A Review Paper on Technical Data of Present HVDC Links in India

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Abstract: HVDC trend is increasing day by day due to its technical advantages over AC like long distance bulk power transmission, asynchronous integration of AC systems etc. One of the important applications of HVDC is bulk power wind energy transmission from offshore to onshore grid. This paper provides present complete individual technical data of HVDC links of both Bi-polar and Back-to-back transmissions projects commissioned in India.

Keywords—HVDC links, Bi-polar Transmission, Back-to-back transmission.

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I. INTRODUCTION

HVDC Technology which is used for long distance bulk power transmission, asynchronous interconnection of two different systems to solve AC Transmission problems.

In HVDC through the controlled actions of power electronics devices, AC power is converted to DC power and made ready for transmission. For applications of Power transmission via cables, bulk power transmission over long-distance, unsynchronized AC-system connection, power system stability improvement and firewall function against instability spread, HVDC transmission is more advantageous than HVAC transmission.

One of the most important applications of HVDC transmission is integrating offshore wind farms to onshore grid via DC cables. HVDC transmission helps for high voltage long distance transmission under water. There are two technologies of HVDC transmission: the LCC-HVDC and VSC-HVDC transmission. The line commutated converter based HVDC is also known as classical HVDC. It is currently a widely used DC transmission system. It uses thyristor based converters. Thyristor converters turning off need the current flow through them to be zero. Hence the switching frequency is system frequency 50 or 60 Hz. This results in production of low order harmonics and a requirement of larger filters for filtering out the generated harmonics. Conventional HVDC always consumes reactive power. This is due to the lagging current which is generated by delayed firing of the converter switches. This reactive power demand is a disadvantage to the Surrounding AC network. The reactive power supply is done by shunt capacitors or Static Var Compensators (SVC) installed at the end terminals.

II. TYPES OF HVDC SCHMES

Mainly there are three types of HVDC schemes. The selection of each scheme at planning stage depends on the operational requirements, flexibility of demand, reliability issue and cost. The following are the most common HVDC configuration schemes [3].

1. Mono Polar: In this configuration scheme a single line is used between the converters and either a positive or negative voltage is used for the transmission. The ground or sea or metal can be generally used as return path. Most HVDC installations start as a mono polar transmission, latter developing to the advanced schemes such as bipolar or homopolar schemes shown in Figures 2.1, 2.2 and 2.3 respectively.

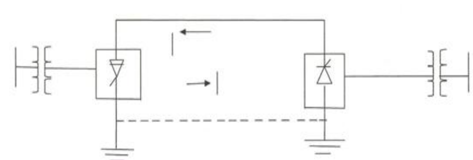

Fig.2.1. Mono Polar link

2. Bi Polar: Here power transmission is carried out using two conductors of opposite polarity. It is a combination of two mono polar systems. Due to this doubling reliability of the system is increased. When one pole of the transmission is removed the other part resumes the normal operation using ground as a return path.

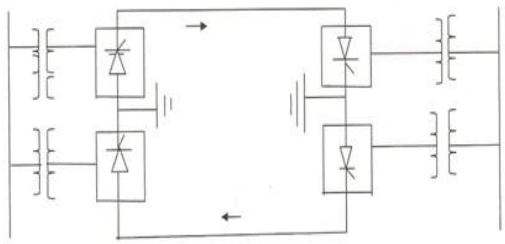

Fig.2.2. Bi Polar link

3. Homo Polar: This is a zero distance transmission. The two converters are connected to each other without any DC line. Back-to-back scheme is applied when two transmission systems of different frequency and different control principle are interconnected.

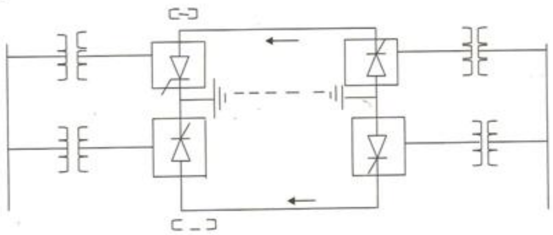

Fig.2.3. Homo Polar link

4. Long distance Transmission:

This type of transmission is applied when voltage to be carried is high and distance between both AC stations is more than break even distance.

