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According to the HVDC Transmission System Review Paper,

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Abstract

Power transmission could be disrupted more easily with AC (alternating current) than DC in early days of electrical delivery since transformers utilised it (direct current). For industrial and residential clients, high-voltage AC grids may connect previously isolated distribution networks and massive power plants. Many decades after the introduction of high-voltage direct current (HVDC) technology, the first commercially feasible high-voltage direct current link was not created. This study's focus is on India's existing and future high-voltage direct current (HVDC) transmission networks. The article discusses new developments in HVDC transmission and other technologies. This research compares the design, operation, construction, and maintenance of HVDC transmissions to HVAC. HVDC transmission over an AC framework is also analysed in the paper, which includes an economic assessment In this research, the HVDC transmission frameworks in India are examined in detail. Using HVDC frameworks is recommended in the present development of power frameworks, according to the text.

Bipolar transmission, HVDC linkages, and transmission are the focus of this section..

HVDC History:-

During the first year of the world's first HVDC transmission in Miesbach-Munich power transmission, just 1.5 KW of energy was transferred. It was built on the border of Germany between Miesbach and Munich [16,17]. Obviously, the AC system was instantly adopted for the generation, distribution, and so on of electricity. [13] Voltage conversion was simplified by the transformer in an alternating current system. Among a transformer's most distinguishing features are its low power loss and high electrical output. Synchronized three-phase generators are a great alternative to DC generators. As a result, transmission over an AC network is more straightforward than transmission over a DC network. The HVAC system may be used in a broad variety of settings when employing asynchronous grids and long-distance transmissions.

Table 1 below demonstrates the development of HVDC technology throughout time.

[1]

Table 1: HVDV Technology Development

Hewitt's mercury-vapour rectifier, which showed up in 1901.
Experiments with thyratrons in America and mercury circular segment valves in Europe before 1940.
First business HVDC transmission, Gotland 1 in Sweden in 1954. • First robust state semiconductor valves in 1970.
First microcomputer-based control gear for HVDC in 1979.
Highest DC transmission voltage (+/ - 600 kV) in Itaipú, Brazil, 1984.
First dynamic DC channels for excellent separating execution in 1994.
First Capacitor Commutated Converter (CCC) in Argentina-Brazil interconnection, 1998

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Why choose HVDC over HVAC:-

It's a fascinating question why we choose HVDC over HVAC. In order to transfer electricity, three-phase alternating current is the most popular means of doing so. Furthermore, how does HVDC transmission integrate into today's transmission systems? "" Why do we use HVDC instead of AC for the vast bulk of three-phase energy transmission? Is HVDC transmission a viable option in the existing system? Even though AC is the most widely used electrical transmission system, there have been several drawbacks to this method. To provide one example, the ability to transmit AC over long distances is limited by these factors as well as by the SKIN's effects. [14] The skin effect and the corona effect have less significance for DC and AC conductors. HVDC transmission is ideal for linking several AC grids due of its high efficiency and precision controllability. Our HVDC transmission solution is possible because DC is capable of carrying a large amount of energy with little losses. DC should be utilised instead of AC for power transmission since most renewable energy sources are located in metropolitan areas. HVDC is necessary or desirable from a technology perspective. [2] [16]

HVDCTransmission Network Component:

Poles and a levelling reactor are also included in the conversion station, which includes high-frequency filters and a reactive power source.

Converting Station:

The substation's Rectifier terminal converts AC to DC, whereas the inverter substation does the opposite. Each terminal's rectifier and inverter functionalities must be included within the device itself. A single HVDC transmission line connects the two terminals in this kind of system. Fig. 1 depicts a typical HVDC conversion station.

Fig (1).- Schematic Diagram of A Typical HVDC Converter Station [3]

Converting Unit:

A converter unit is used to convert AC to DC and back again in three-phase bridge converters. The Graetz Circuit is another name for this circuit. A 12-pulse bridge converter (shown in figure[2]) is used to connect two or six bridge converters while utilising HVDC transmission.

