Innovation in the Market: HVDC Light, the new technology

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Abstract

ABB was awarded a contract in December 2000 by the Murraylink Transmission Company Ltd (MTC) for the turnkey, engineering, procurement and construction (EPC) of the Murraylink Transmission Interconnection Project, which is Australia's second privately funded electricity transmission project.

Murraylink provides an innovative solution to the electricity generation shortfalls in South Australia and Victoria. It links the South Australian and Victorian electricity grids using an underground high-voltage, direct-current cables and ABB's new HVDC Light technology.

By interconnecting two AC grids, at these connection points it has become possible to exchange up to 220MW of power between each grid. If there is a surplus of generating capacity in either of the state's grids it can be utilised in the other's grid.

The connection points for the new transmission link are located on the Victorian side at the existing Red Cliffs Terminal substation owned by SPI PowerNet and in South Australia at a new substation which was also built as part of the project outside Berri for ElectraNet SA.

The transmission link is fully underground for its 180km route, which sets the record for the World's longest underground high-voltage cable installation.

This new transmission and distribution technology, HVDC Light provides an important role to today's requirements on our network systems and opens up new opportunities for both investors and environmentalist alike.

Introduction

Competition in the electricity power industry, coupled with continued load growth require that the existing transmission system assets are utilised more effectively and some times closer to their technical limits.

As the existing AC lines become loaded closer to their thermal capacity with increasing losses and reduced power quality we face the risk of declining network stability. One solution would be to simply build new, more powerful AC lines.

But, it is getting increasingly difficult to obtain permits to build new high voltage overhead transmission lines, the right-of-way occupies valuable land. Overhead lines change the landscape, causes public resentment and is often met by political resistance. People are increasingly concerned about the possible health hazards of living close to overhead lines.

There are many examples today of public agitation against overhead powerlines and the call for them to be buried. Media reports which link living close to power lines with higher cancer risks and leukaemia in children don’t help the situation.

On the other hand laying an underground cable is an 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 rarely meet with public opposition.

There are technical constraints, which limit the distance of traditional AC underground cables to around 80km.

And, even though the cost of laying AC cables is rapidly reducing it still costs more than equivalent overhead lines.

Currently there is little incentive for putting high voltage lines underground particularly when the Network Service provider is predominantly driven by cost to provide performance-based transmission services at a competitive price. So what it is solution?

HVDC Light technology has the potential to play an important role in achieving this solution. It provides improved power quality and power flow control as well as introducing extruded DC-cables which have no technical limit to distance which can be installed, and can provide an alternative to overhead lines particularly when the total capital and environmental costs are considered.

In Australia, at Direct Link and Murraylink, we have two such examples where HVDC Light technology with underground DC-cables has been implemented in a competitive, market-oriented network service.

HVDC Light Technology

As its name implies, HVDC Light is a high voltage, direct current transmission technology and is well suited to meet the demands of competitive power market for transmission up to 330MW and for a DC voltage in the ± 150kV range.

Traditional HVDC, or if you like HVDC Heavy, is designed for high voltage, direct current transmission above 300MW and for DC voltage up to ± 600kV.

HVDC Light design is based on modular concept build up from standardised designs with compact transportable modules, which are factory assembled and pre-tested to provide short delivery and a fast response to the competitive market demands.

These standardised modular designs allow for delivery times as short as 12 months.

It consists of two AC to DC converter stations and a pair of underground cables inter-connecting each converter station.