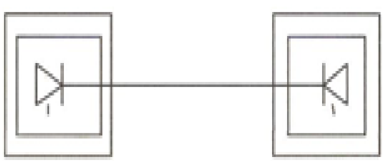

Fig.2.4. Long Distance Transmission

5. Back to Back Transmission:

This type of transmission is applied when voltage to be carried is high and both stations are operating at different frequencies.

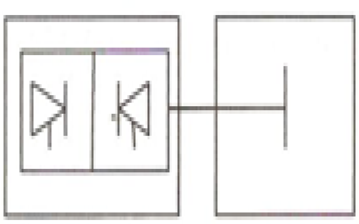

Fig.2.5. Back to Back Transmission

III. COMPONENTS OF HVDC SYSTEM

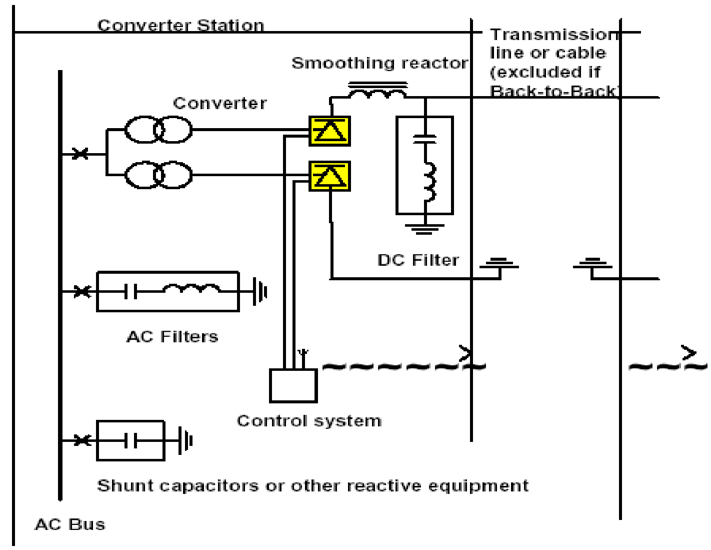

Fig.3.1. Components of HVDC system

The main components in the HVDC transmission system are:

1. Converter unit: This usually consists of two three phase converter bridges connected in series to form a 12 pulse converter unit. The total number of valves in such a unit is twelve. All modern HVDC valves are water-cooled and air insulated.

2. Converter Transformers:

Special features of converter Transformers:

High stresses: As compared to power transformers, the generator transformers are subjected to higher stress due to: Valve side windings are subjected dc voltage during polarity reversals highest voltage stresses occur, Presence of dc voltage in addition of ac voltage, Higher magnetizing current due to dc voltage, Higher harmonic content, Higher abnormal over voltage and frequency short-circuits currents during converter operation.

Special design requirements:

(a) Special design of windings and insulating system.
(b) Special design of core and magnetic circuit.
(c) Special design of bushings.

Converter transformers are arranged in different ways as shown in fig.3.2.