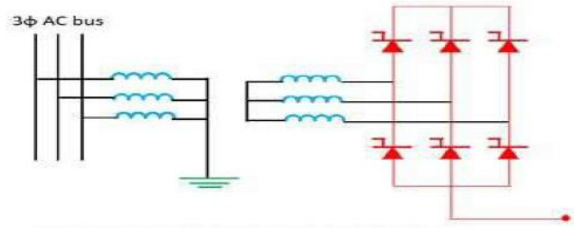


Fig. (2).- 6-Pulse Converter Unit [3]

Converting Valves:

Figure 3 shows the total number of valves in each group of the new HVDC converter's 12-pulse converter units. Series connection valves are made using thyristor-based modules. The necessary voltage across the valve determines the quantity of thyristor valve needed.

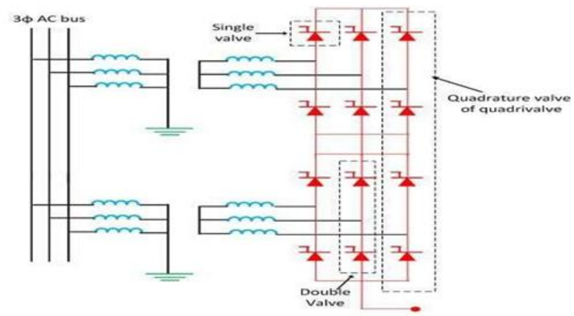


Fig. (3).- 12-Pulse Converter Unit [3]

Converting T/Fs:

Depending on the application, the converter transformer may convert from AC to DC or vice versa. They feature two three-stage winding configurations: AC sidewinding and valve sidewinding, respectively. The converter can eliminate different consonant currents by using Star-Delta and Wye-Delta Connection of T/F to operate with 12 heartbeats each cycle in the AC supply. The whirlpool current's misfortunes, on the other hand, have been boosted by the music current. These other factors have led to the transformer's centre becoming magnetised.

The converter transformer is used to convert from AC to DC and then back again. An AC winding and a Valve sidewinding make up the three stages of winding on these. While the converter used star-delta and delta-star association of T/F to expel different symphonious currents, here the whirlpool current disasters are growing due to sound current. It functioned with 12-heartbeat in every cycle of AC supply. It is because of the following factors that the converter T/F centre gets charged: -: -[17]

a) The sound arrangement for AC.

b) The valve side terminal coordinate voltage also has a few melodies.

Filters:-

In addition, filtering harmonics is essential for the line cumulative converter station's generation of receptive power. The AC and DC sound tracks are pumped into the AC and DC lines separately. In the music, the same focus points may be found. Filtration is required for the generation of reactive energy at a converter plant that is increasing its range. The tones of AC and DC are intertwined with each other. The noises have the following drawbacks:

As a consequence, phone lines are jammed.

In the context of the sounds, machine and capacitor power failures are related.

c. Completed voltages resulted by the reverberation of sound waves in an AC circuit.

d. Instability in converter control.

To limit the quantity of music that may be played, AC, DC, and high-recurrence channels are employed. Networks include AC, DC, and high-frequency filters, among others. A Power Source That Responds: Converting responsibilities are required. Reaction power. Additional power may be provided by using Shunt Capacitors or Static Var Frameworks' Synchronized Stage Modifiers. In making this decision, it was important to evaluate how fast the controller could be turned on and off. Reactor Smoothing:- High-inductance oil in an oil-cooled reactor makes it smooth. The converter is currently connected to this reactor. It may either be on the neutral or line-side of the line. Smoothing reactors are used for two basic reasons:

I. Direct current surges are reduced.

To add insult to injury, they alter the DC voltage and current balance.

Fault current is also reduced by these devices.

The incident's aftereffects Smoothing reactors minimise the rate at which the DC line climbs in the scaffold to avoid inverter disappointments when the direct voltage of another arrangement's associated voltage breakdown occurs.

