Design of 765kV Transmission Line for Enhancement of Power Transfer Capability

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Abstract: The growth of electricity with its generation,transmission and distribution mechanism has shown amultifold growth in the past few decades. The generationdistribution have undergone paramount changes whereastransmission has not, thus in theexisting 400KV transmissionsystem there are constraints to transfer growing electricitydemands .This paper presents a novel aspect of 765kVtransmission system for efficient transmission of power andmakes a comparison with existing system.

Keywords-Lossminimization, Physical infrastructure reduction(RoW), Conductor Selection, Design aspect of765kV line.

I. INTRODUCTION

There has been steep increase in Power demandin recent years in India during the recent years whichforces utilities and IPP's to operate more or less their fullcapacities. The demand in Electricity is mainly subjugatedby Industrial Sector followed by residential, commercial,agriculture and transport sector (recently with introductionof Metros in cities). With increase in Generating capacity,India's transmission network also requires parallel growthto cope up with this demand. However, there areenvironmental and economic constraints to build newgenerating plants and further evacuation by transmissionlines due to ROW (Right of Way) constraints. Thelocations of generating stations are largely determined byregulatory policies, environmental clearances andavailability of coal, water etc. The amount of electricpower that can be transmitted between two locationsthrough a transmission network is restricted by securityand stability constraints as per St. clair's curve. Thus,these lines are not loaded to their thermal limit to keepsufficient margin against transient instability.There has been increasing difficulties faced infinding suitable corridors for new overhead transmissionlines. This results in many electric power utilities to lookfor other alternatives like going for up rating / upgradation of existing transmission lines to avoid right-ofways (ROW) problems which is still far cheaper thangoing to underground transmission as most of the stretchfalls in rural areas. Efforts have been made in recent yearsin studying and analyzing various possibilities like:

- Converting HVAC to HVDC lines by making suitablemodifications in the existing tower structures
- Connecting FACTS devices to the existing HVACtransmission lines to upgrade it.

Conversion of existing AC transmission line toHVDC line requires certain modifications to be carried outin the tower, insulators etc. Moreover, tower modificationrequires proper analysis of civil foundation and towerstructures to cross check whether all required criteria aremet and certain minimum amount of down-time isrequired during up gradation period. The proposed schemerequires no modification and down-time.The flexible AC transmission system (FACTS)concepts, based on applying state-of-the-art powerelectronic technology to existing AC transmission system,improve stability to achieve power transmission close toits thermal limit [4]. Such devices are installed by utilitiesand by many private entities in India. In order to achievethis identical goal other way is by converting existing400kV / 765 kV double circuit HVAC line to HVDC linewithout any modifications in the existing tower structure,insulators and conductors considering heavy pollution asthe worst case.Multi-Agent systems (MAS) consist of multipleIn India, 400kV Double circuit Transmission lineis predominant with Twin Moose / Quad Mooseconfiguration. Similarly

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765kV Double circuitTransmission line with Hexa zebra conductor configurationis predominant taking care of bulk power Transfer fromremote generating stations and connecting various regionalgrids. However these lines are under utilized due tostability constraints. Clerici [1] suggested conversion ofexisting AC line to HVDC line with some modification inthe tower structure cross arm and conductor stringing isrequired once again after modification. This requirescertain amount of shut down time and alternate feeders arerequired to be identified to feed the existing load. Thispaper proposes literally no modification in existing towerstructure, insulators and existing conductors will be utilizedfor HVDC power transmission.

Fig.1 depicts the schematic drawing forconversion of HVDC line from an existing double circuit400kV / 765kV AC transmission line. ConventionalHVDC bi-polar line is connected to the existing doublecircuit AC transmission line. One of the important aspectsof this conversion is that there is no modificationenvisaged in tower structure, insulator and conductor. Onepole of the DC line is connected to one of the AC circuitand another pole is connected to second circuit. DCcurrent can be allowed to flow through the circuit and theonly constraint being the thermal limit of the conductor. Inthis paper, two cases after HVDC conversion have beenanalyzed. First case will be with 400kV double circuittwin moose and quad moose transmission line. Secondcase will be with 765kV double circuit with hexa zebraconductor configuration.

