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Implementing the latest technology in interconnects

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Abstract

The development of power semiconductors and powerful computers have made it possible to develop HVDC systems, HVDC Light, for power transmission that can meet the demands from the rapidly deregulated electricity market.

The most important benefits from HVDC Light are :

- Excellent controllability
- Environmentally friendly
- Short delivery times

The function as well as the characteristics of HVDC Light are described. Examples are given how it can affect the market, its benefits and how it can be used.

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1. Introduction

The development of power semiconductors, such as the IGBT, and powerful computers have made it possible to develop HVDC systems for power transmission that can meet the demands from the rapidly deregulated electricity market.

In the “old” regulated market all HVDC transmission was based on phase-commutated converters using thyristors. The power rating was normally more than 600 MW and the delivery times around 3 years. The customers were often state owned utilities, with their own engineering staff and the specifications were often written by consultants. All this together created a somewhat “heavy” environment for the suppliers, no standardisation was possible because each project was built according to the customers specification. The process from first idea to project realisation was often 5-15 years.

Deregulated projects are often built by investors looking for return on investment. This means that the projects often are motivated by business decisions and not by network conditions. This has led to new project requirements. Some of these are:

- Short delivery times
- Rated power up to 200 MW
- Environmentally friendly solutions

It is important that the time period from a project decision to commercial operation is as short as possible, say max 12 month. To achieve this it is necessary to develop standardised designs and to have a smooth and efficient installation and commissioning process. Furthermore the permitting, including environmental reports and network studies, can not go on for ever. The investor must know that he can get the permits in a reasonable time to even consider the build the project.

By nature, a big project always needs more studies and impacts the environment more than a small project, which makes a big project more risky to build. This , of course, has an impact on the financing and the willingness from the investors to build the project. Experiences from other parts of the world has shown that a rated power of maximum 200 MW is a feasible size in many respects. The power is to small to have a negative impact on the network, should a disturbance occur, and it shouldn’t be to difficult for the investors to sign a PPA (Power Purchase Agreement) for this power level.

Today, environmentally friendly solutions is a must in order to get the necessary permits. For a transmission project there are the sending and receiving stations and the over-head line or cable in between. To get a permit to build an over-head line today is almost impossible, the out-come of the process is very unsure and it can take years until a decision is reached. Using a cable for the transmission will normally not create any permitting problems and the out-come is predictable and will not take long time. The stations should be as compact as possible and should be designed not to have a negative impact on the environment. Audible noise and other possible disturbance factors must be addressed during the design and follow the local standards in order to get the building permits.

2. The HVDC Light Converter

The new HVDC system mentioned above is called HVDC Light and is an invention by ABB. It is based on voltage source converters utilising the latest in power semiconductors and modern control technology. HVDC Light has characteristics which makes it ideal in a deregulated market. The performance during steady state and transient operation makes it very attractive for the system planner as well as for the project developer. The benefits are technical, economical, environmental as well as operational. The most advantageous are the following:

- Independent control of active and reactive power
- Feeding of power into passive networks (i.e. network without any generation)
- Power quality control
- Modular compact design, factory pre-tested
- Short delivery times

2.1 Independent control of active and reactive power

The control makes it possible to create any phase angle or amplitude, which can be done almost instantly. This offers the possibility to control both active and reactive power independently. As a consequence, no reactive power compensation equipment is needed at the station, only an AC-filter is installed. While the transmitted active power is kept constant the reactive power controller can automatically control the voltage in the AC–network.