Smoothing reactors are used to reduce the steepness of voltage and current spikes from the DC line. The converter valves and surge diverters' weight may be reduced in this way. In this segment of the transmission system, HVDC substation equipment is included. This device may also be used to connect to transmission lines. It has a simple polarity with regard to the Earth when it is running properly. As a consequence, the direct current path that has the same polarity as the planet is referred to as a "pole." [12] The medium of communication:-

In most cases, the overhead wire conductors are bipolar, meaning they have opposite polarity. HVDC wires are often used in submerged transmission. It is often accepted that healthy relationships are ones that are rich with oil. There is no limit to the length of the strips or the depth of the oil that may be infused into paper to maintain solids. All of the autonomous oil connections are filled with low-thickness oil so that they may continue to work even when they are under stress. This kind of link, it has been said, might be as far as 60 kilometres. A new underground or subsurface HVDC power supply line has been developed in recent years as new power cable technologies have grown in popularity. VSC HVDC systems make use of this extruded polyethene cable. [14]

Things to keep in mind while creating, building, managing, maintaining, and budgeting for:-

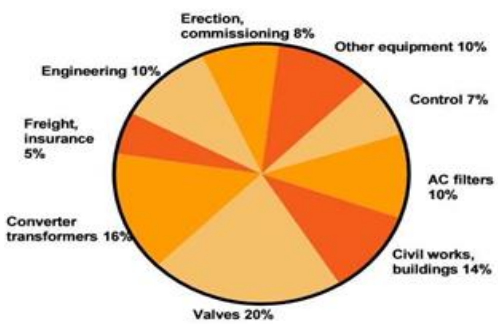
For large HVDC frameworks with one-year thyristor thyristors, the development time might range from three years to HVDC VSC frameworks dependent on contract date to dispatch. Table 2 shows the experience of numerous HVDC advancements and the unique kind of HVDC through time. [4] [1]

Ordinary commutated HVDC 3 years
CCC based HVDC 2 years
VSC found HVDC 1 year

Table 2: HVDC Operation Time for Various Systems
Because the term "task" relates to continuing operations to maintain the framework's accessibility at a textual level, we'll use it here. It is now possible to remotely operate HVDC connections thanks to integrated semiconductor and chip-based control frameworks already available. In the meanwhile, there are unmanned offices. HVDC frameworks are also designed for jobs that do not need human interaction. If there are just a few personnel who are capable of operating several HVDC connections from a central location, this component is required. High-voltage direct current (HVDC) systems have maintenance that is quite similar to high-voltage alternating current (HVAC) systems. Methods employed in AC substations may be utilised to maintain high-voltage equipment in switch stations. Work has to be done on AC and DC channels, smooth reactors, dividers, valve cooling gear, and thyristor valves to get them ready for production. In most cases, the amount of time it takes to get up, start, and get underway on a job is sufficient to plan and help.

First, a breakdown of costs.

An HVDC framework's price depends on a variety of factors, including the maximum power transferred, environmental conditions, the kind of transmission medium used, and other administrative and well-being needs, for instance. The cost structure may be shown in Figure 4.



Fig(4).- Cost Structure[1]

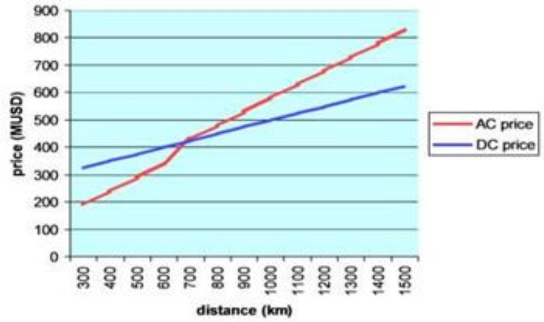


Fig.(5).- price variation for an AC transmission compared with an HVDC transmission[1]

Figure 1 shows the pricing difference between an 2000 MW may be delivered by an AC transmission or an HVDC transmission (5).

