ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016

HVDC VS Facts Transmission

[1] R.G. Lokkesh, [2] R. Harihara Subramanian
[1][2] 4TH Year, Department of EEE
R.M.K Engineering College
[1]rglokkesh@gmail.com, [2]harishrameee@gmail.com

Abstract: ***This paper deals with the recent technologies introduced in both HVDC and facts. It also includes information about the technical challenges faced during and after the setting up of HVDC and facts technologies. This gives idea about both practical and theoretical knowledge of both technologies. It also compares between various facts technologies separately and compares between variousHVDC technologies, so that the clear point of view on each technologies is gained. at the end of paper the rough summary and the best of two is given.***

Keywords:
TCSC – Thyristor Controlled Series Capacitor.
SVC –Static Var Compensation
CSC –Current Source Controlled.
VSC –Voltage Source Controlled

I. INTRODUCTION

Normally we are going to high voltage , since the transmission capacity increases with the voltage and thus losses and installation cost of wire per km also decreases Compared with traditional AC transmission, in the economical and technical aspects, high-voltage direct current transmission has the following advantages: The structure of the tower is simple, the costing of the line is low, the line corridors are narrow, and the loss is small; transportation capacity is not restricted by system operating; it can achieve cross-regional asynchronous network; it is very suitable for high voltage, long distance, and large capacity transmission .it balances the uneven distribution of energy produced inside the country. it is easy to start from the black start as it is no need to do transient stability analysis and frequency stability. HVDC prevent cascading disturbances. Even though HVDC has advantages but it is used more economically only during long transmission and not for distribution as transformer action in dc is difficult, so ac circuits are used. So the smart grids which are interconnection of ac and dc circuits are used in the power system. HVDC can be controlled independently of phase angle between source and load. There wont be production of charging current and short circuit power at connection point but usage converters to convert ac to dc absorbs 50 percent of real power which was not the case in HVAC.

II. RECENT TRENDS IN HVDC AND FACTS DEVICES:

Up to 6 GW can be transmitted over long distances using HVDC at +/- 800 kv. only when the transmission distance is larger than 600km(>1000MW) the HVDC is economical otherwise known as “break down point”. The break down point is the point at which the transmission cost gain is equal to the converters cost used in HVDC. First HVDC line was used in china of 5000MW.

Facts are also used for long transmission of ac. facts are flexible ac transmission which solves interconnection problems, reactive power problems and also dynamic transient stability. There are both series and shunt compensation.

Series compensation:

Line impedance modified(net impedance decreases)

↓

Increases transmittable real power

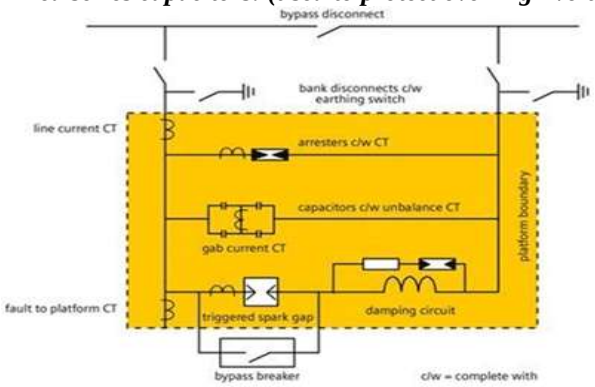
↓

Reduction of inductance in line – means the line length is virtually shortened– reduces transmission angle.

(FSC, Fixed Series Compensation - TCSC/TPSC, Thruster Controlled/Protected Series Compensation - S³C, Solid-State Series Compensator).

ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016

Fixed series capacitors: (used to protect over high voltage):



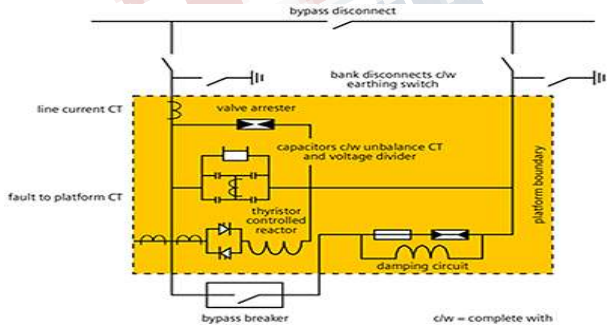
It contains parallel arresters, spark gaps by pass switch and same as capacitor banks.

