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HVDC Light

An excellent tool for City Center Infeed

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Abstract

Adding new transmission capacity by AC lines into city centers is costly, and in many cases permits for new rights-of-way are difficult to get. HVDC Light is a DC transmission technology with a power rating up to 200 MW, using a compact extruded polymeric DC cable, which can be fit in an existing cable duct or a rights-of-way. The technology can also utilize existing AC overhead lines, and by converting to DC, power transfer capability can increase by some 50%.

HVDC Light is based on voltage source converter technology. This type of converter has the advantage of providing control of active and reactive power independently. This interesting feature can be very useful in city centers as reactive power control of systems containing a significant amount of AC cables is both complicated and expensive to implement.

HVDC Light has demonstrated a substantial number of advantages, which would be applicable to feeding of loads such as city centers. In an electricity market, the following characteristics could be of special importance: short delivery time due to standardized and factory tested stations; step-wise expansion as the systems can be built in a series of smaller stages; and control of the active power transfer.

1 Introduction

Competition in the electric power industry, coupled with continued load growth and the difficulty in siting new transmission lines, require that the existing transmission system assets are utilized closer to their technical limits. The transmission owners are driven to provide performance-based transmission services at a competitive price. Just as the deregulation has put pressure on generation, transparence in prices will have a similar effect on transmission and distribution systems. This will lead to maximizing of utilization and flexibility of both existing and new transmission assets eliminating “loop flows” and reducing system losses.

As the existing AC lines are loaded closer to their thermal capacity with increasing losses, reduced power quality and declining network stability as a result, it will become necessary to design new transmission assets to provide for lower losses and increased power quality. Modifications of the existing lines or cables may be required to increase power densities on the limited rights-of-way.

HVDC Light technology has the potential to play an important role in achieving higher density transmission corridors, or utilize other existing rights-of-way by introducing extruded DC-cables or DC overhead lines with lower losses and improved power quality through the control of active and reactive power.

2 HVDC Light technology

HVDC Light is a transmission technology up to 200 MW using single units. The converters are based on Voltage Source Converters (VSC) technology with series connection of turn- off power semiconductors to obtain high converter voltages, (up to ±150 kV for economic transmission). HVDC Light is a balanced converter technology, which makes it natural to operate in a bipolar mode. The converter control is based on the Pulse Width Modulation (PWM) concept, which enables flexible controllability of active and reactive power.

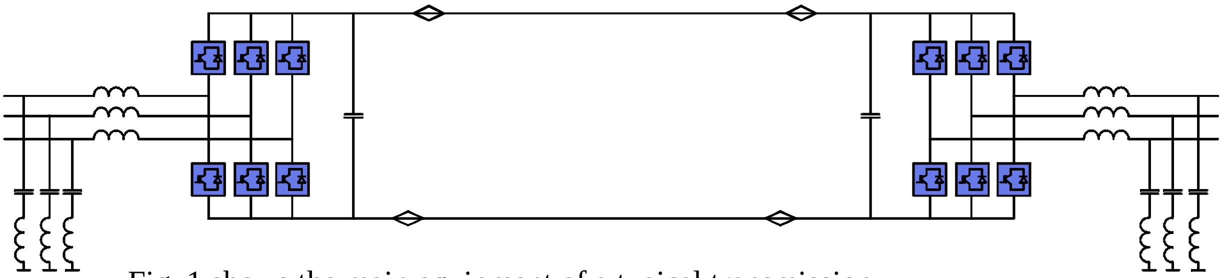


Fig. 1 shows the main equipment of a typical transmission

2.1 Advantages of HVDC Light cables

The new HVDC Light cables have insulation of extruded polymer. The robustness of the cable opens the way for new cable applications i.g. direct ploughing of underground cables, insulated aerial cables and submarine cables for particularly severe conditions.

As the polymeric DC insulation is thinner than for an extruded AC cable of the same voltage, the HVDC Light will have a more dense power capacity. HVDC Light cable is of a very robust design, which makes it easy to handle and install. The land cable can be installed cost- effectively by using the ploughing technique and the submarine cable can be laid in very deep waters on a rough sea bed. The HVDC Light cable can also be used overhead as aerial cables.