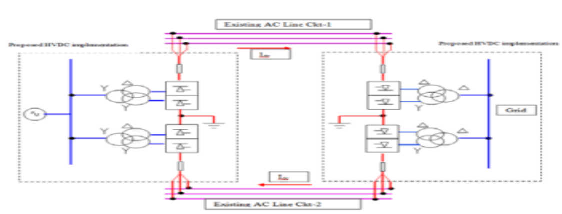

Fig.1. Basic scheme for HVAC to HVDC conversion.

II. CERATAIN TECHNICAL REQUIREMENT FORDESIGN OF TRANSMISSION NETWORK ARE AS FOLLOWS

For capacity enhancement of transmission line differentoption available are:

A. Improvement of transmission system

1. Use of Higher Voltages

While selecting higher voltages different calculations arerequired as mentioned below:

a. No of conductor per phase(bundle): In high power transmission, to reduce losses and limit thecorona phenomenon, it is needed to increase the number ofconductors per bundle, for which line current is calculatedusing Eq. (1)

$$I = \frac{S}{\sqrt{3}V} \text{…………………(1)}$$

To balance the weight, the number of conductor bundlesmust be even (four or six).

b. Crossection of conductor

i. Short circuit calculation :Conductor cross section is determined according to therated current, and then based on the level of short circuittest. Eq. (2) and (3) assess the minimum cross-sectionrequired to withstand the heat generated due to the shortcircuit. [4]

$$S = \frac{I_{SC} * \sqrt{t}}{K} \text{……………….(2)}$$

$$K = \sqrt{\frac{\omega . C \Delta\theta}{0.24 * \rho}} \text{ ………………..(3)}$$

Where:

S: Cross-section of conductor (mm)
ISC: Standard SC current (A)
t: The persistence time of SCcurrent (s)
K: Constant coefficient related to the conductor materialwhich is dependent on:
ω: Specific weight of the conductor (gr/cm3)
C: Specific heat of conductor metal (Calorie/g-°c)
Δϴ: The conductor temperature rise (°c)
ρ: Specific resistance of the conductor (ohm-m/mm^2).

ii. Crossection for fitting two parts together:One of the problems occurred in fittings due to short circuitcurrent is in welded joint corrosion,such as connecting twoparts together or celebrating with a hole between the boltsand nuts. Considering the amount and time of currentpassing through lines, a cross section can be obtained usingEq. (2) and (3) for existing connections in the line, whichare of steel and aluminium type such that short circuitcurrent and in turn the generated heat do not deform them.

2. Bundle Conductor

Geometric mean radius (GMR) and Geometric mean distance (GMD) are calculated using:

a. Geometrical Mean Radius

$$GMR = (N^* r^* R^{N-1})^{1/N} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where: N-No. of conductor in a bundle

r- Radius of each sub-conductor

R- Radius of bundle

b. Geometrical Mean Distance[4]

$$GMD = \sqrt[3]{D_{12} * D_{13} * D_{23}} \qquad \ldots\ldots\ldots\ldots(5)$$

From this, inductive & capacitivereactance's can be calculated:

$$C = \frac{2*\pi\varepsilon_0}{\ln(\frac{GMD}{GMR})} F/m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$L = 2 * 10^{-7} ln \frac{GMD}{e^{-\frac{1}{4}*GMR}} H/m \ldots\ldots\ldots\ldots(7)$$

$$X_L = 2 * \pi * F * L \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$X_C = \frac{1}{2*\pi*F*C} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

3. Size up of system

For sizing up of the system various parameters are requiredto find out those are:

a. No of insulators in the string: To calculate the voltage distribution along the insulatorstring, the capacitance between insulators themselves andthe tower should be determined. Although, capacitance ofall insulators is not same, however, considering the shortlength of insulator string respect to the tower height and itsuniformity, capacitance of whole insulators is same, C1, andthe capacitance between insulators and tower is C2.Accordingly, by calculating α, voltage on to ends ofinsulator string is obtained [4],

$$\alpha = (\frac{C_2}{C_1})^{0.5} \ldots\ldots\ldots\ldots\ldots(10)$$

$$V_{kg} = V_{ng}.\frac{\sin(\alpha.K)}{\sin(\alpha.n)} \ldots\ldots\ldots\ldots\ldots(11)$$

Where, C_1 and C_2 values are the capacitance between themetal part and earth, and insulator capacitance, respectively.