Estimated costs for the AC substations and compensation (over 600 km) for two-circuit AC transmission vary from 250 USD/km to 80 MUSD/km. Because converter stations are priced at $250 million, 250 USD/km for the bipolar OH line was acceptable. [5]

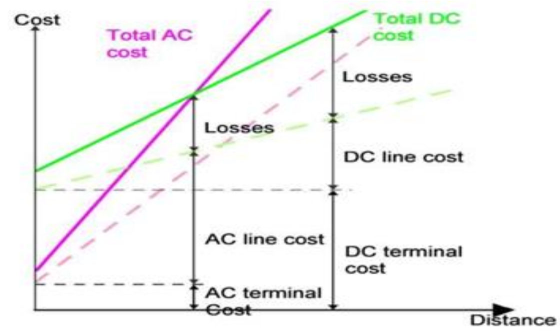
Both HVDC and high voltage AC transmission frameworks have been discovered to have a significant connection with each other, as have an HVDC framework given VSC and an AC framework and an age source.

High voltage AC versus thyristor based HVDC:

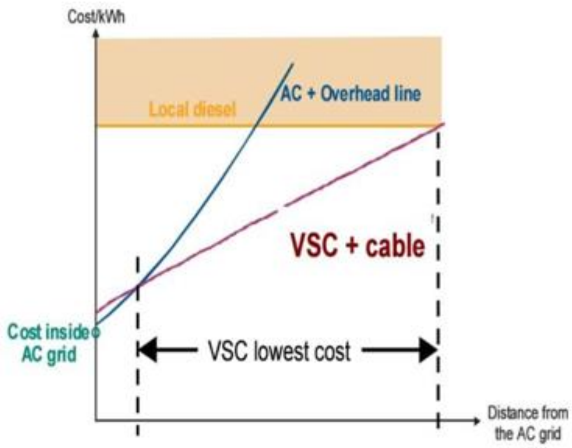
In comparison to high voltage AC substations, the cost of HVDC converter stations is significant. HVDC also reduces operating and support expenses. The HVDC framework has greater levels of introductory misfortune, but this does not change when the HVDC framework is removed. As shown in Fig. 2, a high voltage AC framework's misfortune levels rise with deletion, despite what one may suppose (6).

HVDC vs AC: Which one is better?

Short range parts of the power transmission range (many kilometres) may benefit from VSC HVDC-based frameworks. As shown in the following picture, the most feasible alternative to a high voltage AC framework is the VSC-based HVDC framework (7). [5]



Fig(6): Thyristor based HVDC system [5]



Fig(7): VSC based HVDC system[5]

Overview Of HVDC Application:- Following Fig(8) is showing an outline of HVDC application.

	Long distance transmission over land	Long distance transmission over sea	Interconnections of asynchronous networks	Windmill connection to network	Feed of small isolated loads
Natural commutated HVDC with OH lines	x		x		
Natural commutated HVDC with sea cables		x	x		
Capacitor Commutated Converters (CCC) in Back-to-Back			x		
Capacitor Commutated Converters (CCC) with OH lines	x		x		
Capacitor Commutated Converters (CCC) with sea cables		x	x		
VSC Converters in Back-to-Back			x	x	
VSC Converters with Land or Sea Cables	x	x	x	x	x

Fig. (8).- Overview of HVDC Application [5]

3 types of HVDC frameworks are the most used in the industry. The operational necessities, demand adaptability, problem of consistent quality, and cost all play a role in determining each structure throughout the arranging stage. The following are some of the most well-known HVDC design diagrams. [15]

Monopolar

It employs a single negative extremity driver and either land or water to gain velocity. In very rare cases, a metal back may be appropriate. This arrangement has two converters at the end of each post. Anodes are utilised to attach shafts to their foundations at 15 and 55 km from the terminal stations. Since this connection depends on the Earth as a return route, it has several limitations. Monopolar interfaces are seldom used in the current world. Figure 3 depicts the monopolar contact (9). [5]

