magnetic fields surrounding overhead lines and AC cables.

These limitations can be eliminated if direct current (DC) transmission is used. A DC transmission system improves transmission capability, has lower losses and the transmission lengths are practically unlimited due to the elimination of the capacitive currents. Additionally, DC transmission is very environmentally friendly. However, since electrical power is generated as AC in a power station and delivered as AC to the consumers, a HVDC transmission needs AC to DC and DC to AC conversion at each end. Two main techniques, the conventional current source converter (LCC) and the voltage source converter (VSC), are used to do this.

2 Extruded HVDC Light® land cables

The main advantage of HVDC Light® cables over their HVAC counterparts is their reduced weight and dimensions, which result in a higher power density.

HVDC transmission and HVDC Light®
The classical HVDC technique (high-voltage direct current) was first introduced in Sweden in 1954 by ASEA. HVDC Light® is a relatively new power transmission technology developed by ABB in the 1990s. It is also known as "The invisible power transmission" since it is based on underground cables. The main advantage of HVDC Light® cables over their HVAC (high-voltage alternating current) counterparts is their reduced weight and dimensions, which result in a higher power density 1. In other words, the power that can be transported per kilogram of cable is higher for HVDC Light® cables than for HVAC cables. The main reasons for this are:

- HVDC Light® cables work at a higher electrical field stress, and because of this the cable insulation is thinner than that of HVAC cables.
- HVAC cable conductors must be dimensioned for skin effect losses, proximity effect losses, induced losses in screens and sheaths, and

in the case of submarine cables, induced losses in armouring. HVDC Light® cables have to be dimensioned only for their ohmic conductor losses.
- An HVAC cable system needs three cables whereas a HVDC cable system only needs two.

Polymer HVDC Light® cable systems 2 have been developed, installed and are in service on voltage levels from 80 kV to 150 kV. These installed systems cover power ranges from 50 MW [2] to 350 MW [3].

It is foreseen that the future demand for HVDC transmission and in particular HVDC cables will increase. The fact that long electrical power transmission can be built underground makes ABB's HVDC Light® system very attractive. Currently, the traditional market and technical driving force behind the use of HVDC cable systems is long distance submarine transmission, which is necessary especially if asynchronous networks need to be connected together[1)]. But the introduction of VSC and extruded polymer HVDC cables has created new market potential for HVDC Light® systems. For example, remote locations with weak networks can now be easily connected to, as can off-shore wind power[2)] [4], and oil and gas platforms [5]. "Undergrounding" has been identified as a strong market driver. The forces behind this include new and demanding European EMF standards, more difficult and time consuming "permission processes" for overhead lines (in particular in Europe), and increasing public opinion that solutions with higher aesthetic values are needed.

Overall, a robust HVDC Light® system is deemed a low maintenance and cost-effective solution.

More power on less land

A comparison between HVAC XLPE Cables, HVDC Light® cables and overhead lines for systems typically rated between 220 kV and 400 kV is shown in the Factbox. The width of the right of way (ROW) or affected width of the land is given in the same table.

In terms of power transmission, it can be seen from the table that a HVDC Light® system is approximately 25 to 30 times more compact than the corresponding overhead line system. If the power rating per kg of the two is also compared, then a HVDC cable system is about 15 to 25 times more effective.

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Reliability

The first commercial HVDC Light® cable system was installed in Sweden in 1999. A wind park at the southern tip of Gotland island was connected to the city of Visby, also located on Gotland, by an 80 kV, 50 MW connection. Since then many other projects have been realized, including the Estlink project, a 150 kV, 350 MW link [3]. In less than a decade, almost 1,500 km of HVDC Light® cables have been installed, with another 400 km on the way proving that HVDC Light® really is a mature and reliable technology. On top of this, approximately 500 cable joints are now in service. This can be compared to the more than 1,700 km of mass impregnated cables installed by ABB since 1953.