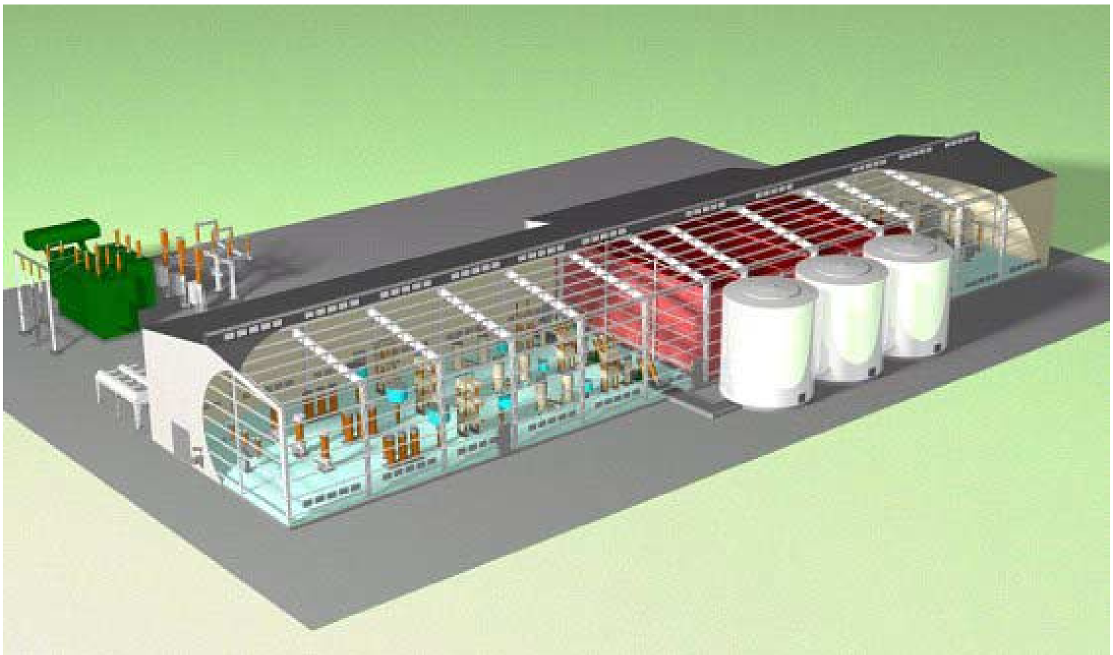

Fig. 2, Layout of a 330MW HVDC Light converter station

The converter stations are designed to be unmanned and virtually maintenance-free. Operation can be carried out remotely or automatically based on the requirements of the Network Service contract.

The AC to DC converters employ the latest in power semiconductor technology, the IGBT (Insulated Gate Bipolar Transistor). This technology provides the HVDC Light converter with a switching speed 27 times faster than a traditional HVDC, thyristor-controlled converter.

This fast control makes it possible to create any phase angle or amplitude which can be done almost instantaneously providing independent control of both active and reactive power. From a system point of view it acts as a motor or a generator without mass.

While the transmitted active power is kept constant the HVDC Light converter can automatically control the voltage of the connected AC network by compensating the generation and consumption of reactive power within the capacity of its rating.

In the presence of a fault on the existing AC system the HVDC Light converter can rapidly assist with voltage support to avoid severe disturbances in the local grid. The response time for a change in voltage can be as quick as 50ms. With this speed of response HVDC Light will be able to control transients up to around 3Hz, thereby helping to keep the AC bus voltage constant.

In summary, HVDC Light combines the operational features of traditional HVDC converters with those of static Var compensators (SVC) to provide new levels of performance in terms of power quality during both steady state and transient operation.

HVDC Light Cable

The HVDC Light cable is a new design triple extruded, polymeric insulated DC-cable, which has been successfully type tested to150kV DC, following a comprehensive R & D program. It is a new lightweight cable similar in appearance and characteristics to a standard AC, XLPE cable except that the problem associated with space charges which breakdown the insulation when using AC, XLPE cables on DC has been overcome with this new design.