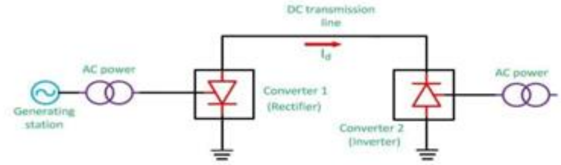


Fig.9.- Monopolar Link [3]

Bipolar link –

A bipolar connection has two conductors: one is positive for the earth and the other is negative. In both directions, the link is reshaped by the connection. At their midpoints, anodes link the converter stations to the earth. Conductor power is only transmitted via the field voltage terminals, which are linked to the conductor. Due to the arrival to ground, a bipolar connection transitions to monopolar mode if one of the connections breaks. Framework. Only half of the structure is now producing electricity. These sorts of connections are common in HVDC setups. As seen in figure (10) [4,] there is a bipolar link between the two.

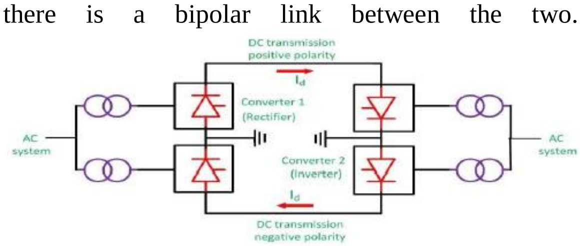


Fig.10- Bipolar Link [3]

Homopolar Link–

Mass or metallic returns are employed in connection with conductors having equivalent extremities, generally of the negative variety. Because the shafts are connected in series, the cost of protection is lower. In the meanwhile, this framework is not being utilised. Figure 11 depicts homopolar security.

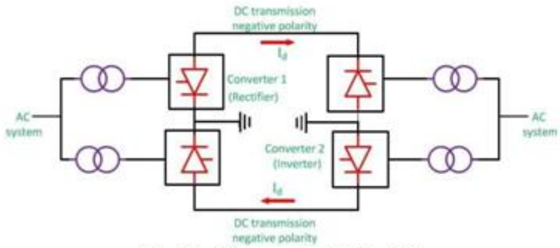


Fig.11- Homopolar Link [3]

Long-distance Transmission:-

High-voltage transmission is made possible by using this transmission method when distance between the two AC stations is greater than the initial outlay. Fig.12 shows the HVDC transmission system with a long spacing. [5]

Fig.12- Long Distance Transmission [3]

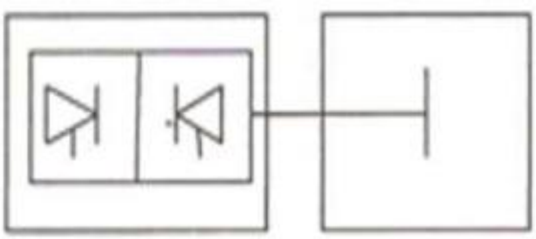


Fig.13-Back To Back Transmission [3]

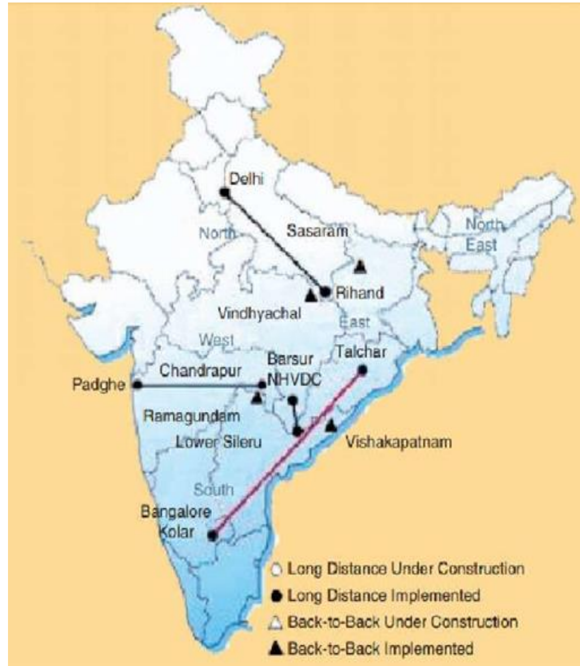
Back to Back Transmission:-

When the voltage to be transferred is high and the two stations operate at different frequencies, this sort of transmission is linked. Consecutive Fig. 13 shows the HVDC transmission structure.

