EMPLOYING HVDC FOR TRANSMISSION BY CONVERTING EXISTING HVAC LINES INTO HVDC LINES

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Abstract: A high voltage direct current (HVDC line) electric power transmission system using direct current for transmission of electric power. The evolutionof industrial growth during the recent years has lead to increased consumption of electrical energy. When a bulk power is to be transported over very long distances, HVDC transmission system is used which is more economical compared to AC transmission system. HVDC also suffer lower electrical losses. Since the power flow through the HVDC link can be controlled independently of the phase able between source and load, it can stabilize a network against disturbances due to rapid changes in power. Also, improvement in stability and economy of each grid is found, by allowing exchange of power between incompatible networks due to these advantages over AC lines, HVDC is preferred. This proposed model uses existing infrastructure of HVAC a line to convert it into HVDC lines. The surplus generation of electric power can be reduced by employing HVDC for transmission as the losses in this is only 3% per 1000KM. This in turn reduces the coal consumption in thermal power plants. This impacts on life span of coal reserves in India.

Keywords:- HVDC, Optimum voltage level for HVDC, Overhead insulators for HVDC, Conversion of HVAC into HVDC

1. INTRODUCTION

Installed power station capacity in India as of June 30,2016 is 303Gigawatt. Among this 60-65% electricity consumed in India are generated by thermal power plants. Thermal power is the largest source of power. There are total 132 coal based thermal power plants in India.

Indian coal is of low calorific value and high ash content. The carbon content is low in India's coal and toxic trace element concentration are negligible. The natural fuel value of Indian coal is poor. On average the Indian plants using India's coal supply consume about 0.7Kg of coal to generate a kWh, whereas USA thermal power plants consume about 0.4Kg of coal per kWh. This the big difference in quality of measured by gross calorific value(GCV).

Every 7 years the demand of electricity is increasing twice. Coal demand in 2020 is unlikely to be anywhere near 1500 MT for domestic coal. It is estimated that coal reserves suitable for thermal plants would last for next 4-5 decades. Thus, the life of coal power plants is about 4-5 decades. Therefore, it may lead to energy crisis. One way to overcome this is to increase the life span of thermal power plants. The amount of coal should be used effectively to produce more power. The supplying of power with respect of demand should be done at higher efficiency. The higher efficiency in transmission line is achieved by employing HVDC technology.

Consider a thermal power plant which produces 2000MW and transmits at 765kV, the receiving end power is nearly 1840MW as efficiency of AC lines is 90-92% without shunt compensators. In HVDC lines the receiving power is nearly 1940Mw as only 2 to 3% losses exist in HVDC technology. So in HVAC line to supply load of 2000MW plant has to produce 2160 MW whereas for HVDC line 2060 MW has to produces for the same load. So nearly 100MW production is reduced which results in the saving of huge amount of coal. This impacts on the extending the coal reserves in India, which in turn increase the life span of thermal power plants.

2.TECHNICAL PERFORMANCE OF HVDC

The HVDC preferred technology for sending a chunk of power across long distance with fewer losses. HVDC results in high efficiency, excellent voltage profile regulation, economical, lesser conditions of conductors, lesser number of conductors, no reactive power compensation. Healthy stability and reliability, than the equivalently sized high voltage AC system transmitting the same amount of power. HVDC losses are 3% per 1000km. The power transfer in AC line is dependent on the angle difference between voltage phasors at 2 ends. For a given power level, this angle increases with the distance. The maximum power is limited by the consideration of steady state and transient stability. The power caring capability of DC lines is unaffected by the distance of transmission and is limited only by the current carrying capacity of conductor.