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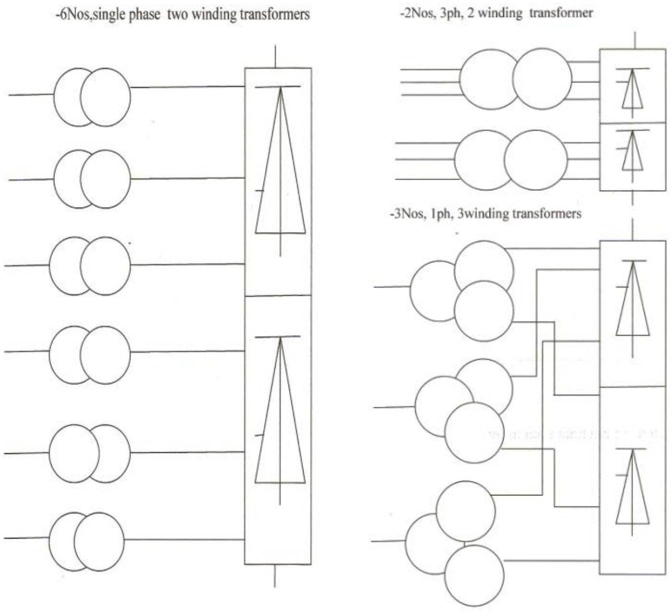

Fig.3.2. Different arrangements of converter Transformer

3. Smoothing Reactor:

It is a coil connected to DC line which reduces ripple in DC link, Limits over current during faults and also helps to prevent from commutation failure.

4. AC and DC Filters:

They are connected on both sides of the station purpose is to reduces harmonics generated in AC and DC links

IV. IV. TECHNICAL DATA OF HVDC PROJECTS IMPLEMENTED IN INDIA:

1. BIPOLAR PROJECTS:

(i) Chandrapur-padghe HVDC bipolar project:

Commissioning year	1999
No. Of poles	2
Length of overhead dc line	752km
Rated Power	1,500MW
AC system voltage	400KV
DC voltage, nominal	500KV
Overload capacity	1,650MW for 2 hours, 2,200MW for 5 sec.
Maximum continuous current	1700A
AC Filters	
Number of banks in Chandrapur	4*200MVAR
Number of banks in Padghe	4*200MVAR
Thristor valves	
Valve Type	Quadruple
Cooling system	Water
Thyristor size	$45cm^2$
Number of thyristors per valve	96
No. Of dc banks per station	2
Maximum voltages per thyristor	7KV
Converter transformer	
Type	Single-phase, 3- winding
Rated power	300 MVA each
Ac grid at both ends:	Synchronous
Ambient temperature:	33^0C
Main reasons for choosing HVDC	Long distance, stability, frequency and Damping control.
Emergency change of power flow	manual or automatic
Power company	Maharashtra state electricity board, Bombay
Supplier	ABB/BHEL

(ii) Rihand-delhi HVDC bipolar project:

The Rihand-Delhi HVDC transmission is the first commercial long-distance HVDC link in India.

Configuration	single bipiole circuit
Power rating	Monopolar -750MW at 1991 bipolar-1500MW at 1992
No of converters per station	2
Transmission	overhead
Main reason for choosing HVDC	long distance, stability
Operating voltage for ac yard	400KV
Operating voltage for dc yard	±500 kV
No of converter transformers	6 each of 300MVA; 3 winding single phase.
No of quadruple valves	6
Minimum clearance phase to phase on 400KV AC side	5.75m
Minimum clearance phase to ground on 400KV AC side	3.65m
Minimum clearance phase to phase on 500KV DC side	12m
Minimum clearance phase to phase on 500KV DC side	7m
Size of busbars in DC yard	10
Size of busbars in AC yard	4
Transmission line voltage	7KV

Transmission line length	820km
Power rating	1500MW
Total Mvar of ac filter in 2 stations	200 Mvar
Direct current	1568A
Reactive power supply	capacitors
Ac grid at both ends	synchronous
Control	constant power, damping control
Emergency change of power flow	manual or automatic
Power company and main supplier	National thermal power cooperation India, LTD, BHEL

(iii) Talcher-kolar HVDC bipolar project:

This is the largest power transmission project in India Linking the Indian states of Karnataka and Orissa over a distance of some 1450 km with the rectifier (AC into DC) and inverter (DC into AC) stations very distant from each other.