HVDC TRANSMISSION IN INDIA:

Following Fig.14 is showing HVDC Transmission Existing in India.[6][10]

HVDC Transmission Existing in India
Source: Central Electricity Authority of India



Electrical Authority of India).

a) Bipole line	±500 kV	Circuit kilometers
Chandrapur-Padghe (1999)		1,504
Rihand-Dadri (1990)		1,634
Talcher-Kolar (2002)		2,738
Balia-Bhiwadi (2009)		1,800
Biswanath-Agra (2014)		3,600
b) Bipole transmission capacity		MW
Chandrapur-Padghe (1999)		1,500
Rihand-Dadri (1990)		1,500
Talcher-Kolar (2002)		2,500
Balia-Bhiwadi (2009)		2,500
Biswanath-Agra (2014)		4,000
c) Back-to-back transmission capacity		MW
Vindhachal (1989)		500
Chandrapur (1999)		1,000
Gazuwake (2009)		1,000
Sasaram (2002)		500
Vizag (1990)		500
d) Monopole line Barsur-Lower Sileru (2000)—162 circuit kilometer		200
e) Monopole transmission capacity Barsur-Lower Sileru (2000)		200

Fig14.- HVDC Transmission In India [6]

(1) Dadri HVDC Project: Below Fig. 15 & Table 3 is showing details of this project.

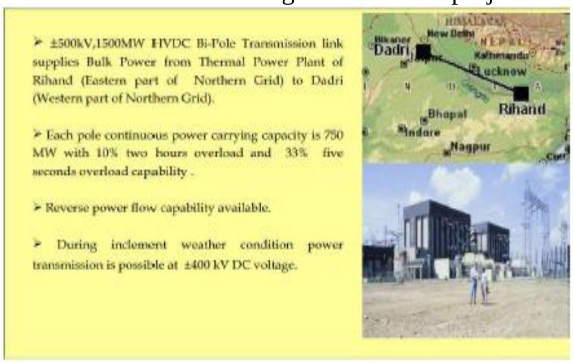


Fig.15.- Dadri-HVDC Bi-Pole Transmission Link [10]

Main Data:

a) Commisioning Date: Dec-1991
b) Rating: 1500 MW
c) Poles: 2
d) Voltage (AC) : 400 kV
e) Voltage (DC) : + 500 kV
f) Converter Transformer Rihand
g) Terminal: 6 x 315 MVA Dadri
h) Terminal : 6 x 305 MVA
i) Length of overhead HVDC line: 816 KM.

Table 3.- Dadri HVDC Project Details[6]

2) Vindhyachal Back to Back Station:

Table 4 is showing details of this project.

Main Data:

a) Project Completing Date: April 1989
b) Power rating : 2 x 250 MW.
c) Blocks : 2
d) Voltage (AC): 400 kV
e) Voltage (DC): ± 70 kV
f) Converter Transformer : 8 x 156 MVA

Table 4 - Vindhyachal Back to Back Station Project Details.[10]

3) Chandrapur Back to Back Station:

Main Data:

a) Starting date: November 1993
b) Completing period: Dec 1997
c) Power rating: 2 x 500 MW.
d) Blocks : 2
e) Voltage (AC) : 400 kV
f) Voltage (DC) : 205 kV
g) Converter Transformer : 12 x 234 MVA

Table 5 - Details of Chandrapur Back to Back Station Project Details.[10]

4) Talchar – Kolar Transmission: -

The longest commercial HVDC link in India is Talchar-Kolar transmission, the distance around (1369 Km.). Table 6 is showing details of above project.

project:

System Salient Features:

Main Data:

a) Completing date: June 2003
b) Power rating : 2000 MW
c) Poles : 2
d) Voltage (AC): 400 kV
e) Voltage (DC): + 500 kV
f) Converter Transformer at Talcher : 6 x 398 MVA
g) Kolar : 6 x 398 MVA

Table 6.- Talchar-Kolar Transmission Project Details[10] Project Details [10]

(5) Sasaram Back to Back Station:

It is located between Pusauli (Eastern Region) to Sasaram (Eastern part of Northern Grid) of Indian Grid (Power Transfer mainly from ER to NR). Table 7 is showing details of the above

Main Data:

a) Completing date: Sep 2002
b) Power rating: 1 x 500 MW.
c) Blocks : 1
d) Voltage (AC) : 400 kV
e) Voltage (DC) : 205 kV
f) Converter Transformer : 6 x 234 MVA

Table 7 - Details Of Sasaram Back to Back Station

6) Gazuwaka Back to Back Station:
This transmission line is connected between Jeypore (Eastern Region) to Gazuwaka (Southern Region) Thermal Power Stations of Indian Grid.
Following Table 8 is Showing details of this Project:-

Main Data:

a) Completing date: 1st Block: Feb 1999, 2nd Block: March 2005
b) Power rating: 2 x 500 MW.
c) Blocks : 2
d) Voltage (AC) : 400 kV
e) Voltage (DC) : 205 kV in 1st Block and
   i. 177 KV in 2nd Block,
f) Converter Transformer: 1st Block : 6 x 234 MVA
   1. 2nd Block: 6 x 201.2 MVA

Table 8.- Details of Gazuwaka Back to Back Station [10]

7) Ballia – Bhiwadi Transmission Link:
That transmission line is connected between Ballia (Eastern Part) and Bhiwandi (Northern Part).

Main Data:
Pole 1 Commissioned on 31-03 2010
Power rating: 2500 MW
Poles: 2
Voltage (AC) : 400 kV
Voltage (DC): + 500 kV
Length of Overhead HVDC transmission: 780 Km.
Converter Transformer at Ballia : 8 x 498 MVA
And at Bhiwadi 8 x

Table 9.- Details of Ballia – Bhiwadi Transmission Link Project [10]

Advantages of HVDC over AC transmission:

a) HVDC frameworks currently make use of decades' worth of experience, as well as the most recent advancements in technology and materials. An environmentally-friendly method of distributing electrical vitality is the final product. If an AC transmission method had been employed, the usefulness of an HVDC system would have been much more difficult to comprehend, since it carries electrical power from one site to the next.
b) Among other things, the following are some of them:
c) Due to the fact that just two wires are needed to transfer data, the cost of transmission is less.
d) b) b. There is no reactive power. As a result, transmission losses have been reduced..
e) c) c. The same power current is lowered due to high voltage transmission. Thus, the I2R loss is quite minimal.
f) d) Due to the lack of skin effect in DC transmission, very thin conductors may be used. Thick conductors are required for HVAC transmission in order to eliminate the skin effect.
g) It is possible to connect two AC frameworks with different frequencies using HVDC transmission lines. This is not possible with HVAC transmission structures.
h) As a result of the lower cost of installation, f) With HVDC, just two cables and fewer towers are required.
i) g) Electronic converters are employed in HVDC. In contrast, HVAC may be put in place much more rapidly. Thus, the DC transmission design has greatly increased transient stability.
j) h) The electrical control levels of the HVDC framework may be altered if necessary (i.e., quick).
k) I Because it does not need charging current or active power, HVDC is ideal for transfer of control across connections.
l) When compared to HVDC transmission, HVAC activates body streams close to the wires.
m) k) k. HVDC transmission is not affected by dielectric misfortune warming in conduit protection.
n) l) l. The radio and television impedance of HVDC is the lowest and the noise level is the lowest.
o) m) m. Bipolar transmission alters the voltage levels in reference to the ground.n. DC connections are less costly than AC links for transmission.
p) The absence of charging and reverberation in HVDC leads to a high level of productivity.

