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HVDC Light - a new technology for a better environment

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1. Introduction

A new transmission and distribution technology, HVDC Light, makes it economically feasible to connect small-scale, renewable power generation plants to the main AC grid. Vice versa, using the very same technology, remote locations as islands, mining districts and drilling platforms can be supplied with power from the main grid, thereby eliminating the need for inefficient, polluting local generation such as diesel units. The voltage, frequency, active and reactive power can be controlled precisely and independently of each other. This technology also relies on a new type of underground cable which can replace overhead lines at no cost penalty.

Equally important, HVDC Light has control capabilities that are not present or possible even in the most sophisticated AC systems.

- **Connect small scale renewable power generation to a main AC-grid**
- **Feeding remote isolated loads from a main AC-grid**
- **Flexible transmission system**

A hundred years ago, the transformer and the three-phase system made it possible to transmit AC power efficiently and economically over vast distances and to distribute the power to a multitude of users.

Since then all aspects of transmission and distribution have developed by means of technical improvement and evolution. This AC transmission and distribution technology has made it possible to locate generating plants in optimum locations, and to utilise them efficiently. This has also resulted in great environmental gains. Thermal plants have been located where they can be supplied with fuel through an efficient transportation system, thereby reducing waste and pollution. Hydro plants have been located where the hydro resources can be used at the greatest advantage. And large generating plants have meant fewer overhead lines than a multitude of smaller generating plants would have required.

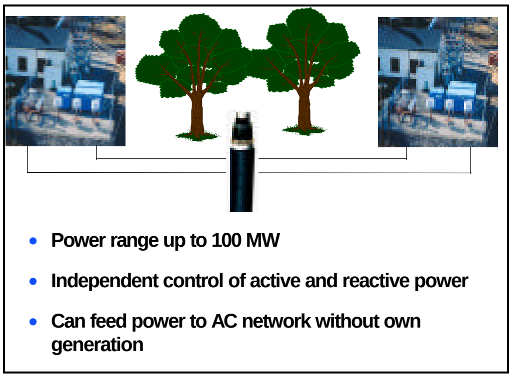
However, today's AC transmission and distribution systems are, at least in principle, based on ideas that haven't changed much since a hundred years ago: to generate power, step up the voltage with transformers, transmit power, step down the voltage and distribute power. Despite their proven advantages, it is difficult and expensive to adapt AC transmission and distribution systems to the numerous small-scale generating plants that are being built, or to the increasingly complex and variable production and load demands. Environmental concerns and regulations also put heavy restrictions on building new right-of-ways and on small-scale, fossil-fuelled generating plants, such as diesel generating plants.

These new trends require networks that are flexible. The networks must be able to cope with large variations in load and frequent changes in productions patterns, as well as with tougher environmental regulations. Also, in such flexible networks, the power flow and the voltages require precise control in order to make the grids stable and economical.

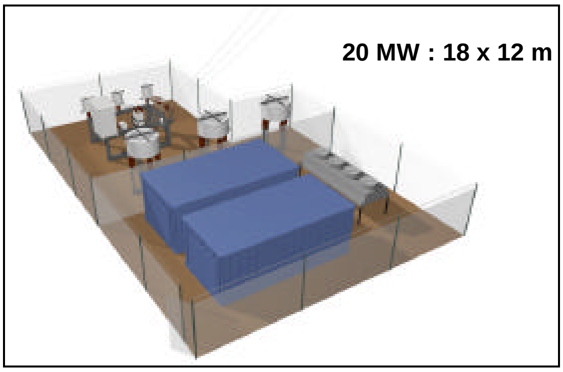
2. Technology

As its name implies, HVDC Light is a dc transmission technology. However, it is different from the classic HVDC technology used in a large number of transmission schemes. Classic HVDC technology is mostly used for large point-to-point transmissions, often over vast distances across land or under water. It requires fast communications channels between the two stations, and there must be large rotating units - generators or synchronous condensers - present in the AC networks at both ends of the transmission.

HVDC Light consists of only two elements: a converter station and a pair of ground cables. The converters are voltage source converters, VSC's. The output from the VSC's are determined by the control system, which does not require any communications links between the different converter stations. Also, they don't need to rely on the AC network's ability to keep the voltage and frequency stable. These feature make it possible to connect the converters to the points bests suited for the AC system as a whole.



The converter station is designed for a power range of 1-100 MW and for a dc voltage in the 10-100 kV range. One such station occupies an area of less than 250 sq. metres (2 700 sq. ft), and consists of just a few elements: two containers for the converters and the control system, three small AC air-core reactors, a simple harmonics filter and some cooling fans.