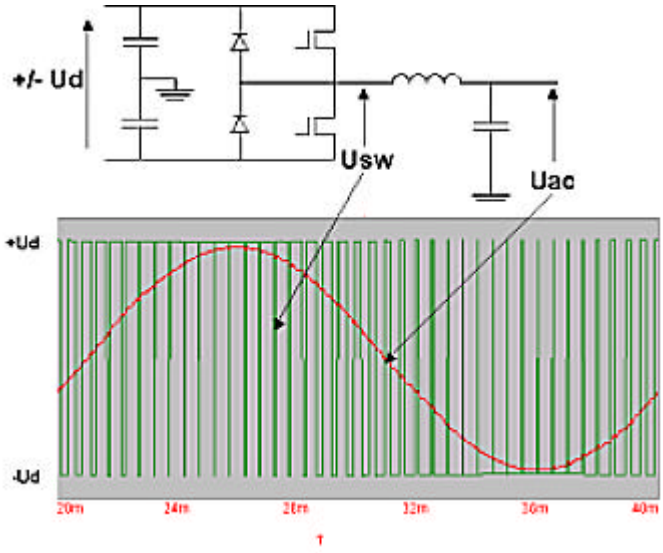

Figure 1. Voltage Source Converter with Pulse Width Modulation (PWM).

2.2 Reactive power support and control

Reactive power generation and consumption of an HVDC Light converter can be used for compensating the needs of the connected network within the rating of a converter. As the rating of the converters is based on maximum currents and voltages the reactive power capabilities of a converter can be traded against the active power capability. The combined active /reactive power capabilities can most easily be seen in a P-Q diagram (positive Q is fed to the ac network).

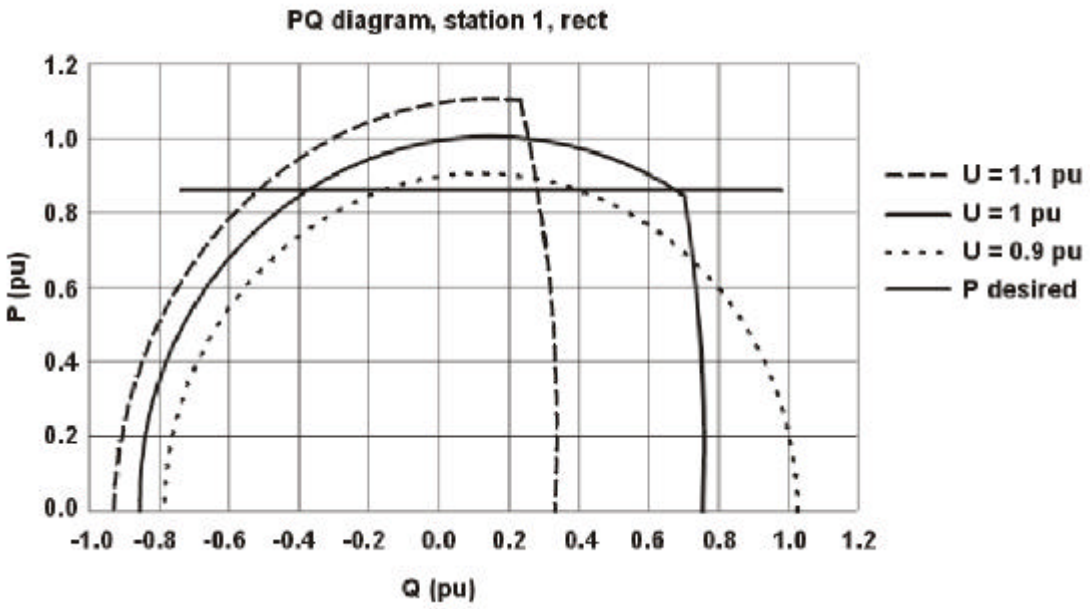

Figure 2. P/Q diagram.
Active/reactive power capabilities of the converter.

2.3 Power Quality and Flicker Control

The Light converter has s a switching frequency of 2 kHz that is 40 times faster compared to a phase commutated converter operated at 50 Hz. This offers new levels of performance regarding power quality control such as flicker and mitigation of voltage dips and sags, harmonics etc caused by disturbances in the power system. Power Quality problems are issues of priority for owners of industrial plants, grid operators as well as for the general public.

In the presence of a fault which would normally lead to an AC voltage decrease the converter can be rapidly deblocked and assist with voltage support to avoid severe disturbances in local industries that are sensitive to voltage dips.

