특집 : HVDC 기술동향

Land and Sea Cable Interconnections with HVDC Light

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Abstract

HVDC Light는 300MW에 이르는 전력을 가지고 있는 압출 성형된 DC Cable과 Voltage Source 컨버터에 기반을 둔 가장 최근의 HVDC 기술이다. HVDC Light 컨버터는 IGBT(Insulated Gate Bi-polar Transistor)와 유효전력과 무효전력 사이의 고속 컨트롤을 위한 PWM(펄스 폭 변조)의 기능을 가지고 있다. HVDC Light 케이블은 압출 성형된 폴리머의 절연을 가진 케이블이며 직류 전압을 위해 특별히 개조되었다. 전력 범위내에서 HVDC Light 컨버터와 케이블은 지중 또는 해저 송전 등에서도 송전전력을 위해 훌륭하게 조합될 수 있었다. 본 원고는 실제의 케이스로부터 얻은 경험지식으로, HVDC Light 기술의 조합을 사용해 해결된 문제점을 소개하고, HVDC Light의 장점을 설명하였다.

1. INTRODUCTION

HVDC Light is the most recent HVDC technology based on Voltage Source Converters and extruded DC cables with power units up to 300 MW. HVDC Light converters include Insulated Gate Bipolar Transistors and operate with high frequency Pulse Width Modulation in order to get high speed control of both active and reactive power.

A successful way to design an HVDC Light transmission is to combine the converters with a pair of HVDC Light cables for a submarine or underground cable transmission. The new HVDC Light cables have insulation of extruded polymer. The strength and flexibility make the HVDC Light cables well suited for severe installation conditions both underground as a land cable and as a submarine cable at sea.

A pilot 3 MW transmission has now been in successful operation for more than three years. Since then four more schemes with a total power of 280 MW have been commissioned.

2. VOLTAGE SOURCE CONVERTERS WITH PULSE WIDTH MODULATION

By use of high switching frequency components, such as the IGBT it is possible to use Pulse Width Modulation (PWM) Technology and reduce the filter size. The ac-voltage in inverter mode is created by switching very fast between two fixed voltages. After low pass filtering the desired fundamental frequency voltage is created. See figures 1and 2.

To use the VSC for power transmission, it is needed to increase the direct voltage to such levels as can be effective for useful levels of power-distance combinations. This is achieved by series connection of semiconductor devices in the same way as is made with conventional thyristors.

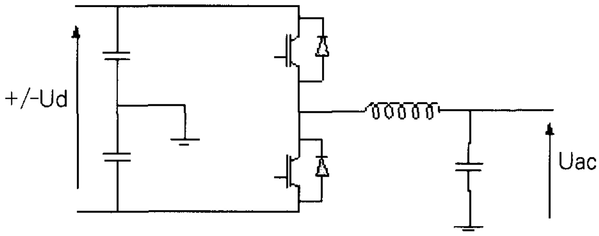

Figure 1 shows one phase of a VSC converter using PWM

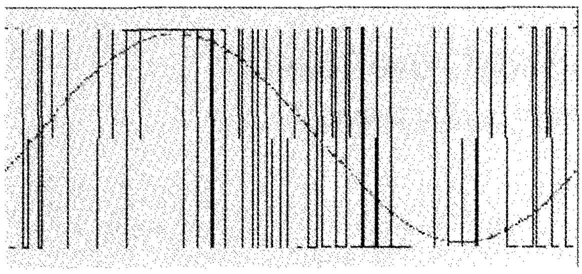

Figure 2 shows the PWM pattern and the fundamental frequency voltage

With PWM it is possible to create any phase angle or amplitude (up to a certain limit) by changing the PWM pattern, which can be done almost instantaneous. Hereby PWM offers the possibility to control both active and reactive power independently. From a system point of view it acts as a motor or generator without mass that can control active and reactive power almost instantaneously. Contrary to a generator it does not contribute to the short circuit power as the ac current can be controlled.

The reactive power capabilities can be used to control the ac voltages of the networks connected to the converter stations.

3. HVDC LIGHT CABLES

3.1 Experience

The HVDC Light polymeric cables system is now qualified for two voltage ranges, i.e. Uo = 80 kV (Um = 88kV) and 150 kV (Um=165 kV). The qualification tests have comprised Long term tests and Type Tests successfully performed.