Fig. 3. Murraylink, after cable installation

DC underground cables provide significant advantages, compared with overhead power lines. These include:

- Reduced environmental impact, an underground cable has no visual impact on the landscape. Once it's installed the cable route can be replanted with Native vegetation.
- Faster and easier issue of permits using DC underground cables. Underground cables rarely meet with public opposition and often receive political support.
- The system reliability is enhanced with reduced risk of damage from natural causes such as storms, wind, earthquakes and fire. You simply bury it and forget it.
- Operation and maintenance costs of the transmission easement are virtually eliminated as there is no need for long term contracts to maintain the easement with suitable access roads, thermographic checks of conductors joints, insulator replacements, constant trimming and removal of regrowth vegetation and public safety and security.
- The width of the corridor to install the underground cable can be as narrow as 4 metres, which will give greater flexibility with the selection of a transmission route.
- There are considerable cost savings to the community in terms of amenity, property values and possible health risks. The installation of a DC cable has no environmental impact, the land can continue to be used and there is virtually no magnetic radiation associated with the bi-polar DC cable.

Compared with AC underground cables the HVDC Light cable also has some significant advantages to be considered:

- DC cables require only two cables between each converter station.
- Unlike AC cables, which generally have a technical limit of around 100km due to reactive power and losses, DC-cables have no technical limit to distance.
- DC cables can carry up to 50% more power than the equivalent AC cable. There is no need to install groups of cables to achieve the required power rating.
- As there is no need to maintain wide distances between groups of cables, DC cables can be ploughed direct in the ground or laid together in narrow trenches.
- DC cables have a longer life expectancy than AC cables due to its lower operational stress level of around 20kV/mm.

In summary, when considering the cost of installing an HVDC Light underground transmission it is important to consider the total life cost benefits and not just the initial up front capital costs.

Experience

HVDC Light technology has been well proven since the first successful pilot installation in March 1977 with a number of commercial projects undertaken and in operation.

Applications to date include connecting wind power generation to the grid. This includes Gotland, off the Swedish mainland, transmitting 50MW back onto the grid. The link has been transmitting power since November 1999.

Fig. 4, Gotland HVDC Light

Wind generation is often placed in remote locations where the grid is weak and short circuit power capability is quite low. They often require expansion within a few years and wind generators absorb reactive power from the grid for magnetisation

The advantages that HVDC Light provides in this application include:

- Flexibility to be expanded
- Limits the short circuit power contribution
- Supplies reactive power to wind generator, independently to active power it receives.
- A meshed DC grid can be built which connects the wind farms

Another application for HVDC Light is interconnecting different Networks. In this application the advantages provided include:

- The flow of energy over the link can be precisely defined and controlled, thereby capacity rights for fully commercial network are readily defined.
- The converter stations at each end can act independently of each other to provide ancillary, reactive power support into the network.
- Underground cables facilitate the issuing of permits. Unlike Government Utilities there are no rights of acquisition for a private developer.
- Rapid construction of the HVDC Light allows a fast response to market conditions of market-driven network services.

DirectLink here in Australia is such an example. It is located in northern NSW and links the regional electricity markets of Queensland and New South Wales; it has a 180MVA capacity and has been in commercial operation since mid December 2000.

It was Australia's first unregulated interconnection and build by a joint venture between Country Energy (formerly NorthPower) and Hydro Quebec International.

DirectLink consists of 3 x 65MVA converter stations at each end with each converter interconnected by a pair of underground cables with a route length of about 60km.

Murraylink

Murraylink is the second HVDC Light project constructed here in Australia. It links the electricity markets of Victoria, New South Wales and South Australia and exchanges up to 220MW of power between the South Australian and Victorian grids. Murraylink is Australia's second non-regulated project, operating similarly to Direct Link as a generator by participating in the spot market and delivering energy into the highest value regional market.

Murraylink has been built to serve the generation short fall in South Australia as well as the tight electricity supply to demand balance in that State particularly when demands are at their highest peaks during summer periods.

Murraylink has been privately funded and built by the Murraylink Transmission Company (MTC) which is jointly owned by Hydro Quebec International and SNC Lavalin who will also operate the link.