The converters are using a set of six valves, two for each phase, equipped with high-power transistors, IGBT (Insulated Gate Bipolar Transistor). The valves are controlled by a computerised control system by pulse width modulation, PWM. Since the IGBTs can be switched on or off at will, the output voltages and currents on the AC side can be controlled precisely. The control system automatically adjusts the voltage, frequency and flow of active and reactive power according to the needs of the AC system.

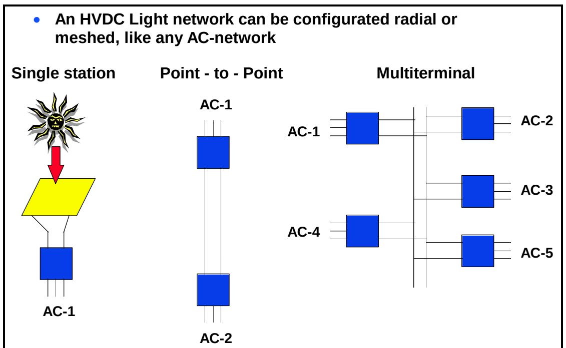
The PWM technology has been tried and tested for two decades in switched power supplies for electronic equipment as computers. Due to the new, high power IGBTs, the PWM technology can now be used for high power applications as electric power transmission.

HVDC Light can be used with regular overhead transmission lines, but it reaches its full potential when used with a new kind of dc cable. The new HVDC Light cable is an extruded, single-pole cable. As an example a pair of cables with a conductor of 95 sq. mm aluminium can carry a load of 30 MW at a dc voltage of +/- 100 kV. The easiest way of laying this cable is by plowing. Handling the cable is easy. Despite it's large power-carrying capacity it has a specific weight of just over 1 kg/m.

Conductor:	95 mm^2 Aluminium
Insulation:	5,5 mm triple extruded DC
Screen:	Copper wires
Sheath:	HDPE
Weight:	1,05 kg/m
Voltage:	> 100 kV DC
Current:	> 300 A
Power:	> 30 MW

Contrary to the case with AC transmission, distance is not the factor that determines the line voltage. The only limit is the cost of the line losses, which may be lowered by choosing a cable with a conductor with a larger cross section. Thus, the cost of a pair of dc cables is linear with distance. A dc cable connection could be more cost-efficient than even a medium distance AC overhead line, or local generating units such as diesel generators.

The converter stations can be used in different grid configurations. A single station can connect a dc load or generating unit, such as a photo-voltaic power plant, with an AC grid. Two converter stations and a pair of cables make a point-to point dc transmission with AC connections at each end. Three or more converter stations make up a dc grid that can be connected to one or more points in the AC grid or to different AC grids.



The dc grids can be radial with multi-drop converters, meshed or a combination of both. In other words, they can be configured, changed and expanded in much the same way AC grids are.

3. Applications

3.1 Overhead lines

In general, it is getting increasingly difficult to build overhead lines. Overhead lines change the landscape, and the construction of new lines is often met by public resentment and political resistance. People are often concerned about the possible health hazards of living close to overhead lines. In addition, a right-of-way for a high voltage line occupants valuable land. The process of obtaining permissions for building new overhead lines is also becoming time-consuming and expensive.

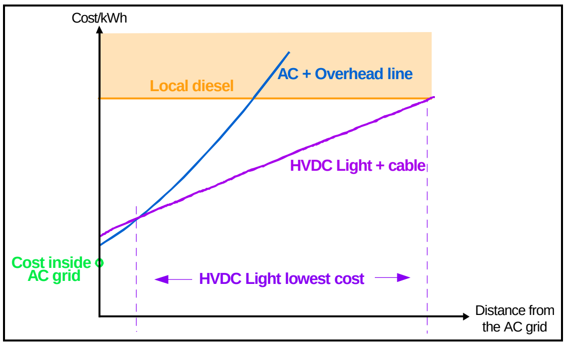
Laying an underground cable is a much easier process than building an overhead line. A cable doesn't change the landscape and it doesn't need a wide right-of-way. Cables are rarely met with any public opposition, and the electromagnetic field from a dc cable pair is very low, and also a static field. Usually, the process of obtaining the rights for laying an underground cable is much easier, quicker and cheaper than for an overhead line.

A pair of HVDC Light cables can be plowed into the ground. Despite their large power capacity, they can be put in place with the same equipment as ordinary, AC high voltage distribution cables. Thus, HVDC Light is ideally suited for feeding power into growing metropolitan areas from a suburban substation.

3.2 Replacing local generation

Remote locations often need local generation if they are situated far away from an AC grid. The distance to the grid makes it technically or economically unfeasible to connect the area to the main grid. Such remote locations may be islands, mining areas, gas and oil fields or drilling platforms. Sometimes the local generators use gas turbines, but diesel generators are much more common.