The amount of commercially delivered HVDC Light

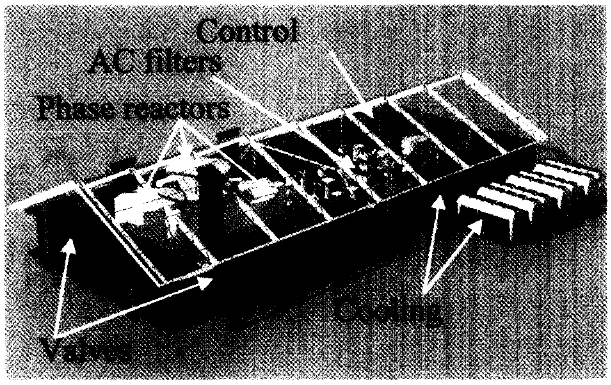

Figure 3 HVDC Light converter

cables is now in excess of 500 km, i.e. 250 km bipole route length for the three projects Gotland in Sweden, Tjaereborg in Denmark and Directlink in Australia where power transmission has started.

3.2 New applications with polymeric HVDC Light Cables

Previously cable types have been used for HVDC transmission.

- The MIND, Mass Impregnated Non Draining, cable which has an insulation of paper impregnated with high viscosity oil.
- The LPOF, Low Pressure Oil Filled, cable which has an insulation of paper impregnated with low viscosity oil.

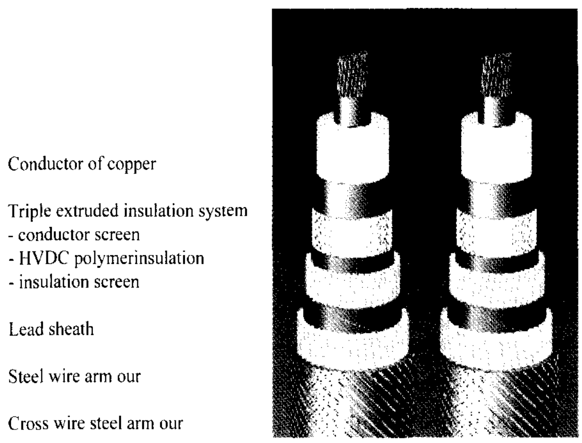

Figure 4 shows 10 - 600 MW deep sea HVDC Light cable

Compared with these traditional paper insulated cables, the polymeric cable immediately shows up to advantage because of its excellent mechanical flexibility and strength, leading to new applications:

- Deep Sea Cables. Submarine HVDC Light cables can be laid in very deep waters and on rough bottoms. The very robust polymeric insulation material can withstand high forces and repeated flexing. The HVDC Light submarine cables are also more suited for deep water than polymeric submarine cables for AC applications. This is because single or double galvanised steel wire armour can be used for DC current whereas non-magnetic and less strong armours normally are used for AC cables.

- Aerial Cables. HVDC Light cables can be used as overhead cable in the same way as other polymeric cables, with the difference though that a DC bipole utilises two cables and am AC three phase system utilises three cable (or cores). HVDC cables have more transmission capacity than AC cables of the same size.

3.3 Cables instead of overhead lines

The increased demand to use underground cables because of reluctance to use overhead lines has many reasons. These reasons could be:

- Storms, falling trees, snow and ice loads do not harm underground cables.
- Cables do not harm the impact of beautiful areas.
- The land can be used for other purposes.
- Overhead transmission lines require maintenance such as clearing of power lanes from growing trees, thermographic checks of conductor jointing sleeves and checks of insulators.

3.4 AC and DC cable cost comparison

The cost for HVDC Light land cables are typically lower than for AC cables. In two of the projects performed the cables have been plowed into the ground instead of laying in excavated cable trenches. This has reduced the installation costs substantially.

3.5 Low magnetic fields from HVDC Light cables

A particular advantage with the HVDC Light cable system is that magnetic fields are almost eliminated with the bipolar system. A classic monopolar HVDC cable scheme with a current of 1000 A gives a magnetic field of the magnitude 20 micro Tesla at a distance of 10 meters. This is about half the magnitude ofthe natural magnetic field from earth. With HVDC Light cables the magnetic field is reduced to less than 0.2 micro Tesla.

3.6 Accessories for the cables

HVDC Light cable joints and cable terminations have been developed for all applications including:

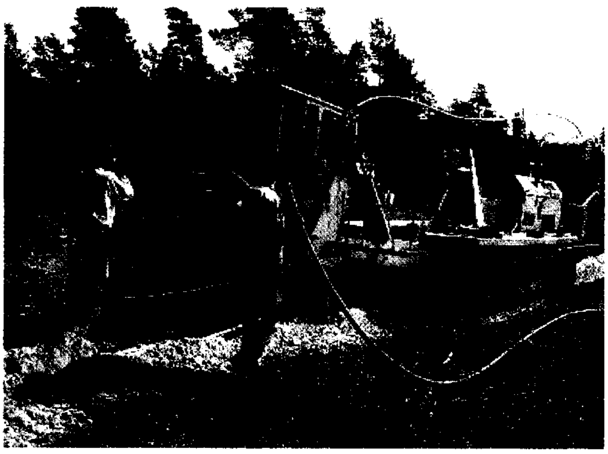

Figure 5 shows low cost installation with plowing

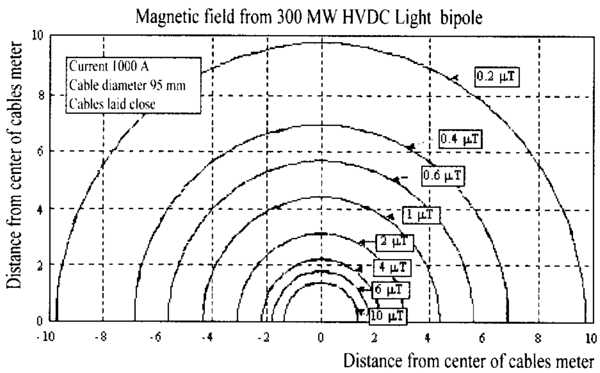

Figure 6 shows iso-Tesla curves for 300 MW HVDC Light submarine and land cables

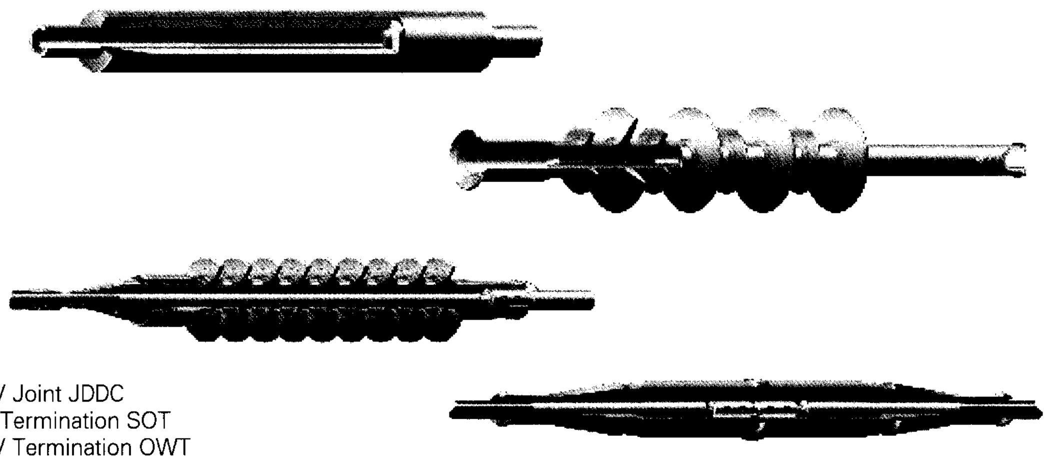

Figure 7 shows cable accessories for HVDC Light.

- Cable terminations inside the HVDC Light Converters.
- Prefabricated stiff joints, normally used on land cables
- Site molded flexible joints, normally used on submarine cables

4. EXPERIENCE

HVDC Light is a recently developed technology and already a number of commercial projects have been undertaken and installed.

4.1 The Gotland HVDC Light

During the past years, there has been a considerable increase in wind power production on the Swedish island of Gotland. The infrastructure built for existing consumption cannot receive the increasing production. Wind power production does not conform to consumption.

HVDC Light has been chosen to transmit 50 MW between the windpower park and the centre of the island. By this link the Owner received an underground transmission, which provided an environmentally sustainable link and considerably eased permitting. With the Gotland HVDC Light transmission, the reactive power capabilities are used to control the AC voltages of the networks connected to the converter stations and keep the power quality high despite the high amount of wind power infeed. The link has been in operation and transmitting power since November 1999.

4.2 The Tjaereborg HVDC Light

The Tjæreborg Wind Farm is in the western part of Denmark, on the West Coast. A dc feeder rated 8 MW is installed to be able to operate as the only infeed of the wind power or in parallel with the ac- feeder. Disconnected from the ac net the windfarm may be operated at frequencies varying between 35Hz and 52 Hz and thus use the windforce more efficiently. The link will be used to investigate how wind power can be fed into the network in an efficient way by a dc transmission. The link was commissioned mid 2000.