The response time for a change in voltage is 50 ms i.e. for a step order change in the bus voltage the new setting is reached within 50 ms. With this speed of response HVDC Light will be able to control transients and flicker up to around 3 Hz, thereby helping to keep the AC bus voltage constant.

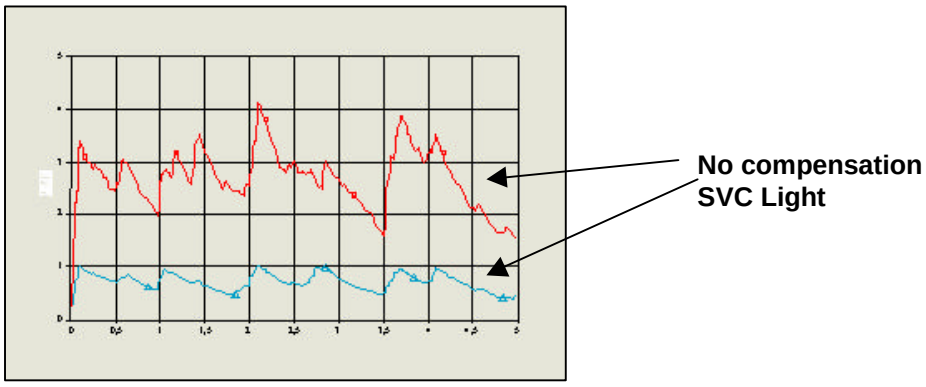

Figure 3. Flicker mitigation with HVDC Light.

2.4 Modular compact design, short delivery times

Major electrical equipment is delivered in enclosures and tested at factory before shipment. This simplifies the civil works and also makes the installation and commissioning faster than for a traditional converter. The heaviest piece of equipment weighs about 20 tons and is transportable by truck direct to site.

Figure 4. Delivery of valve enclosure to the site.

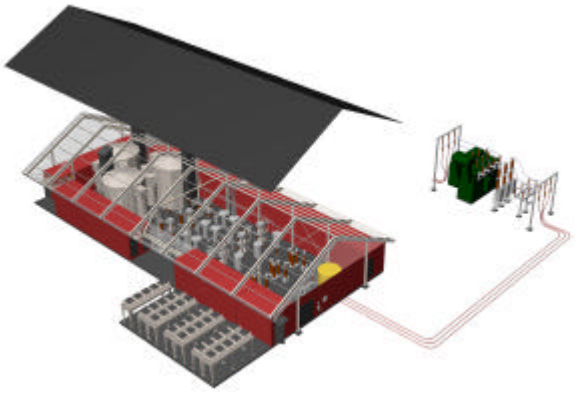

Figure 5. Compact and modular design.

The key to short delivery times is standardisation. The Light concept lends itself to a modular standardised design with a high degree of factory testing. Different types of Light stations have many modules in common which shortens the time for design and manufacturing. The absence of buildings and a minimum of civil work also contributes to short delivery times.

A normal delivery time for a complete Light project today is about 12 month. A 6 month delivery time f.o.b. factory is within reach.

3. The HVDC Light Cable

The HVDC Light extruded cable is the outcome of a comprehensive development program, where space charge accumulation, resistivity and electrical breakdown strength were identified as the most important material properties when selecting the insulation system. The selected material gives cables with high mechanical strength, high flexibility and low weight. Extruded HVDC Light cables systems in bipolar configuration have both technical and environmental advantages. The cables are small yet robust and can be installed by ploughing, making the installation fast and economical.

Conductor:	70-1200 mm^2 aluminum
Insulation:	Triple extruded DC
Screen:	Copper wires
Sheath:	HDPE
Weight:	1- 6.5 kg/m
Voltage:	± 150 kV DC
Current:	< 1200 A

Figure 6. The HVDC Light Cable.

Figure 7. Ploughing of the HVDC Light Cable.

3. Environmentally friendly

The HVDC Light is an environmentally friendly which makes the permitting process fast and smooth. The stations are small and compact which minimises the visual impact. The current , flowing in a pair of cables, generates no electromagnetic field since the cables are installed close to each other. The cables can be buried in existing right of ways such as rail ways , roads or under an existing over-head line. Thus the impact on the environment is reduced to an absolute minimum.