Consequently, having the value of α, distributed voltage intwo ends, no. of insulators is obtained.

In addition,

K-- Insulator numbers

n-- Total number of insulators

V_{ng}-- phase voltage of transmission line

V_{kg} --K_{th} insulator voltage.

b. Voltage gradient calculation*:* Voltage gradient around the conductor and fittings can playan important role in the phenomenon of corona and theresulted losses. Voltage gradient for conductors in eachphase is obtained using following eq. [4]

$$g_{max} = \frac{18C.V}{n.r}[1 + \frac{2(n-1)r.\sin(\frac{\pi}{n})}{GMR}] \ldots\ldots\ldots\ldots(12)$$

$$C = \frac{0.02413}{\log(\frac{GMD}{GMR})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$GMR = [r.n[\frac{B_s}{2.sin180/n}]^{n-1}]^{1/n} \ldots\ldots\ldots\ldots\ldots(14)$$

g_{max}: The maximum voltage gradient at the surface ofconductors(kV/cm).

V: Line phase voltage(kV).

n: The number of bundled conductors per phase.

r: Radius of conductor(cm).

C: Line capacitance(F/km).

GMR: Geometric mean radius of the bundled conductors(cm).

B_s: Distance from the bundle conductors(cm).

c. Critical voltage: Critical voltage value is a function of the line physicalfeatures and environmental conditions which is calculated.

d. Amount of corona losses: The main disadvantage of corona phenomenon is theresulted losses which may be increased to ten times onrainy/snowy days. In typical EHV transmission line, thelosses can be of a significant amount. Therefore, indesigning transmission line the corona losses should be also calculated.

e. Corona ring design: In corona ring design, three main parameters should bedetermined,[4]

1) Diameter profiles

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2) Radius of the ring
3) Position of ring along the insulator strings.

B. Type of conductor

The conductor used in electric power transmission at 400kV/765kV in INDIA are:

- ACSR Moose/Bermis
- AAAC Conductor

Due to technological development different types of conductors are available which have advantages over others.

Different High Tension Low Sag (HTLS) Conductors are[5]

1. AL59
2. TASCR(Thermal Alloy conductor steel Re-inforced)
3. ACSS(Aluminium Conductor Steel supported)
4. STACIR (Super thermal Aluminium Conductor INVAR Re-inforced)
5. ACCC (Aluminium Conductor Composite Core)
6. ACCR (Aluminium Conductor Composite Reinforced)

These conductor have following important properties:

- High current carrying capacity.
- Low sag tension property.
- Easy and rapid installation,
- Long term reliability.
- Conductor cost is less.
- Low line loss.

III. DESIGN ASPECT OF 765 kV LINE

For showing the effectiveness of the technical requirementsand their benefits a typical 5000MVA power system hasbeen considered which is to be transmitted over a distanceof 800km assuming 50% of capacitor compensation, thenthe total reactance will be half of the positive sequencereactance, let's consider sending and receiving end voltagesare equal, the phase shifting between two voltages is 30°.Different parameters for 400 kV and 765 kV line can becalculated by using following formulae's:

Power handling capacity per circuit

$$\left(\frac{E^2 * sin\delta}{L * x} + \sim 10\% \; overloading\right) MW$$

Resistance of conductor used for 400kV = 0.031Ω/km [6]

Resistance of conductor used for 765kV = 0.0136Ω/km [6]

$$Total\ current\ I_t = \frac{S}{\sqrt{3V}} kA$$

Power Loss per Circuit = 3* Resistance Per phase* $(I_t)^2$MW

Total Power Loss = No. of Circuits * Power loss per CircuitPower Loss per km = total power loss / Distance in kmBy using above equations following parameters can becalculated:

Table 1: Comparison of parameters for 400kV and 765kV

Parameters Calculated	400kV	765kV
Power handling capacity	680MW	2980MW
No. of Circuit	8 Single Circuits 4 Double circuits	2 Single Circuits 1 Double Circuit
Total current	7.2169kA	3.7735kA
Current per circuit	0.91kA	1.89kA
Resistance for 800km	0.031*800 = 24.8Ω	0.0136*800 = 10.88Ω
Power Loss per circuit	$3*24.8*(0.91^2)$ = 61.61MW	$3*10.88*(1.89^2)$ = 116.59MW
Total loss	492.88MW	233.18MW (46.7%)
Loss/km	616.1KW	291.48KW

IV. RESULTS & DISCUSSION

From the table.1 shown above following inferencescan bedrawn:

1. The power handling capacity of single circuit 765 kVsystem is four times than a single circuit 400 kV system.
2. Total power loss in 765 kV system is only 46.7% as thatof power loss on 400 kV system
3. Theno of circuit required to transfer the same amount ofpower are four times in 400 kV than 765 kV, increasesRoW & spacing.

