**3.DC POWER TRANSMISSION**

**3.1 Introduction**

Over long distances bulk power transfer can be carried out by a high voltage direct current (HVDC) connection cheaper than by a long distance AC transmission line**. HVDC** transmission can also be used where an AC transmission scheme could not (e.g. through very long cables or across borders where the two AC systems are not synchronized or operating at the same frequency).

However, in order to achieve these long distance transmission links, power convertor equipment is required, which is a possible point of failure and any interruption in delivered power can be costly. It is therefore of critical importance to design a HVDC scheme for a given availability.

The HVDC technology is a high power electronics technology used in electric power systems. It is an efficient and flexible method to transmit large amounts of electric power over long distances by overhead transmission lines or underground/submarine cables.

It can also be used to interconnect asynchronous power systems. The fundamental process that occurs in an HVDC system is the conversion of electrical current from **AC to DC** (rectifier) at the transmitting end andfrom DC to AC (inverter) at the receiving end.

[](http://en.wikipedia.org/wiki/File:Nelson_River_Bipoles_1_and_2_Terminus_at_Rosser.jpg)

**3.2 Configurations of HVDC Systems:**

There are different types of HVDC systems which are

* **Mono-polar HVDC system:**

In the mono-polar configuration, two converters are connected by a single pole line and a positive or a negative DC voltage is used. In Fig. There is only one Insulated transmission conductor installed and the ground or sea provides the path for the return current**.**

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**Fig:3.1 Monopolar**

* **Bipolar HVDC system:**

This is the most commonly used configuration of HVDC transmission systems. The bipolar configuration, shown in Fig. Uses two insulated conductors as positive and negative poles. The two poles can be operated independently if both neutrals are grounded. The bipolar configuration increases the power transfer capacity. Under normal operation, the currents flowing in both poles are identical and there is no ground current. In case of failure of one pole power transmission can continue in the other pole which increases the reliability. Most overhead line HVDC transmission systems use the bipolar configuration.

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**Fig:3.2 Bipolar**

* **Homo-polar HVDC system:**

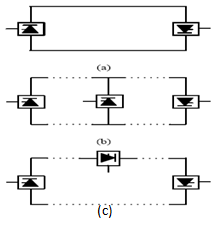
In the homo polar configuration, shown in Fig. Two or more conductors have the negative polarity and can be operated with ground or a metallic return. With two Poles operated in parallel, the homopolar configuration reduces the insulation costs. However, the large earth return current is the major disadvantage.

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**Fig 3.3 Homo Polar**

* **Multi-terminal HVDC system:**

In the multi terminal configuration, three or more HVDC converter stations are geographically separated and interconnected through transmission lines or cables. The System can be either parallel, where all converter same voltage as shown in Fig (a) or series multi terminal system, where one or more converter stations are connected in series in one or both poles as shown in Fig. (c). A hybrid multi terminal system contains a combination of parallel and series connections of converter stations.

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**Fig 3.4 Multi Terminal HVDC System**

**3.3 Advantages of HVDC lines :**

The advantage of HVDC is the ability to transmit large amounts of power over long distances with lower capital costs and with lower losses than AC. Depending on voltage level and construction details, losses are quoted as about 3% per 1,000 km High-voltage direct current transmission allows efficient use of energy sources remote from load centers. In a number of applications HVDC is more effective than AC transmission. Examples include:

* [Undersea cables](http://en.wikipedia.org/wiki/Submarine_power_cable), where high capacitance causes additional AC losses. (e.g., 250 km [Baltic Cable](http://en.wikipedia.org/wiki/Baltic_Cable) between [Sweden](http://en.wikipedia.org/wiki/Sweden) and [Germany](http://en.wikipedia.org/wiki/Germany),  [Nor Ned](http://en.wikipedia.org/wiki/NorNed) cable between Norway and the Netherlands.
* Endpoint-to-endpoint long-haul bulk power transmission without intermediate 'taps', for example, in remote areas
* Increasing the capacity of an existing [power grid](http://en.wikipedia.org/wiki/Power_grid) in situations where additional wires are difficult or expensive to install
* Power transmission and stabilization between unsynchronised AC distribution systems
* Connecting a remote generating plant to the distribution grid, for example [Nelson River Bipole](http://en.wikipedia.org/wiki/Nelson_River_Bipole).
* Stabilizing a predominantly AC power-grid, without increasing [prospective short circuit current](http://en.wikipedia.org/wiki/Prospective_short_circuit_current)
* Reducing line cost. HVDC needs fewer conductors as there is no need to support multiple phases. Also, thinner conductors can be used since HVDC does not suffer from the [skin effect](http://en.wikipedia.org/wiki/Skin_effect)
* Facilitate power transmission between different countries that use AC at differing voltages and/or frequencies
* Synchronize AC produced by renewable energy sources

Long undersea [high voltage cables](http://en.wikipedia.org/wiki/High_voltage_cable) have a high electrical [capacitance](http://en.wikipedia.org/wiki/Capacitance), since the conductors are surrounded by a relatively thin layer of insulation and a metal sheath. The geometry is that of a long co-axial [capacitor](http://en.wikipedia.org/wiki/Capacitor). Where alternating current is used for cable transmission, this capacitance appears in parallel with load. Additional current must flow in the cable to charge the cable capacitance, which generates additional losses in the conductors of the cable. Additionally, there is a [dielectric](http://en.wikipedia.org/wiki/Dielectric) loss component in the material of the cable insulation, which consumes power.