3. ECONOMY & MODIFYING HVAC LINES

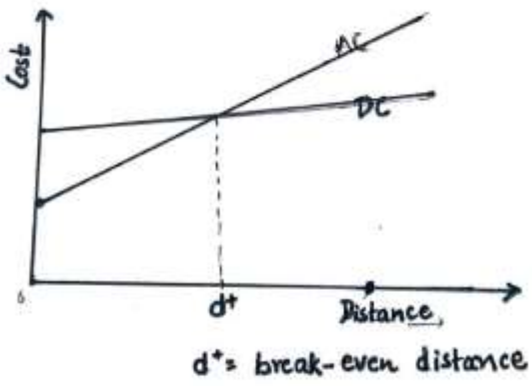


Fig.1 Cost v/s Distance

The above figure(1) shows variation of cost of transmission with respect to distance for AC and DC transmission lines. For the distance less than breakeven distance AC tends to be more economical than DC and costlier for long distance. The break distance varies from 500KM to 800KM in the overhead line depending on the per unit line cost. For converting HVAC line into HVDC line, the point lying beyond lying on DC line beyond breakeven point is chosen.

4. OVERHEAD INSULATORS & CONDUCTORS CAPACITY FOR DC

The relation between DC and AC insulation shows that the number of insulator disc required for HVDC lines is less than AC lines for same voltage level.

Assume same %losses in both case. $3Ip^2 * R = 2Id^2 * R$

$$Ip = \sqrt{(2/3)} * Id$$

Since same power is to be transmitted, Pac=Pdc

$$3Vp*Ip*\cos\emptyset = 2Vd*Id$$

Let cos∅ =0.9 $3Vp*\sqrt{(2/3)}\, Id*0.9 = 2Vd*Id$

$$Vd=1.1Vp$$

We know that the insulation is decided on the basis of maximum voltage, we can write

$$\frac{DC\ insulation}{AC\ insulaton} = \frac{Vd}{\sqrt{2}*Vp} = \frac{1.1*Vp}{\sqrt{2}*Vp} = 0.78$$

$DC\ insulation$ = 0.78* $AC\ insulation$

Consider a 500kV AC transmission line, it requires 27 insulator discs assuming 11 kV for each disc. For HVDC line, from above relation

$$0.78*27 \cong 21 \text{ insulator discs}$$

Therefore for HVDC line the number of insulator discs required less than the HVAC for same voltage level.

We know that, Pac = (3/√2)* Vp *I cos∅ and Pdc =2VpI, where Vp is peak voltage of conductor with respect to ground, cos∅ is power factor and "I" is effective current rating of the conductor. Thus, Pac≅Pdc. This implies that for a given power level DC line requires simpler and cheap towers, reduce conductors and insulation cost. The power losses are also reduced with DC as there are only two conductors.

For DC, current distribution is uniform in all over cross section of cable so electrical cross section is equal to physical cross section. For AC, current distribution is not uniform due to the time varying nature of time varying magnetic flux produced which results in skin effect. So, in AC lines the electrical cross section < the physical cross section. So, for DC transmit same current as of AC we need to reduce the diameter of conductors. Thus, we can modify AC cables to make ti suitable for AC transmission. The other way of existing AC cable for DC transmission without modification is that transmitting higher DC power as skin effect is absent in DC.

5. CHOICE OF OPTIMUM VOLTAGE LEVEL

With increase in the transmission voltage the cost of conductor material can be reduced and the efficiency can be increased. But the cost of switch gear is increased at the time. Thus, for overall economy there is an optimum transmission voltage. The voltage level is chosen to minimize the total cost for a given power level.