Total value	200 million euro
Transmission length	1,450 Km
Commercial operation	February, 2003
Rated power	2000MW, bipolar (2003), 2500MW (2007)
Dc transmission voltage	±500 kV
Rated current	400KV
Maximum allowable over load	1.15 Pu for 120Min, 1.3Pu for 30Min and 1.47 Pu for 5Sec.
Ac system voltages	
Eastern terminal (Orissa)	400Kv, 50HZ
Southern terminal (Bangalore)	400Kv, 50HZ
Smoothing reactor	250mH dry air core type/pole
Dc filter , per station and pole	1 Double-tuned filter 12/24, 12/36.
Ground electrode	Dry type ground electrodes
Ac filters/ reactive power compensation elements	
Eastern terminal (talcher)	6 no double-tuned (Ac) filter 12/24, 120Var, each. & 3no (DT) ac Filter 3/36, 97 Mvar each. 1 no shunt capacitors, 66 Mvar, 2 no shunt reactor, 80 Mvar, each.
Southern terminal (kolar)	106no Double tuned ac filter 12/24, 120Mvar, each. 3no DT ac filter 3/36, 97 Mvar each. 5no shunt capacitor 138 Mvar each
Power thyristors	
Converter values	3,888no (ETT)
Converter transformers	7no single phase 3winding rated at 397MVA (inc 1 spare transformer) (same for both sides).

(iv) Lower sileru-barsoor HVDC Bipolar project:

Parameters	Stage-1	Stage-2	Stage-3
Voltage	+100Kv DC Monopole 6 -pulse	+200Kv DC Monopole 12 -pulse	+200Kv DC Bipole 12 -pulse
Current	1000A	1000A	1000A
Transmitted power	100MW	100MW	100MW
Ac side voltage	220Kv	220Kv	220Kv
Line segment	196KM	196KM	196KM
Valve type	Double	Quadric	2 Quadric
Valve cooling	water	---	----
Valve insulation	Air	---	----
Converter transformer	40.5 Mvar, 10 Kv	---	----
Smoothing reactor	single phase 0.45 Henry, 200Kv 1000A DC	0.45 Henry, 200Kv 1000A DC	----

(v) Biswanath -Agra HVDC Bipolar project:

Commissioning year	2015
Project type	Multi terminal (UHVDC)
No of poles	2
No of converters	4
Power transmitted, MW	6000MW

Dc voltage, KV	800Kv
Ac voltage	400Kv
Length	1728Km
Reactive power supply	capacitors
Connecting region	North-Eastern and Eastern region of India
Emergency change of power flow	Automatic power reduction triggered by ac signal
Main reason for choosing hvdc system	Long distance, bulk power
Power company and supplier	ABB has been selected by Powergrid Corporation of India Ltd

(vi) Ballia- Bhiwadi HVDC Bipolar project:

Commissioning year	Pole1: March 2010 Pole 2: March 2011
No of poles	2
Power transmitted, MW	2500MW
Dc voltage, KV	500Kv
Ac voltage	400Kv
Length	780Km
Reactive power supply	capacitors
Connecting region	North-region and Eastern region of India
Emergency change of power flow	Automatic power reduction triggered by ac signal
Main reason for choosing HVDC system	Long distance, bulk power

(vii) Mundra- Mohindergarh HVDC Bipolar project:

Commissioning year	2012
No of poles	2 (bipole)
Power transmitted, MW	1500MW
Dc voltage, KV	500Kv
Ac voltage	400Kv
Length	986Km
Reactive power supply	capacitors
Connecting region	Western-region and Northern region of India
Emergency change of power flow	Automatic power reduction triggered by ac signal
Main reason for choosing hvdc system	Long distance, bulk power

2. Back-to-back interconnected Projects:

(i) Vizag HVDC project:

Commissioning year	2005
Rated power	500Mw (1999) vizag-1 500Mw (2005) vizag-2
Overload capacity	550Mw for2 hours 666MW for 5sec
Dc voltage	205KV vizag-1 88KV vizag-2
Type of link	back to back
Ac system voltage	400Kv
Smoothing reactor	2no air insulated, 3 0MH each
Station occupies an area	450x150m
AC filters	
Number of banks, east side	3x110Mvar, hp12/24(each)
Number of banks, south side	3x110Mvar, hp12/24(each)
Shunt reactor each side	80 Mvar
Max increase of firing angle	63’ deg
Thyristor valve	
Valve type	Quadruple 1 valve consists of six thyristor modules with 6 thyristor/module
Cooling system	de-mineralized water
Thyristor size	5 inches
No of thyristor per single valve	36
Total no of thyristors	864
Max voltage per transistor	7.2KV
Converter Transformer	
Type	Single phase, 3 winding (6 units).
Rated power	201MVA (each)
Main reason for choosing HVDC	Asynchronous network
No of poles	1
Converters per station	2x2
Direct current	2860A
Reactive power supply	capacitors
Ac grid at both ends	Asynchronous
	Power control, frequency control, voltage control

Control	
Supplier of equipment	ABB

(ii) Vindhyachal HVDC project:

Commissioning year	1989
No of poles	2
Power transmitted, MW	2x250
Dc voltage, KV	2x69.7
Direct current, Amp	3600
Reactive power supply	capacitors
Converter station location and ac grid voltage	Northern system, 400Kv, Western system, 400Kv
Ac grids at both ends	Asynchronous
Control	Constant power in either direction and damping control
Emergency change of power flow	Automatic power reduction triggered by ac signal
Main reason for choosing hvdc system	Asynchronous link
Power company and supplier	National thermal power Cooperation New Delhi India, ABB

(iii) Sasaram HVDC project:

Year of commissioning	2002
Power rating	500MW
Dc voltage	205kV
Line/cable	back to back
Power company	power Grid Corporation India ltd.
Ac grids at both end	Asynchronous
Rated current	2,475A
Valve configuration	Configuration 50 thyristor form a valve and 4 valves stacked vertically form a Quadri-valve tower
Diameter of a thyristor	100mm
Reason for choosing HVDC	Asynchronous link
Control	constant power in either direction
Length of cable	back to back
No.of poles	1
Emergency change of power flow	Automatic power reduction triggered by ac signal

(iv) **Chandrapur HVDC project:**

Commissioning year	1998
No. Of poles	2
Length of the line	736km
Rated Power	1,500MW
DC voltage, nominal	500KV
Operating current	2,475A
Valve configuration	54 thyristors in series in each Valve 4valves stacked vertically form quadric valve tower
Diameter of thyristor	100mm
Cooling system	Water
Each pole parameters	500Mw, 205Kv dc, 2,475A
Shunt capacitors each side	424Mvar of each side of 500Mw, configured as four switch able units of 106Mvar
Over load capability	10% for 2hours and 33% for 5 sec
Transformers	1-phase 400/93/93KV 234Mvar each
Voltage of thrysistor valve	5.2kV
Power company	PGCIL
Supplier	ABB

V. FUTURE SCOPE

Here we gave complete data about present HVDC links in India which can be taken for further research work. Multi terminal HVDC system was 1st introduced with 800 KV, 3000 MW upgradable to 6000 MW [1]. The proposed site for rectifier station is in Bishwanath Chariali and Alipurduar handling 3000 MW and the Inverter station at Agra handling 6000 MW power. This system is proposed to originate from Assam and pass through West Bengal, Bihar and terminate in Uttar Pradesh with an approximate length of 1728 km. It will be the highest capacity HVDC project of the world considering the continuous 33% overload feature. Each pole of the multi-terminal shall been designed for 2000 MW which are the highest capacity poles in the world. The Earth Electrode shall be designed for 5000 Ampere DC continuous current which shall be the first of its kind in the world. This project is expected to commission by 2015. It also includes the extension of the Mundra- Mohindergarh HVDC link currently operating at 1500 MW to its full installed capacity of 2500 MW. Further projects are in progress.

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VII. BIOGRAPHIES

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