HVDC's drawbacks as a means of transmission

- HVDC transmission necessitates a high cost of switching and changing sources. This means that low power supplies over short distances are not cost-effective.
- Controlling converters is a mind-boggling undertaking.
- An HVDC transmission architecture will need additional channels at various stages. As a result, there is an immediate high cost

of entry. [7] [8]

The Electricity Industry's Use of HVDC Technology:-

HVDC transmission vs AC transmission is often a topic of discussion. In the past, HVDC was considered the best option for situations such as:

1. Long-distance transmission of broad measurements of intensity (>500 MW) was required;
2. Submerging a force in water;
3. In a nonconcurrent method, two AC's are linked together.
4. HVDC frameworks continue to be the most cost-effective and environmentally friendly option for the above-mentioned typical applications. HVDC frameworks, on the other hand, may be preferred over high-voltage AC frameworks in a variety of situations due to three distinct factors: innovation advancement, deregulation of the power sector around the world, and a quantum leap in efforts to moderate the Earth. I'll go into further detail about this:
5. For example, the VSC-based HVDC frameworks, and the new ejected polyethene DC connections, have enabled HVDC to become financially viable at bringing down power levels (up to 200 MW) and across a transmission distance of just 60 kilometres.

6. Different demands for the foundation of power have been hastened as a result of liberalisation. Today, transmission is a contractual service, and any divergence from the agreed-upon specifications or costs may have serious consequences. HVDC is the preferred method for legally binding transmission administrations because it provides greater control over the power interface.
7. Liberalism has sped the marvel of transferring power, which is bi-directional power swaps depending on economic circumstances. 7. The bi-directional power streams can only be enabled by HVDC frameworks, as opposed to AC frameworks (two parallel structures would be required).
8. Because establishing rights-of-way used to be easier under the old norm of "Famous Domain" (i.e. a state-owned, vertically organised utility), it used to be easier to secure the transmission benefit. The transmission benefit arrangement is generally in the region of corporatized, now and then privatised, substances with development of the transmission benefit arrangement. Land acquisition and right-of-way acquisition are currently significant expenditures for the project. In comparing HVDC vs. AC, these costs are added up and it becomes clear that HVDC is far more environmentally friendly since it uses less land/right-of-way to produce the same amount of power.
9. The reduced impression of HVDC transmission frameworks becomes the primary probable technique to manufacture a power connection in an environmentally sensitive place, for example, national pauses and assured asylums.
10. How should control framework organisers, investors in control foundation (both open and private), and agents of such foundation be directed in choosing between HVDC and high voltage AC elective? Allowing the "market" to decide is the proper course of action. When it's all said and done,
11. As an alternative to the practise of publishing specialised details (which are often unyielding and frequently incorporate more seasoned advancements and strategies) while accepting transmission framework proposals, the organisers, speculators and lenders should issue useful decisions for the transmission framework to qualified temporary workers.

12. For example, the power limit, separation, accessibility and unchanging quality requirements; and, finally, the ecological circumstances might be specified.
13. Bidders should be able to provide either an HVDC or AC solution, and the best option should be selected.
14. Many additional transmission projects may choose HVDC as a result of changes in power market circumstances, developments in mechanical technology, and environmental considerations. [9][11].

Conclusion

We can only conjecture about the future of HVDC. In order to benefit organisations and the general public, this may be done, but more modern and open spectra from the HVDC innovation must be added. The neighbouring states will continue to work together in the future. More current or new major power stations might be connected to HVDC in the future (as observed today in India, China, Brazil...). HVDC lines will eventually be "interlaced" across the EU, and then the next phase will be an integration of these lines into one complex framework. Please keep me in your prayers.Do you think this might happen in the future? If that's the case, I'm at a loss. There are challenges to be addressed, and the HVDC control framework is one (and maybe the only) answer. I am certain that the techniques will be created, despite the torturous process that goes along with practically every EU decision and arrangement.

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