Following figure shows the difference between the Right ofWay requirements for different lines.

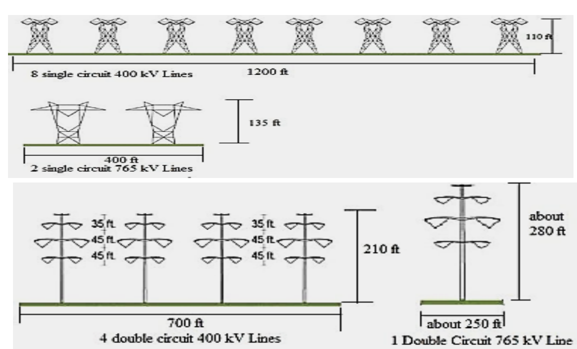

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Fig1. : RoW comparison of 765kV and 400kV System

V. CONCLUSION

From the discussion made in the paper, it is evident thathigher transmission capacities can be achieved by propertechnical design of transmission system. Accordingly theresults obtained from the design of 765kV lines shows thatthe power handling capacity increased from 3-4 times ascompared to 400kV lines, whereas the losses can be reducedto the extent of 53.3%. Further the bulk power can betransferred with same or less area of land use by highertransmission network.From which it is concluded that the increase in powerdemand can be fulfilled by enhancing transmission voltageto 765kV and above with proper technical design.

REFERENCES

[1] S. Rao, "EHV-AC, HVDC Transmission & Distribution", KhannaPublication, 3rd Edition 9th Reprint, ISBN No.: 81-7409-043-6.

[2] Rakosh Das Begumudre, "Extra High Voltage AC TransmissionEngineering", New Age International Publishers, Fourth Edition:2011

[3] Aydin Sakhavati, Mostafa Yaltagiani, Shirin Saleh Ahari andSeyed Mahdi Mahaei, "765 kV Transmission Line Design(Electrical Section)", International Journal of Electrical andComputer Engineering (IJECE), Vol.2, No.5, October 2012, pp.698-707, ISSN: 2088-8708

[4] R. Geary, T. Condon, T. Kavanagh, O. Armstrong & J. Doyle"Introduction of high temperature low sag conductors to the IrishTransmission grid" B2-104, CIGRE 2012 ESB InternationalIreland.

[5] Manual on Transmission Planning Criteria, Central ElectricityAuthority, New Delhi. January 2013.

[6] Abhilash A. Netake, P. K. Katti, "765kV Transmission Line forCapacity Enhancement", International Journal on Research andScientific Innovation (IJRSI)Vol. I, Issue VII, NOV 14, pp. 200-204, ISSN: 2321-2705.

[7] Central Electrical Authority's "Manual on Transmission PlanningCriteria" January 2013.

[8] CBIP Manual on Transmission Line Towers. NewDelhi, India.

[9] H. Rahman and B.H. Khan. 2008. Stabilityimprovement of power system by simultaneous ACDC power Transmission. Electrical Power SystemsResearch. 78: 756-764.

[10]L.K. Gyugyi. 1995. Unified Power flow controller; anew approach to power transmission control. IEEETrans. Power Delivery. 10(2): 1085-1097.

[11]D. Marene Larruskain, Inmaculada Zamora, OihaneAbarrategui, Zaloa Aginako. 2011. Conversion of ACdistribution Lines into DC lines to upgradetransmission capacity. Electrical Power systemsResearch 81, Science Direct. pp. 1341-1348.

[12]M.I. Khan, R.C. Agrawal. 2005. Conversion of ACLine into HVDC. IEEE PES 2005 conference andExposition in Africa, Durban, South Africa.

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