Factbox Comparing different cable transmission systems

	HVAC XLPE Cables	HVDC Light® Cables	Overhead line
220 kV rating	200–500 MVA	100–300 MVA (150 kV)	300–800 MVA
400 kV rating	400–1,000 MVA	300–1,000 MVA (320 kV)	500–2,000 MVA
Width of affected land	1–2 m	0.5–1 m	40–60 m
MVA/m for 220–420 kV	200–500 MVA/m	200–1,000 MVA/m	7.5–33 MVA/m

Installation

The relatively low weight, small dimensions – which enable a reduced number of joints – and robustness of HVDC Light® cables have a positive influence on installation costs, which constitute a significant part of the total investment cost. This, combined with newly developed land installation equipment, means that the cost ratios between overhead line systems and those based on HVDC polymer cables are – depending on the circuit length and conditions – comparatively low.

Nowadays, installation is aided by mechanized cable laying machines with wheel cutters and automated backfilling devices. Existing infrastructures often have defined soil compositions and installation is easier if boulders etc. can be avoided. In one project in Australia, HVDC Light® cables 3 were laid at a speed of one to three kilometers per day [6, 7]. This is possible only with HVDC Light® technology and lean HVAC XLPE cable designs.

HVDC Light® cables can be installed on land or at sea. Their relatively low weight and dimensions strongly influence the amount of cable that can be reeled up on one drum, or the amount that can be transported on a cable installation vessel.

Environmental effects

Besides the economical benefits of using less land for transmission systems in existing infrastructures, the environmental impact of using HVDC Light® is also reduced. For example,

Footnotes

1) Traditionally paper insulated cables are used for these kinds of connections.

2) One of the characteristics of HVDC Light® is its superior ability to stabilize the AC voltage at the terminals. This is particularly important for wind parks, where the variation in wind speed can cause severe voltage fluctuations.

3 Laying HVDC Light® cable in Australia: Transporting the large cable drums a. Preparing to lay the cable using a chain excavator (left) and refilling machine (right) b. A typical narrow cable trench with minimum environmental intrusion c.

an overhead line system routed through a forest results in a loss of CO_2 uptake because trees convert carbon dioxide from the atmosphere into carbon stored in the wood. In fact, a 400 kV line through a forest represents a loss of approximately 42 tons of CO_2 per km per year [7].

The earth's magnetic field originates from large convective DC currents in its interior. This natural magnetic field varies from between 30 to 60 µTesla for different latitudes on the earth's surface. The same type of magnetic field is produced by an HVDC Light® cable, and is not considered unhealthy to the human body. A DC cable will generate a magnetic field of between 5 and 10 µTesla one meter above the ground surface. This will then be superposed to the natural magnetic field of the earth, which is much the same as saying that the magnetic effect from a DC cable corresponds to travelling from the south to the north of the earth. This is not considered dangerous from a magnetic point of view. With regard to an AC field, a discussion has been ongoing and some precaution limits have been established in some countries, but as of yet, no definite conclusions have been reached.

In less than a decade, almost 1,500 km of HVDC Light® cables have been installed, with another 400 km on the way.

Safety

The laying and installing of cables along roads or other infrastructures is generally easier than in the countryside. Cable positions and locations can be defined according to the systems used to route roads or railways. National road and railway administrations normally have very good systems for doing this. In Sweden all roads have fixed coordinates in a GPS system, which means that other services like electrical and fiber cables can be positioned and logged in the same system. Hence, the risk for third-party damage is reduced. Additionally, an HVDC Light® system will reduce the short-circuit current to zero approximately 15–20 times faster than conventional AC lines and this will have a positive effect on the personal risks involved.

Non-invisible benefits

The use of extruded HVDC Light® cables for electrical transmission has several advantages. The most obvious is that cables that are laid underground make the electrical energy transport invisible. This together with the other advantages of using DC cables, such as environmental and safety related features as well as the ability to transfer electricity over long distances mean a more comfortable electrical transmission system is easier to obtain.

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Further reading

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