Parallel arrestors (metal oxide variastors) –
To protect overvoltage during and after transmission line fault.

By pass switch – protects spark gap. totally 3 high voltage switches are used to isolate the fsc from transmission line.

Spark gap – protects from the excessive energy absorption.
A damping circuit is connected in series with spark gap and it will get ON only during fault times and in parallel to spark gap by pass breaker is connected, and it comes to act when the current due on the line is more than the MOV capability.

TCSC:



It controls both current and voltage, thus load flow is also controlled. It also controls power oscillation damping and mitigation of sub synchronous resonance of line thus allowing Higher level of compensation even in the networks containing generator-turbine tensional vibration and in interconnected areas of high mega watt power by varying the reactance of the interconnected lines (variable capacitive reactance).

***Working*:**

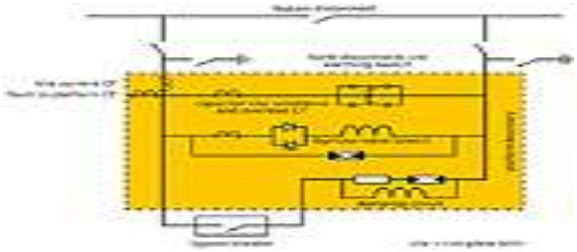
During fault the thyristor is fired just before the current in the capacitor reaches zero, thus the current is injected into the capacitor and thus the reactance of capacitor is added into the line and thus the oscillation of active power is controlled. this is called as boosting.
TSSC – thruster switched series capacitor is evoluted from TCSC to increase the power performance and POD.

So in short it acts as,
Variable capacitor – normal frequency
Variable inductor – subsynchronousfrequencies.

It is often used at bottlenecks in which the power transfer limit is determined by poor damping oscillations. To get smooth current interception, the thrusters are only fired at the zero current. And moreover, many thyristor are connected which are of different rating for smooth reactive power compensation. This saves grid from transients.

Note: since these are connected directly to capacitor bank and to transmission lines there will be a transient current produced.to reduce it series inductors are used.The thyristor controlled reactors are mostly connected in delta formso that it reduces harmonics.

TPSC: (thyristor protected power capacitor)



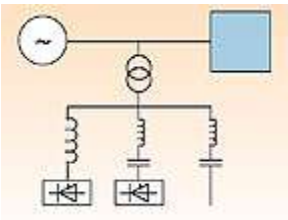
It returns to the maximum power transmission capability in a short time after an failure or fault, bcuz it does not have more components like surge arrestors and spark gap,

ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016

since thyristors are light triggered. And also due to very short time cooling of thyristors also makes it faster into commsission after a fault.

Shunt compensation: (SVC, Static VAR Compensator – STATCOM, Static Synchronous Compensator) reactive current injected – dynamically voltage regulated .

III. STATICVAR COMPENSATION:



The following 3 principle branch types are available:

TCR: T hyristor **C** ontrolled **R** eactor for linear injection of inductive reactive power.

TSC: T hyristor **S** witched **C** apacitor for stepwise injection of inductive reactive power.

Filter: Tuned filter capacitor for fixed capacitive reactive power and harmonic filtering.

***The system ratings of SVCs are*:**
Typical voltage levels: approx. 33 < kV < 800
Typical overall ratings: approx. 40 <MVAr< 800.

An SVC will typically regulate and control the voltage to the required set point under normal steady state and contingency conditions and thereby provide dynamic, fast response reactive power following system contingencies (e.g. network short circuits, line and generator disconnections). SVC also increase transfer capability, reduce losses, mitigate active power oscillations and prevent over voltages at loss of load.

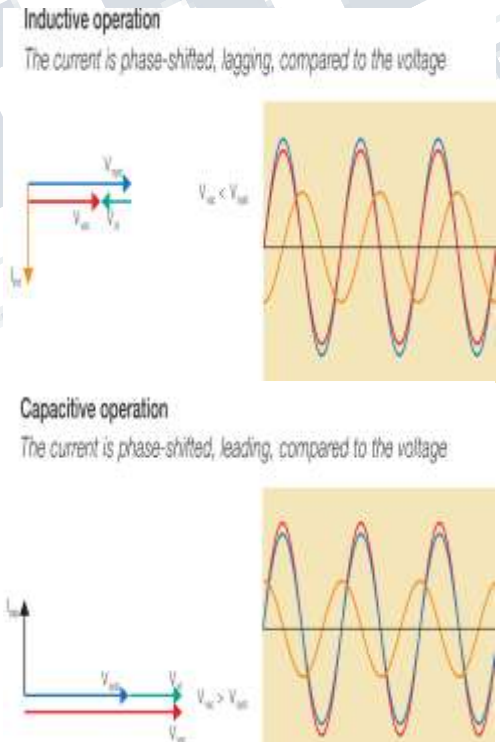
An SVC typically includes a combination of at least two of the given items below (e.g. TCR/FC or TCR/TSC/FC):