Schemes to multi terminal systems. Controlling power flow in a multi terminal HVDC can carry more power per [conductor](http://en.wikipedia.org/wiki/Conductor_%28material%29) In contrast to AC systems, realizing multi terminal systems is complex, as is expanding existing because, for a given power rating, the constant voltage in a DC line is lower than the peak voltage in an AC line. The power delivered is defined by the [root mean square](http://en.wikipedia.org/wiki/Root_mean_square) (RMS) of an AC voltage, but RMS is only about 71% of the peak voltage. The peak voltage of AC determines the actual insulation thickness and conductor spacing. Because DC operates at a constant maximum voltage, this allows existing transmission line corridors with equally sized conductors and insulation to carry more power into an area of high power consumption than AC, which can lower costs.

Because HVDC allows power transmission between unsynchronized AC distribution systems, it can help increase system stability, by preventing [cascading failures](http://en.wikipedia.org/wiki/Cascading_failure) from propagating from one part of a wider power transmission grid to another. Changes in load that would cause portions of an AC network to become unsynchronized and separate would not similarly affect a DC link, and the power flow through the DC link would tend to stabilize the AC network. The magnitude and direction of power flow through a DC link can be directly commanded, and changed as needed to support the AC networks at either end of the DC link. This has caused many power system operators to contemplate wider use of HVDC technology for its stability benefits alone.

**3.4 Disadvantages of HVDC lines:**

The disadvantages of HVDC are in conversion, switching, control, availability and maintenance HVDC is less reliable and has lower availability than AC systems, mainly due to the extra conversion equipment. Single pole systems have availability of about 98.5%, w DC system requires good communication between all the terminals; power flow must be actively regulated by the inverter control system instead of the inherent impedance and phase angle properties of the transmission line. Multi-terminal lines are rare.

One is in operation at the Hydro Québec - New England transmission from Radisson to Sandy Pond. Another example is the [Sardinia-mainland Italy](http://en.wikipedia.org/wiki/HVDC_Italy-Corsica-Sardinia) link which was modified in 1989 to also provide power to the island of Corsica.

High voltage DC [circuit breakers](http://en.wikipedia.org/wiki/Circuit_breaker) are difficult to build because some mechanism must be included in the circuit breaker to force current to zero, otherwise arcing and contact wear would be too great to allow reliable switching.

Operating a HVDC scheme requires many spare parts to be kept, often exclusively for one system as HVDC systems are less standardized than AC systems and technology changes faster.

Costs vary widely depending on the specifics of the project such as power rating, circuit length, overhead vs. underwater route, land costs, and AC network improvements required at either terminal. A detailed evaluation of DC vs. AC cost may be required where there is no clear technical advantage to DC alone and only economics drives the selection. However some practitioners have given out some information that can be reasonably well relied upon.

For an 8 GW 40 km link laid under the English Channel, the following are approximate primary equipment costs for a 2000 MW 500 kV bipolar conventional HVDC link (exclude way-leaving, on-shore reinforcement works, consenting, engineering, insurance, etc.)

* Converter stations ~£110M

**Table-4.1 Power Transfer of HVAC-HVDC System**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **1000 MW Windfarm,50 km transmission distance** | | | | | | | |
|  | **HVAC + HVDC VSC** | | **HVAC + HVDC LCC** | | **HVAC LCC + HVDC VSC** | | |
|  |  | | **Case 1** | **Case 2** | **Case 1** | | **Case 2** |
| **Rated power** | 200 MW (220kV) AC +  (2\*350+220) MW VSC) | | 200 MW  (400kV) AC +  (600+250)  MW LCC | 330 MW  (400kV) AC +  (600+130)  MW LCC | 600 MW  LCC +  (350+220)  MW VSC | | 250 MW  LCC +  (2\*350+220)  VSC |
| **Cable Numbers** | 1(AC) + 4(VSC) | | 1(AC) + 2(LCC) | 1(AC) + 2(LCC) | 1(LCC) + 24(VSC) | | 1(LCC) + 6(VSC) |
| **1000 MW Windfarm,100 km transmission distance** | | | | | | | |
|  | | **HVAC + HVDC VSC** | **HVAC + HVDC LCC** | | **HVAC LCC + HVDC VSC** | | |
|  | |  | **Case 1** | **Case 2** | **Case 1** | | **Case 2** |
| **Rated power** | | 500 MW (400kV) AC +  (350+220) MW VSC) | 800 MW  (400kV) AC + 250  MW LCC | 900 MW  (400kV) AC + 130  MW LCC | 600 MW  LCC +  (350+220)  MW VSC | | 250 MW  LCC +  (2\*350+220)  VSC |
| **Cable Numbers** | | 1(AC) + 4(VSC) | 2(AC) + 1(LCC) | 2(AC) + 1(LCC) | 1(LCC) + 4(VSC) | | 1(LCC) + 6(VSC) |
| **1000 MW Windfarm,200 km transmission distance** | | | | | | | |
|  | | **HVAC + HVDC VSC** | **HVAC + HVDC LCC** | | | **HVAC LCC + HVDC VSC** | |
|  | |  | **Case 1** | **Case 2** | | **Case 1** | **Case 2** |
| **Rated power** | | 500 MW (220kV) AC +  (350+220) MW VSC) | 800 MW  (220kV) AC + 250  MW LCC | 900 MW  (220kV) AC + 130  MW LCC | | 600 MW  LCC +  (350+220)  MW VSC | 250 MW  LCC +  (2\*350+220)  VSC |
| **Cable Numbers** | | 2(AC) +2 4(VSC) | 3(AC) + 1(LCC) | 4(AC) + 1(LCC) | | 1(LCC) + 4(VSC) | 1(LCC) + 6(VSC) |