4.3 Directlink HVDC Light Project

Directlink project is a transmission in Australia. This is an ITP (Independent Transmission Project) developed by the Hydro-Quebec group and North Power. The so-called Directlink is rated at 180 MVA, route length is 65 km and it interconnects the Queensland and New South Wales networks. The extruded HVDC Light cable is installed along an existing rights-of-way along a railway, where the

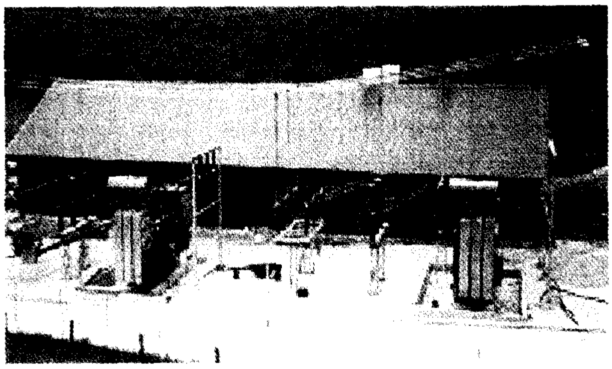

Figure 8 shows one of the two converter stations in Directlink

extruded HVDC Light cable is ploughed into the ground for a large part of the transmission route.The driving forces behind this project are a capacity shortage in Queensland combined with surplus capacity in New South Wales and the possibility to trade electric energy in a deregulated market. HVDC Light was the preferred choice due to the short delivery time, just 12 months, and the ease of cable installation. The link has transmitted power since April 2000.

4.4 Eagle Pass

Central and South West Corporation (CSW) (NYSE: CSR) and Commission Federal de Electricidad (CFE) will install an asynchronous electrical tie using HVDC Light technology. The 36 MW back to back tie will link the transmission system of CSW's Central Power and Light Company (CPL) subsidiary with the Mexican transmission system owned and operated by CFE. The link is scheduled for operation mid 2000.

4.5 Cross Sound

The order for the 330-megawatt, 40-kilometer link was placed by TransEnergie U.S. Ltd., a subsidiary of TransEnergie, the transmission division of Hydro-Quebec, Canada. The link is scheduled to begin operation by May, 2002.

Under the terms of the contract, ABB will provide a complete HVDC Light transmission system. The system is made up of high-tech extruded cables buried under the seabed, with a converter station at each end of the link.

5. HVDC LIGHT APPLICATIONS

HVDC Light has been ave thought of and presented for a variety of applications, using both land and submarine cables. The following could be worth mentioning:

5.1 Land cables

5.1.1 Small isolated remote loads

Many isolated communities are not connected to the electrical grid and are dependent on expensive local generation for their needs. The VSC transmission concept for dc makes it feasible, in many cases, to connect such communities to the main grid where low price electricity is available. The receiving network does not need to have generation of its own.

5.1.2 Infeed to cities

Adding new transmission capacity by ac lines into city centres is costly and in many cases the permits for new ROW are difficult get. A dc 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.

5.1.3 Remote small scale generation

Remote small scale generating facilities such as low-head hydropower and wind power have normally not been economic to develop, due to too high transmission costs and low transmission capacity of the ac lines. Especially for wind power the active and reactive control possibilities with HVDC Light would improve the feasibility of such projects.

5.2 Sea crossings

5.2.1 Power supply to islands

The power supply to small islands is often provided by expensive local diesel generation. By installing an HVDC Light transmission with a low cost extruded cable, low price electricity from the main-land grid can be imported.

5.2.2 Remote small scale generation

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

Generation on platforms can of course be considered in the same way and use an HVDC Light connection to land.

5.3 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 the connected networks. An interconnection could be with land cable, and/or submarine cable or without a transmission link, a so-called back-to-back connection.

6. DEREGULATED MARKET

The present ongoing deregulation makes interconnections more interesting. As in all trade the driving force is differences in prices. In the case of a deregulated electricity market trade will take place as soon as there is a price difference between two places if there is a transmission capacity available. In reality, the lack of transmission capability is one major force that creates price differences.

This fact makes it increasingly interesting to interconnect networks that are neither synchronous, nor have bottlenecks.

In both these cases HVDC Light is very suitable as there are no problems created in the connected ac networks by the dc link. On the contrary, the power quality will be improved as the HVDC Light terminals can control reactive power in each station in excess of the active power transfer between stations.

As has been demonstrated earlier there is also much higher probability to get the necessary permissions for laying cables than to get permissions for overhead lines, thereby reducing the project risks.

7. CONCLUSIONS

The new electric transmission system, HVDC Light, is utilising state of the art semiconductors, control and cable insulation and can offer many new transmission opportunities. In many cases transmission can give new opportunities to trade electric energy in the new deregulated markets. As HVDC Light has been developed to minimise environmental impact and impact on the connecting ac grids, the permitting procedure is generally more favourable than more traditional solutions. As several schemes are now in operation all over the world the technology is now maturing rapidly.

References

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