- Thyristor controlled reactor (TCR)
- Thyristor switched capacitor (TSC)
- Harmonic filter (FC)
- Mechanically switched capacitor bank (MSC) or reactor bank (MSR).

But mostly tsc combination is used to reduce the losses.

SVC light technology: (statcom)

It is name called by ABB and siemens. Due to high speed response of stator it does active harmonic filtering and voltage flickering, fluctuation. It requires less in size of land as it does not has harmonic filters. It is excellent for hybrid technology by connecting thyristor/capacitor in parallel. The VSC which is working on the PWM and IGBT technique gives unequalled performance in speed and regulation. The major advantage is the grid will consider it as a synchronous device , so no voltage regulation or stability is affected. Thus no capacitive banks and reactors are needed to suppress or absorb the reactive power generated from the VSC.



When VSC voltage red < system voltage blue -VSC absorbs reactive power.

ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016

When VSC voltage red > system voltage blue – VSC produces reactive power.

In both these cases the voltage angle does not changes thus no active power between grid and statcom.

World's biggest FACTS project with series compensation is in Gorakhpur, india of 1.7gvar.

World's largest HVDC link in Rio Madeira, brazil of 3150 MW.

IV DYNA FLOW:

It was recent technology invented by ABB. even though the active power is controlled by TSSC. It can't work congested area where more number of controlling devices are connected. Thus ABB has introduced DYNA flow. it consist of PST(phase shifting transformer) with multi step and TSSC with coordinated control. The method combines the advantages of both the PST and TSSC. it is capable of performing loss minimization, loop flow control – pre disturbance period, swing stability ,POD(power oscillation damping),thermal limitations, voltage transients in post disturbance period.

PST – handling thermal limitation as it will be too slow in transient period. But it causes voltage absorption and angular instability.

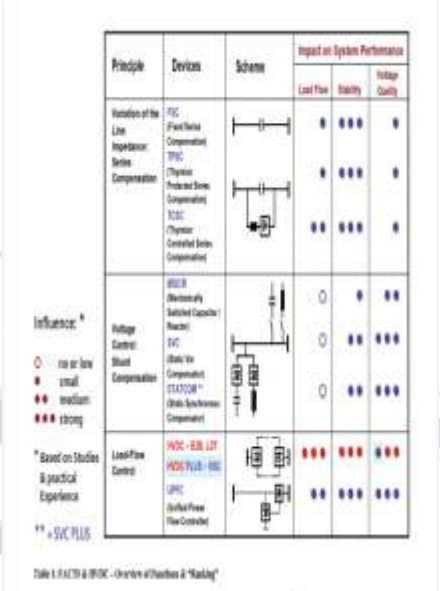
TSSC- acts fast and supports voltage during transient period.

Working:
Assume the line fault occurred in the parallel path which causes uneven distribution of voltage on the line.

- In the predisturbance, it focus on minimizing active losses. Then set point is maintained which is given by control centre.
- Since during fault voltage drop occurs ,thus the capacitor is switched using thyristors which will recover voltage drop. Thus after recovering voltage ,the thermal limits are maintained by PST. Dyna flow then distribute the load between different parallel path as it would give some time to take right decision by operator.

Up to now the HVDC has been achieved in both submarine cable and over head transmission cable. The 300km of transmission was achieved in submarine cables and 1000km was achieved in overhead transmission cable.
HVDC can be classified on type of converters and the type of link:

V COMPARISION OF FACTS DEVICES:



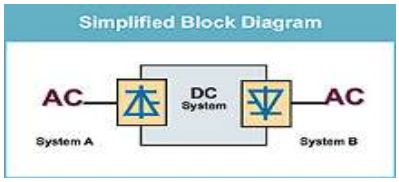
HVDC technologies:
HVDC – High-Voltage DC Transmission: It makes P flow

- HVDC "Classic" with 500 kV – up to 4,000 MW
- HVDC "Bulk" with 800 kV – for 5,000 MW up to 7,200 MW
- HVDC VSC (Voltage-Sourced Converter)
- HVDC can be combined with FACTS
- HVDC back – back system.

