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HVDC USING VOLTAGE SOURCE CONVERTERS - A NEW WAY TO BUILD HIGHLY CONTROLLABLE AND COMPACT HVDC SUBSTATIONS

GUNNAR ASPLUND
ABB POWER SYSTEMS
SWEDEN

SUMMARY

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 and reducing system losses.

Environmental concerns regarding overhead transmission lines and the construction of big substations makes it often difficult to get permissions for the needed reinforcement of the transmission system needed due to increase of demand and also changing load patterns due to deregulation and increased competition in the electric power industry.

1. INTRODUCTION

A new type of HVDC making use of the latest semiconductor technology to convert ac to dc and vice versa has been developed. The semiconductors used are IGBT:s (Insulated Gate Bipolar Transistors), the converters are VSC (Voltage Source Converters) and they operate with very high frequency (1- 2 kHz) utilising PWM (Pulse Width Modulation). The result is converters that are extremely fast both in control of active and reactive power. As the conversion process takes place at high frequency and is very efficient, there is little need for auxiliary equipment such as filters and switches, ~~why~~ therefore these stations become very small and compact. This technology has been developed under the name of HVDC Light.

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.

As the converters are based on voltage source converter technology they have the advantage of providing independent control of active and reactive power.

Due to the high conversion frequency the converters can be made very compact and require far less area than conventional HVDC converter stations.

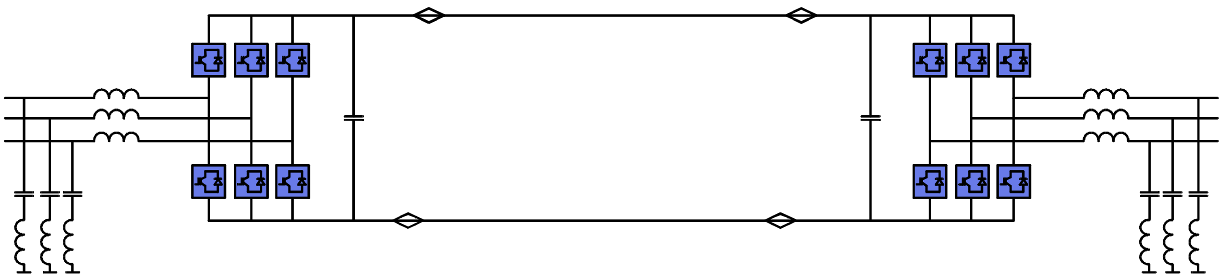

Fig 1. shows the main equipment of a typical transmission.

Gunnar Asplund, ABB Power Systems, SE-771 80 Ludvika, Sweden

2. HVDC LIGHT TECHNOLOGY

The HVDC Light converters are based on Voltage Source Converters (VSC) technology witries 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.

2.1 HVDC Light Stations

The stations are very compact in comparison to conventional HVDC. The reason for this is mainly that due to the high switching frequency (up to 2 kHz) and the possibility to control the reactive power with the converter as well as the reactive power. this reduce the need for ac-filters and shuntbanks that need to be switched in when the converter increase its power The stations have only one single filterbank which is always connected to the ac-side of the converter and is not switched during the change of active power. The stations only need a transformer if the voltage rating of the converter is not equivalent to the ac voltage in the connecting point or if the ac system has not an efficient grounding. This also means that if the ac voltage is high in the connecting network and a transformer is used to lower the voltage, the ac- filter is connected to the lower voltage of the converter and will due to this also be smaller in size due to the lower voltage.

Due to the compact stations the requirement of the air insulation in the station is very stringent. As the valves are air insulated the design of the screening electrodes inside the valve enclosures has to be made with great care. The use of modern 3D field calculation programs together with CAD tools makes it possible to optimize the designs much faster than was possible only one decade ago. All designs of course have to be verified also by dielectric tests.

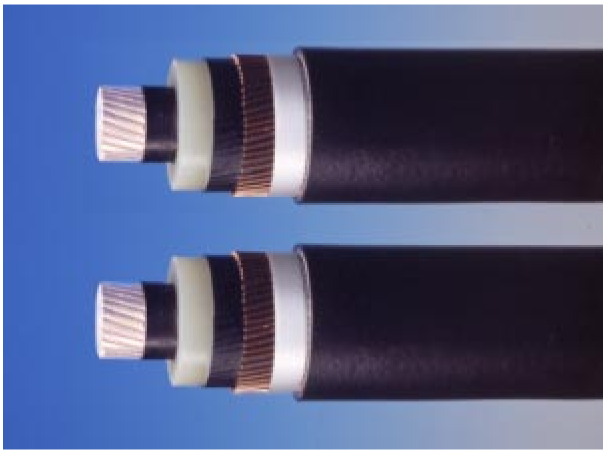

Fig 2. shows the Land Cable.

2.2 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 3. shows cable ploughing technique

2.3 Gotland scheme

Several HVDC Light schemes are under delivery. The Gotland transmission scheme was commissioned during autumn 1999. The transmission link is rated 50 MW, cable length is 70 km. It is 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, connects the two substations.

Fig 4. shows the Gotland layout.

The compactness of design means that all equipment was installed in enclosure modules at the factory and factory tested, so that time spent on civil works, installation and commissioning could be kept low. With its underground cable the link can be made with no visual impact on the surroundings.

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 Direct access to load center

4 AREA REQUIRED

Altogether there can be quite substantial savings in area required for the converter stations as can be see in figure 7 where the area requirement in the Gotland 2 converter station (conventional Thyristor converters) is compared to two HVDC Light stations (Gotland HVDC Light) that together has the same power rating as Gotland 2.

5 CONCLUSIONS

New semiconductors and new insulating materials together with new design tools makes it possible to build very compact HVDC stations connected by extruded cables. This new type of HVDC transmission called HVDC Light is very well suited for transmitting electric energy to places where restrictions regarding environmental impact or scarcity of land makes it very difficult to get permissions to build conventional ac transmission schemes.

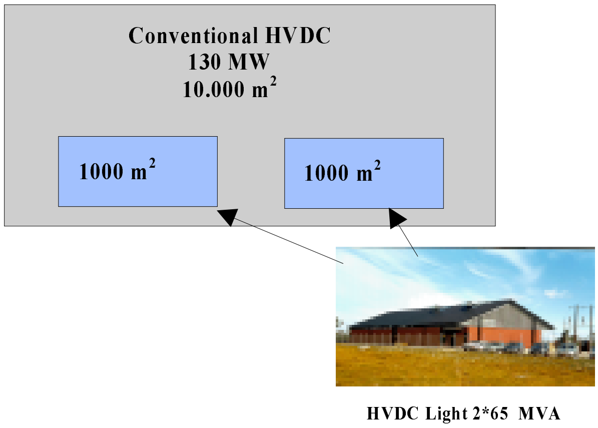

Fig 6. Comparison of area required for HVDC Light compared to conventional HVDC.

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