An HVDC Light cable connection could be a better choice than building a local power plant based on fossil fuels. The environmental gains would be substantial, since the power supplied via the dc cables will be transmitted from efficient power plants in the main AC grid. Also, the pollution and noise produced when the diesel fuel is transported will be completely eliminated by an HVDC line, as the need for frequent maintenance of the diesels. Since the cost of building an HVDC Light line is a linear function of the distance, a break-even might be reached for as short distances as 50 - 60 kilometres.

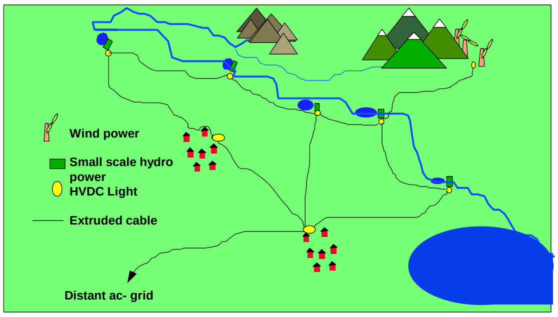


3.3 Connecting remote power grids

Renewable power sources are often built from scratch, beginning on a small scale and gradually expanded. Wind turbine farms is the typical case, but this is also true for photovoltaic power generation. These power sources are usually located where the conditions are particularly favourable, often far away from the main AC network. At the beginning, such a slowly expanding energy resource cannot supply a remote community with enough power. An HVDC Light link could be an ideal solution in such cases.

First, the link could supply the community with power from the main AC grid, eliminating the need for local generation. The HVDC Light link could also supply the wind turbine farm with reactive power for the generators, and keeping the power frequency stable.

When the power output from the wind generators grows as more units are added, they may supply the community with a substantial share of its power needs. When the output exceeds the needs of the community, the power flow on the HVDC Light link is reversed automatically, and the surplus power is transmitted to the main AC grid.



Waste gas is usually burned at offshore drilling platforms, since it is too expensive, or technically difficult, to use the gas for power generation and transmit it by an AC cable to the main grid on the shore. Thus, the energy content of the gas is wasted, and the primitive burning process is source of pollution. With an HVDC Light underwater cable transmission, the gas can be used as gas turbine fuel, supplying both the platform and the main AC grid with power. The process of burning the gas in gas turbines would also produce much a cleaner exhaust than simple burning would do.

The DC underwater cable network could easily be extended to other offshore platforms.

3.4 Asynchronous links

Two AC grids, adjacent to each other but running asynchronously with respect to each other, cannot exchange any power between each other. If there is a surplus of generating capacity in one of the grids it cannot be utilised in the other grid. Each of the networks must have its own capacity of peak power generation, usually in the form of older, inefficient fuel fossil plants, or diesel or gas turbine units. Thus, peak power generation is often a source of substantial pollution, and their fuel economy is frequently bad.

A DC link, connecting two such networks, can be used for combining the generation capacities of both networks. Cheap surplus power from one network can replace peak power generation in the other. This will result in both reduced pollution levels and increased fuel economy. The power exchange between the networks is also very easy to measure accurately.

4. Conclusions

HVDC Light technology saves the environment by replacing remote fossil-fuelled diesel generators with cost-efficient transmission of power from efficient and clean, large-scale generation production units. The efficiency of a modern, large scale, thermal generating plant is usually 25 percent higher than that for a modern, small or moderate scale diesel generator plant.

Vice versa, HVDC Light provides a convenient and cost-effective way for connecting renewable and non-polluting energy sources as wind power farms and photovoltaic power plants to a main grid.

The HVDC Light technology in itself has strong environmental benefits. Since power is transmitted via a pair of underground cables, the electromagnetic fields from the cables cancel each other. Any residual field is a static field, as opposed to the power-frequency fields radiated from AC cables.

Since HVDC Light transmissions are bipolar, they do not inject any currents into the ground. Ground currents can disturb communications systems or cause corrosion on gas or oil pipelines.

A pair of light-weight DC cables can be easily plodded into the ground at a cost that is comparable to or less than for a corresponding AC overhead line. As opposed to an overhead line, an underground cable pair has no visual impact at all on the landscape. Usually it's also much easier to obtain permissions and public approval for a cable transmission than for an overhead line, especially in residential areas.

- **Transmission by HVDC Light saves the environment by :**
  - **replacing local fossil-fueled generation with transmission from main AC-grid**
  - **connecting small scale renewable power to main AC -grid**
- **HVDC Light is inherent enironmentally friendly**
  - **cables instead of OH transmisson lines**
  - **virtually no magnetic field**
  - **no ground currents because of bipolar transmision**