Back – back system:

They are used to interconnect the two different parameters (Frequency / Voltage Level / Short-Circuit Power Level) ac transmission lines. They are also used to connect long ac transmission line. Here since two bipolar components are interconnected in series with opposite polarity (inverter & rectifier), thus it is called **BACK-BAC**K system.

ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016



General aspects:

- To stabilize weak AC links.
- To supply more active power where the AC system already is at the limit of its short-circuit capability.
- For grid power-flow control within synchronous AC systems.
- Inverters and rectifiers are located on the same location.
- Power can be upgraded to desired frequency.

HVDC classic:(HVDC +csc)

In a Current Source Converter, the DC current is kept constant with a small ripple using a large inductor, thus forming a current source on the DC side. The direction of power flow through a CSC is determined by the polarity of the DC voltage while the direction of current flow remains the same.

- Here thyristor based line commutated converter is used, so less losses are produced.
- Less critical line to ground faults.
- Filter switching required for different dispatch levels.
- Commutation failure and operation in weak networks.
- Larger converter station.
- Only operate in energised ac network.

HVDC VSC:

Eagle pass B2B light in Texas: (VSC –HVDC)

It is otherwise called as **HVDC plus** by Siemens and ABB named it as **HVDC light**. These technologies are widely used when black-start operation is needed.

Here HVDC provides strong power transfer and VSC provides dynamic reactive power control. The eagle pass substation is located on Mexican border and is connected to piegos by two 135kv transmission line. theme icon grid and the texas grid are at asynchronous frequency. They control both reactive and real power.

1.as communication is driven in transmission lines the VSC does not rely on ac. the signal is separately given by pwm.
2.they can energise , support ,supply the isolated load meaning to say that it can ensure uninterrupted power to local loads even when the surrounding networks tripped and switching of circuits will not be needed, so current interruption will not be there.
3. in this the real power transfer occurs only when the voltage is within the band, if not the B2B reverts to the voltage control mode(in which reactive power is supplied to maintain voltage and phase).
4. independent operation control of VSC on both sides by opening of dc link, thus the reactive power is given at both ends by VSC and the value is adjusted.
5. can be operated in low short circuit level or even to passive system.
6. it is robust to ac network faults and contribute to short circuit and acts as firewall.
7. thesiemens uses MMC so that the ac lines are directly connected to the VSC .so less harmonics are generated since harmonic filters are not used.
8.the power reversal during fault will takes place so fast by the HVDC –VSC, so that system remains in synchronous.
9. multi terminal configurations are established which is very much helpful for renewable energy integration, since here reversal of current will change the power flow and no need to reverse the voltage. Thus the system very simple.
10.due to effective damping control and dynamic voltage control , transfer capability of voltage will increase.
11.independent control of p and q.

Attributes	**Classical HVDC (CSC –HVDC)**	**VSC-HVDC**
Converter technology	Thyristor valve, grid commutation	Transistor valve (IGBT), self commutation
Max converter rating at present	6400 MW, ±800 kV (overhead line)	1200 MW, ±320 kV (cable)
Relative size	4	1
Typical delivery	36 months	24 months

ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016

time		
Active power flow control	Continuous ±0.1Pr to ±Pr (Due to thchange of polarity normally changing the power direction takes some time, whichis not the case for VSC-HVDC)	Continuous 0 to ±Pr
Reactive power demand	Reactive power demand = 50% power transfer	No reactive power demand
Reactive power compensation & control	Discontinuous control (Switched shunt banks)	Continuous control (PWbuilt-in in converter control)
Independent control of activ& reactive power	No	Yes
Scheduled maintenance	Typically < 1%	Typically < 0,5%
Typical systemlosses	2.5 - 4.5 %	4 - 6 %
Multiterminal configuration	Complex, limitedto 3 terminals	Simple, no limitations

Problems encountered during real time projects:
(Both in facts and HVDC devices)
Facts devices:
Dafang series capacitor project by abb:

Since in china due to steady growing of power demand and population it is difficult to construct new stations. So the idea is to reduce the transmission loss. So two capacitors of each rated at 375Mvar,500kv in the middle of 300km twin cktcorrider between datong and fangshan.