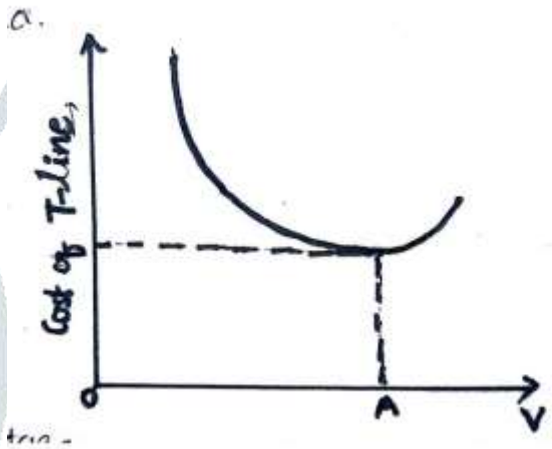
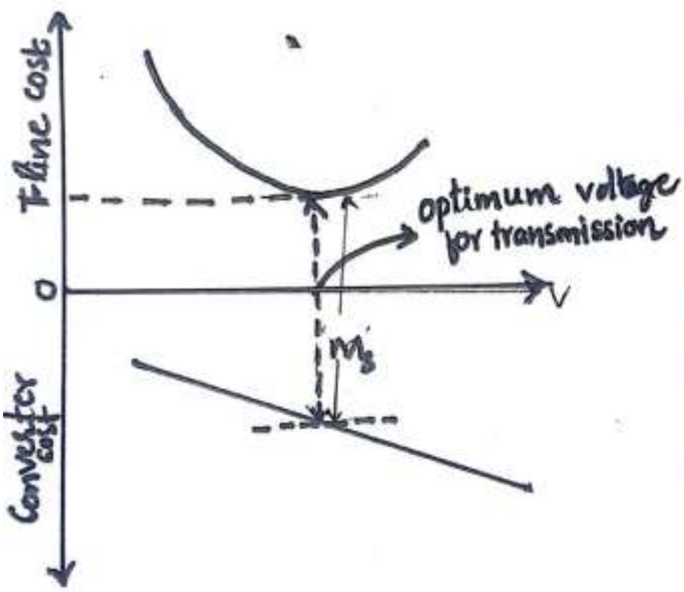


Fig (2). AC line cost v/s voltage

For AC, the length of transmission is known initially some standard transmission voltage is selected and the relative cost of equipment is determined. A graph is drawn fig(2) for the total cost of transmission with respect to various voltage levels as shown in the figure. The lowest point on the curve gives the optimum transmission voltage. Here OA is the minimum optimum transmission voltage.



Fig(3). HVDC line cost v/s voltage

For DC, the same procedure is carried out for the DC line but in this converter, cost is also included. In this the minimum separation between the two curves equals the minimum cost total. The minimum separation denoted by Ms fig(3). The voltage at this point is selected as optimum transmission voltage.

The method of selecting optimum transmission line voltages similar in both cases. The curve of DC system varies in same manner as the AC curve with respect to voltage level. Thus, while converting to existing to AC lines into HVDC lines the choice of standard for new lines preferred which is near to AC system voltage. The standard rated voltages of HVDC and HVAC systems are given below.

HVDC: Bipolar line – pole voltage to ground: Rated voltage in KV $\pm 100, \pm 250, \pm 300, \pm 400, \pm 500, \pm 600, \pm 800$

HVAC: Rated voltage phase to phase: 132KV, 220KV, 345KV, 400kV, 500kV, 765kV, 1000kV.

Therefore from the above technical and economic aspects, the existing AC lines can be converted into HVDC line economically to work at high efficiency.

6. COPPER LOSS IN HVDC LINE

Now consider case using existing AC lines. DC power is transmitted at same power level. Both the systems have equal maximum voltage.

$$\frac{power\ loss\ in\ AC}{power\ loss\ in\ DC} = \frac{3Ip^2R}{3Id^2R} \quad \text{........ equation 1}$$

As $P_{AC} = P_{DC}$, 3VpIp cosØ = 2Vd Id

3VpIp*0.9 = 2*$\sqrt{2}$Vp Id Since, Vmax=Vd=$\sqrt{2}Vp$

Id = 0.954*Ip .... equation 2

Substitute equation 2 in 1, we get $\frac{loss\ in\ AC}{loss\ in\ DC} = 1.64$

Therefore, I^2 R loss in AC = 1.64*(I^2 R loss in DC)

Hence, the HVDC lines, the transmission is at high efficiency.

7. RESULT

It is noted that by modifying the existing HVAC lines to HVDC lines, transmission efficiency is increased. The breakeven distance of overhead lines between AC and DC line is range from 500 km (310 miles) to 800 km (497 miles). The HVDC has less effect on the human and the natural environment in general, which makes the HVDC friendlier to environment. The receiving end power is almost equal to sending end power. Thus, coal consumption is reduced. The insulation level required for DC lines lesser than that of AC lines for same voltage level. The copper loss involved in HVDC is also much lesser compared to HVAC lines. It is also concluded that modification of the HVAC lines into HVDC lines made economical as existing overhead insulators and conductors can be used.

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