The converter stations are located at Red Cliffs on the Victorian side where it connects to 220kV grid at SPI PowerNet's Red Cliffs Terminal Station. On the South Australian side it connects to the132kV grid at Monash Substation, which was also built by ABB as part of the project outside Berri for ElectraNet SA.

The transmission link is interconnected by a pair of underground cables with a route length of 180km making Murraylink the World's longest underground high-voltage cable installation.

The cable route uses existing road corridors and in parts follows the Sturt Highway along with other services such as a gas pipeline and telecommunication cables. The cable route crosses under the Murray River as well as some wetland areas. There are also some shorter crossings, which required the boring under the Calder Highway and under a railway line. The route is predominantly in rural area, but parts are along irrigated agricultural fields.

Fig. 5. Shows typical area along cable route

The cable route has required no easements over private land for installation, and the overall impact on vegetation has been kept to an absolute minimum.

Once the cable was installed the cable route was then replanted with native vegetation providing a net gain in native vegetation.

Construction commenced in Berri in June 2001 and was successfully commissioned in August 2002.

ABB's scope of works included the design, project management, manufacture, works testing, shipment, installation and site testing and commissioning of the complete HVDC Light transmission link consisting of the converter stations, associated substation works at each end including a new Monash Substation and more than 360km of 150kV DC cable. As ABB Sweden is the only manufacturer in the World to have successfully type tested an 150kV DC extruded cable it meant shipping from Sweden 434 cable drums, each weighing around 10.4 ton and measuring 3.1m in diameter and 1.8m in width.

Fig. 5 Shows first shipment of cable drums at Port Melbourne Wharf

The cable installation portion of the project was sub-contracted by ABB to PIHA a Perth based company, which specialise in long distance trenching. The cable trench, which was excavated using a Vermeer T755, chain trencher. The trench required was only 450mm wide and 1400mmm deep. The cable was fed directly into the trench from specially constructed cable de-reeler mounted onto an L330D Wheel Loader, which was located just ahead of the Vermeer trencher.

Fig. 6, Vermeer Trench excavator in action

Prior to trenching work geothermal testing of the soils along the entire 180 km route was undertaken. 500 samples were taken from the installation depth of the cables. From this information, a cable design was developed to enable the native soil to be used for back filling the excavated trench after passing through a screening process, which removed any small stones and foreign objects. In the few areas where the native soil was very rocky, an imported backfill material was used.

Each cable drum held around 800m of cable so, more than 425 x 150kV DC joints and around 75 terminations were needed for the project. The cable joints were manufactured from a one-piece pre-moulded rubber, which considerably reduced the installation time for cable jointing compared with traditional methods.

Conclusions

HVDC Light is a new technology that has been specifically developed to match the requirements of the new competitive electricity markets. It provides the ability to connect renewable generation to the AC grid. It allows us to supply power to remote locations and islands replacing local diesel generation. It is an ideal vehicle for privately funded developers to link different regions and trade energy.

The technical merits are that by virtue of its standardised prefabricated modular construction which lead to short delivery times, it is relocatable and can be expanded to meet growing demand. Moreover, a key advantage is that it provides accurate control of the transmitted active power and independent control of the reactive power in the connected AC networks.

A pair of lightweight DC cables can be laid direct in the ground in a cost-effective way which is comparable to or less than a corresponding total life cycle cost of AC overhead line. As opposed to an overhead line, an underground cable pair has no visual impact on the landscape. Usually it’s much easier to obtain permission and public approval for an underground cable transmission compared with an overhead line, especially in residential areas.

For these reasons HVDC Light provides an important role as a business concept and opens up new opportunities for both investors and environmentalist.

References

1. Lars Weimers: "New Markets Need New Technology", Powercon 2000 Conference, Perth, Dec 2000
2. Gunnar Asplund, Kjell Eriksson and Ove Tollerz: "Land and Sea Cable Interconnections with HVDC Light, CEPSI 2000 Conference, Manila, Oct 2000.