4. HVDC Light -The Ultimate Network Tool

A deregulated market is by its nature dynamic, the conditions and the rules can change rapidly. HVDC Light can easily meet these changing requirements which allows the electricity market to develop without any technical constraints. Some of the most important technical needs are:

- Fast and accurate control of the power transmitted
- Ancillary services (power quality, frequency control e.t.c)
- Location of the converter where it is most needed

5.1 Controllability.

HVDC Light is easy to control and thus well suited for power trading in a deregulated market.. The converter stations can at any time be controlled either by the operator or automatically. There is a choice between a number of control modes :

- Active power
- AC voltage control
- Frequency control
- Reactive power control
- Power quality control

It is also possible to combine some of these, for example Active power with AC-voltage control. At the same time as the converter transmits the ordered amount of active power , the ac-voltage at the ac - busbar is automatically controlled . This is done by letting the converter generate or consume reactive power.

A load profile for the converter stations can be programmed and than executed at a later stage. This can be the case, should the capacity of the HVDC Light be auctioned into a power pool . The dispatch of the link is than controlled by the pool and can easily be programmed into the control system of the converter.

5.2 Ancillary services

The nature of HVDC Light lends itself to ancillary services. At the same time as active power is transmitted , some of the capacity can be used for other purposes. There must be a balance in active power between the stations but the reactive power, generation or consumption, at respective station can be different. This feature can be used for power quality control, or some reactive power can be sold to the network operator should he need it for the operation of the network. The market for this kind of services is new , but it is foreseen that it will increase.

5.3 Location of the converter

The HVDC Light converter is not dependant on the network for its location. Since it can feed a network without any generation, it can be placed where it is best needed from a commercial point of view, without any technical limitations. At the same time, a HVDC Light converter is not sensitive to changes in the network to where it is connected. This means that HVDC Light can adopt to new network conditions without any modifications. Another possibility is to relocate the converter should it be required from a commercial point of view.

5. The Market

HVDC Light was introduced in March 1997. Since than the interest from the market has exceeded all expectations. Today 6 projects have been awarded and many are under preparation. The interest comes from all the electric industry, but most projects under discussion are deregulated and privately financed. Some of the most interesting applications and possibilities for HVDC Light are :

- City center infeed
- Multiterminal DC- grid
- Connection of wind power parks to the main grid
- Utilising existing Rights-Of-Way

7. Directlink

Directlink is a 180 MVA HVDC Light project that will link the regional electricity markets of New South Wales and Queensland. Directlink will be a non-regulated project, operating as a generator by delivering energy to the highest value regional market. By directly participating in the spot market Directlink will earn a market-based return for its owners. That return could include substantial revenues during periods of scarcity in either Queensland or New South Wales, when the market clearing price could rise to as much as $5,000/MWhr.

Directlink employs the HVDC Light technology. In order to facilitate permitting the HVDC Light cable will be installed along existing rights of way for its entire 65 km route, with a substantial portion underground.

The flow of energy over HVDC Light facilities can be precisely defined and controlled, thereby meeting NECA's Safe Harbour Provisions. The ability to control power flow over the facility also means that the capacity rights required for fully commercial network service are readily defined.

The Voltage Source Converter terminals can act independently of each other to provide ancillary services (such as VAR support) in the weak networks to which Directlink connects. The use of the HVDC Light technology will greatly reduce the Directlink construction and commissioning period.

Figure 8. Directlink.

8. Conclusions

It is widely recognised that the role of network services has changed as a result of the introduction of competitive power markets. HVDC Light is a new DC transmission technology that has important advantages for application in competitive markets. These advantages include its modularity, standardised design leading to short delivery times, and compact stations and cables reducing environment impacts and controllability giving possibilities to match the power need and/or to control the voltage in the network. These features mean that HVDC Light facilities can be installed quickly in response to competitive market signals.