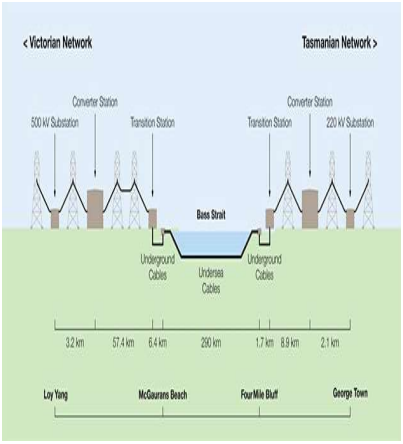
The problems and solutions by ABB,

1. reduces reactance in transmission line – for losses.
2. Voltage drop and instability – the capacitor Increases angular stability (i.e) maintains the voltage phase angle between sending and receiving end.
3. Saturation of weak transmission lines - If there is no capacitors the weak transmission lines saturate first and stops sending of further voltage.so the capacitor optimise the power flow between parallel power lines.

Fault prevention - When one line gets faulted the series capacitor in the line will withstand the load.

HVDC:
Basslink Australia – siemens:

It is an awarded project and came into comission in 2013.it transmits electric power from wind and hydro energy resources from George town to loyyanga in victoria. It transfers power via following
Submarine cable – 295 km
Subterranean cable – 8km to protect landscape
Overhead lines – 370 km.
Power - 500MW.
Voltage – 400KV
Current - 1250A.



Challenges and special features:

1. Sudden de-load will happen.

ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 7, July 2016

2. It has maximum number of corridors connected to the system.
3. In December 2015 , a fault has occurred on 295km submarine cable.it is really difficult to find fault and to repair fault as it all needed to be done under sea and more over the cable weighs 60 kg.
4. Since thyristor has minimum hold on current characterstic thus there will be minimum power flow of 40MW and the submarine cable will takes 2 minutes for deionisation when power flow is reversed.
5. The interconnector transfer the targeted amount of MW every 5 minutes, and sometimes the interconnects limits the AC system frequency excursion by altering the MW transfer.
6. it has automatic control and softwares which continuously monitors the surrounding temperature and if it was not within the safe working limit, then it limits the power flow through the interconnector.

CONCLUSION:

In short HVDC is preffere for long distance transmission where as HVAC containing facts is preffered for long distances but it is not cost effective and also the harmonics generated and protection devices used will be more, due to which efficiency decreases. also facts devices can send only limited amount of power, its not in the case of HVDC.

REFERENCES:

1. D. Povh*, D. Retzmann*, J. Kreusel**, "Integrated AC/DC Transmission Systems – Benefits of Power Electronics for Security and Sustainability of Power Supply". PSCC 2008, Glasgow, July 14-17,2008. Survey Paper 2, * part 1 and ** part 2.

2. Working Group B4-WG 37 CIGRE, "VSC Transmission", May 2004

3. "FACTS Overview", IEEE and CIGRE, Catalog Nr. 95 TP 108

4. "Series Capacitors for increased power transmission capacity in the Finnish 400 kV grid," ABB AB, Vasteras, Sweden, Application Note A02-0222 E, Nov. 2010.

5. E. Kuffel, W.S. Zaengl, *HighVoltage Engineering-Fundamentals*,Oxford: Pergamon Press, 1984, reprint 2004.

6. D.I. Goldsworthy, "A linearized Model for MOV-protected Series Capacitors", IEEE Transactions on Power Systems, Vol. 4 pp957-959, November 1987.

7. M. Bahrman, J. Johansson, B. Nilsson, "VOLTAGE SOURCE CONVERTER TRANSMISSIONTECHNOLOGIES - THE RIGHT FIT FOR THE APPLICATION", IEEE General Meeting 2003.

8. Reference book of Reactive Power Management by D.M.Tagare.

9. L. Y. Dong L., Zhang M. L. Crow "A New Control Strategy for the unified power flow controller" IEEE-2002.

10. A. E. Hammad, "Comparing the Voltage Control Capabilities of Present and future var compensating techniques in transmission system".IEEE transaction on power delivery, vol.11,no.1, jan1996.