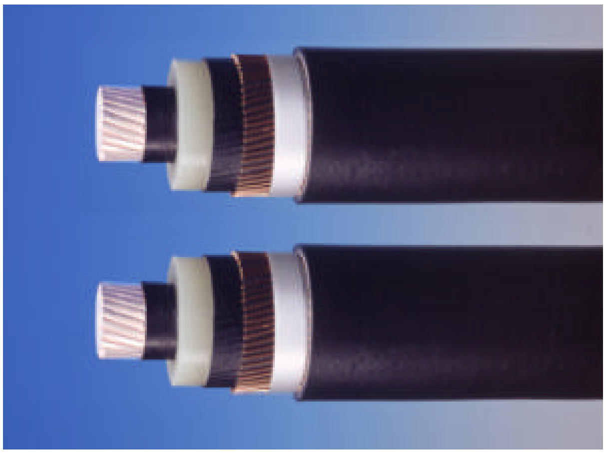


Fig. 2 shows Land Cable

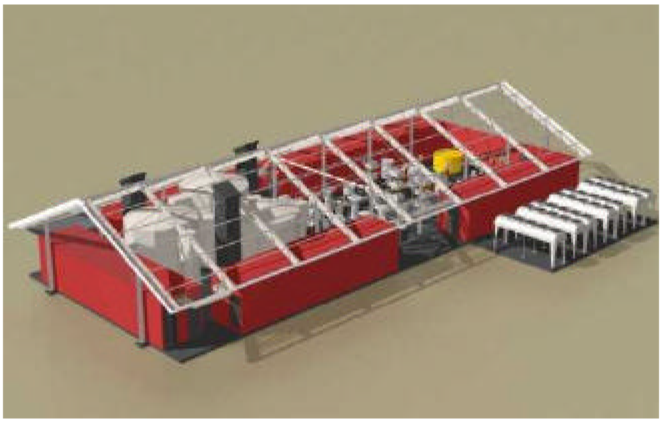
2.2 The Hellsjön Project

On March 10, 1997, power was transmitted on the world's first Voltage Source HVDC transmission between Hellsjön and Grängesberg in central Sweden. Extensive testing was performed for the first six months. To date, the Hellsjön transmission has been in operation for more than two years and has performed excellently as an integral part of the Swedish sub-transmission system.

2.3 Gotlight

The second HVDC light transmission will be commissioned in September 1999. The transmission link will be rated 50 MW, cable length is 70 km. It will be used on the Swedish island of Gotland to connect power from wind farms to the load center. Two extruded, totally 140 km of ±80 kV HVDC Light underground cables, ploughed into the ground close to each other, will connect the two substations.

The compactness of design means that all equipment will be installed in enclosure modules at the factory and factory tested, so that time spent on civil works, installation and commissioning can be kept low. The HVDC Light provides an environmentally friendly transmission, and with its underground cable the link can be made with no visual impact on the surroundings.



60 MW: 45 x 18 m

Fig. 3 shows the Gotland layout

2.4 Directlink

Directlink project is a transmission in Australia. This is an ITP (Independent Transmission Project) developed by the Hydro-Quebec group and NorthPower. The so-called Directlink is rated at 180 MVA, cable length is 65 km and it interconnects the Queensland and New South Wales networks. The extruded HVDC Light cable will be used along an existing rights-of-way. The driving forces behind this project are a capacity shortage in Queensland combined with surplus capacity in New South Wales. HVDC Light was the preferred choice due to the short delivery time, just 12 months, and the ease of cable installation. Here, the customer utilizes an existing rights-of-way along a railway, where the extruded HVDC Light cable is ploughed into the ground for a large part of the transmission route.

Fig. 4 shows the Directlink map

2.5 Tjæreborg

This 8 MVA HVDC Light link will be installed in the year 2000 at Tjæreborg in the western part of Denmark connecting a wind farm to the main AC network. The impetus for the project is that the Danish power utilities are planning to install five offshore wind farms of approximately 150 MW each.

3 Increase of capacity on existing rights-of-way

In city centers, there is an abundance of existing rights-of-ways that are suitable for power infeed, especially by using HVDC Light cable. To date, most of the city center infeeds have used large tunnels for HVAC cables, HVGIS cables or AC overhead lines, bringing large quantities of power to the load center in one corridor. With HVDC Light technology in conjunction with the deregulation process, some very interesting new business opportunities will emerge. The existing rights-of-way such as roads, subways, railways, and existing transmission lines are some examples of suitable routes for the HVDC Light system. The use of channels or possibly even the nearby ocean for power infeed are also very interesting alternatives as the HVDC Light cable for submarine applications is a cost effective transmission solution.

Fig. 5 shows Cable installation

3.1 Converting AC to DC

Existing transmission corridors into city centers will be stressed to carry higher power densities. Also, unwanted loop flows in the system will incur additional stresses. Reinforcements of AC lines by reconductoring and possible voltage upgrades have been some of the means used to increase capacity. On these existing rights-of-way, HVDC Light is an interesting complement to increase the power density. Some situations might justify conversion of an AC line to DC and thereby increasing the power density by some 50%. Given that the AC design permits, the conversion could be made by merely changing the insulators. Another possibility is to use the existing AC towers for an additional DC line, which could be overbuilt on the AC towers.

Using a 70 km, 115 kV line as an example, conversion to a ±100 kV bipolar HVDC Light could double the loadability to about 200 MW. The costs of the conversion would include the two converter stations and replacement of the AC insulators.

3.2 Adding capacity with HVDC Light cable

The use of the HVDC Light cable for additional power capacity into city centers is of special interest. As a DC cable can carry more power than an AC cable of the same size, it will be advantageous to use DC in order to maximize the power density in the limited cable ducts. The robustness of the cable will also facilitate the installation process.

Fig. 6 shows Direct access to load center

3.3 Control of power flow

If there are multiple cable circuits feeding an urban load center, they may not load in proportion to their ratings. This could be due to different impedances or phase angles. Consequently, one circuit may reach its thermal limit before the others. Using the power flow control capability inherent with HVDC Light, however, avoids having the thermal loading on just one circuit, effectively limiting the net transfer capability.

A similar power division control is used on the Gotlight transmission where there is a control function that controls the active power in the DC line depending on the power of the parallel AC line.

4 Improved reliability of city centers

4.1 Sharing of generation system reserves

The electric power system is an example of a very complex industrial process. There is always a probability that a failure will occur somewhere in the system. These failures can emerge either in the generation system or the transmission/distribution system. There is a desire to reduce the number of failures as they lead to disturbances in the supply of electric power. Large disturbances can cause major costs to society, e.g. in the form of increased costs due to reduced production in industry. Examples of large disturbances are the loss of a whole power plant or failure of a major transmission line. In both cases, the power flow in the system will change, since other power plants have to be taken into operation and the remaining transmission lines are used to transport the electricity.

By installing an HVDC Light link, system stability will increase, which makes it possible to share generation reserves over a larger area, while a weak transmission system requires locally available generation reserves. Thus investments in transmission capacity will bring saving in investments regarding generation reserves.

4.2 Overcoming limitations due to voltage stability

The voltage level of a bus in the power system is mainly coupled to the reactive power balance in the bus. However, large transfers of active power also give rise to increased reactive power losses and thus affect the reactive power balance indirectly. When operating the power system, it is desirable to supply the reactive power locally in order to reduce the reactive power flow on the transmission lines. Reactive power flows on the lines will lead to larger ohmic losses and reduced active power transmission capacity. If the active power load is increased in a bus in a system, the voltage in the bus will decrease. For a transmission line, there exists a maximum allowable transmission of power depending on the voltage in the load bus. This maximum allowable power defines the limit for voltage stability. If this limit is passed, the voltage in the node may collapse or cause severe disturbance. This disturbance can spread to other parts of the system, and might imply interruptions in power supply.

The numerous AC cables in city centers require reactive power compensation in order to maintain a stable AC voltage. This is usually costly and complicated to implement. An HVDC Light transmission will not require any reactive power exchange from the AC network. On the other hand, by using HVDC Light the need for generation or consumption of reactive power can be provided by the converter stations in a cost effective way, and hereby reduce losses on the existing AC infeeds. HVDC Light can also reduce flicker in the surrounding network due to its extremely fast var compensation, and thereby improve power quality.

5 Direct access to load centers

The wheeling of energy on a transmission system affects the involved parties both technically and economically. There are effects on, for example transmission losses, allocation of generation system resources and limitations on transmission capacity.

The wheeling cost is usually equivalent to the cost for transmitting electricity from a certain node in the transmission system to an other. The cost for use of transmission capacity will vary in time. At hours with low load, the cost will be low. At hours with high load, the generation may need to be redispatched to avoid bottlenecks in the transmission system and the cost will be high.

An attractive alternative to paying high wheeling costs for infeed to a city center is to own and operate a dedicated transmission link. The advantage with HVDC Light for such a link is the controllability of active power. This could be of special interest for an IPP located some distance from the city center where the spot price for electricity is fairly low. The IPP can use an HVDC Light transmission, matching the installed generating capacity, and transmit the power in to a more attractive location in the network without paying wheeling charges. The HVDC Light link can simply be seen as an extended location of the IPP plant.

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