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Power Upgrading of Transmission Line by using Simultaneous AC-DC Transmission

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Abstarct: Long extra high voltage (EHV) AC lines cannot be loaded to their thermal limits in order to keep sufficient margin against transient instability. With the scheme proposed in this paper, it is possible to load these lines very close to their thermal limits. The conductors are allowed to carry usual AC along with DC superimposed on it. The added DC power flow does not cause any transient instability.

This project presents the feasibility of converting a double circuit AC line into composite AC–DC power transmission line to get the advantages of parallel AC–DC transmission to improve stability and power upgrading. Simulation and experimental studies are carried out for the coordinated control as well as independent control of AC and DC power transmissions. As voltage is kept constant No alterations of conductors, insulator strings, and towers of the original line are needed.

Substantial gain in the load ability of the line is obtained.12 pulse rectifier is used for producing DC as it produces approximately 17% less THD in input line current. By this model we can send extra power in the existing transmission line.

Keywords : Extra High Voltage (EHV) , Total Harmonics Distortion (THD), simultaneous AC–DC power transmission.

I. INTRODUCTION

In recent years, environmental, right-of-way (Row), and economic concerns have delayed the construction of a new transmission line. The demand of electric power has shown steady growth but geographically it is quite uneven. The power is often not available at the growing load centers but at remote locations. Often the regulatory policies, environmental acceptability, and the economic concerns involving the availability of energy are the factors determining these locations. Now due to stability considerations, the transmission of the available energy through the existing AC lines has an upper limit. Thus, it is difficult to load long extra high voltage (EHV) AC lines to their thermal limits as a sufficient margin is kept against transient instability.

Simultaneous AC–DC power transmission was earlier proposed through a single circuit AC transmission line i.e. uni-polar DC link with ground as return path was used. The limitations of ground as return path is due to the fact that the use of ground may corrode any metallic material if it comes in its path. The instantaneous value of each conductor voltage with respect to ground 3 becomes higher due to addition of DC voltage hence more discs have to be added in each insulator string so that it can withstand this increased voltage. The conductor separation distance was kept constant, as the line-to-line voltage remains unchanged. This thesis gives us the feasibility of converting a double circuit AC line into composite AC–DC power transmission line without altering the original line conductors, insulator strings and tower structures.

A. Concept of Simultaneous AC-DC Transmission

The circuit diagram in Figure 1. shows the basic scheme for simultaneous AC-DC transmission. The DC power is obtained through the rectifier bridge and injected to the neutral point of the zigzag connected secondary end transformer, and again it is reconverted to AC by the inverter bridge at the receiving end. The inverter bridge is again connected to the neutral of zigzag connected winding of the receiving end transformer. Fig. 1.depicts the basic model for simultaneous AC-DC power flow through a dual circuit AC transmission line. Line commutated 12-pulse rectifier bridge is used in conventional HVDC and the DC power is injected to the neutral point of the zig-zag connected secondary of sending end transformer and is recovered back to AC again by the line commutated 12-pulse bridge inverter at the receiving end side.

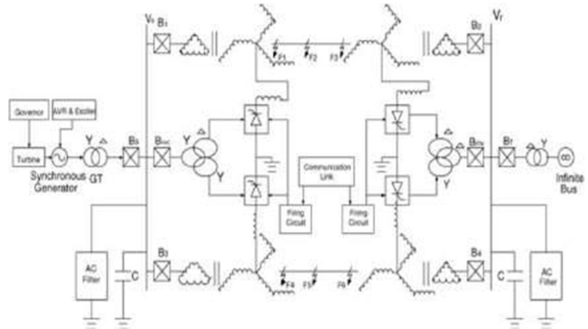

Fig 1. Basic circuit diagram of simultaneous AC-DC transmission

The inverter bridge is also connected to the neutral of zig-zag connected winding of the receiving end transformer to recover back the DC current to the inverter. The dual circuit AC transmission line carriers both three-phase AC and DC power. Each conductor of each transmission line carries one third of the total DC current with AC current superimposed. Since the resistance is equal in all the three phases of secondary winding of zig-zag transformer and the three conductors of the line, the DC current is equally divided in all the three phases. The conductor of the second transmission line provides return path for the DC current to flow. The saturation of transformer due to DC current can be removed by using zig-zag connected winding at both ends. The fluxes produced by the DC current (Id / 3) flowing through each winding of the core of a zig-zag transformer have equal magnitude and opposite in direction and hence cancel each other. At any instant of time the net DC flux becomes zero.

Thus, the DC saturation of the core is removed. A reactor Xd with higher value is used to reduce harmonics in DC current. In the absence of third order harmonics or its multiple and zero sequence, under normal operating conditions, the AC current flow through each transmission line gets restricted between the zig-zag connected windings and the conductors of the transmission line. The presence of these components may only be able to produce negligible current through the ground due to higher value of Xd.

II. SIMULATION MODEL

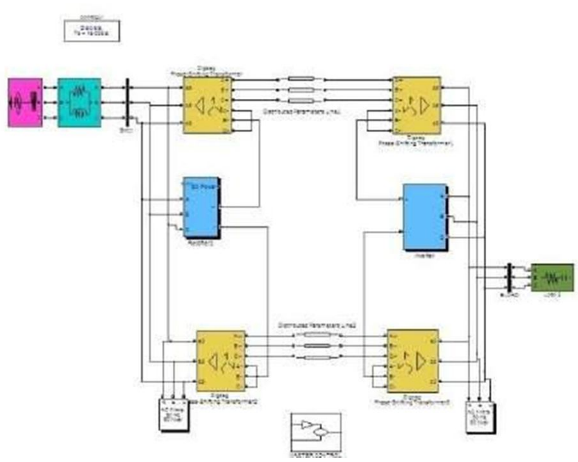

Fig 2. simulation model of existing HVAC model afer upgradation

In this model number of blocks are used such as 500 KV source for the supply, zig-zag transformers at both the ends i.e. sending and receiving end of the transmission line, and 300 Km line is in between two transformer for the transmission purpose and its inductive reactance has a value of 0.9337 mH. And at the receiving end one load is connected which is of 1500 MW to measure the power coming to the receiving side of the system. Rectifier and converter are connected in between to convert some of the AC power to DC so that we can send converted DC current through the neutral of zig-zag transformer to increase the power transfer capability of the system and this DC current again get back through by inverter connected to neutral of receiving end zig-zag transformer. Above model is showing the system after upgradation. The resulting waveforms are shown in the simulation result chapter where all the related waveforms are shown.

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The study is based on the comparison between the response between existing EHVAC system and for combined EHV and HVDC transmission (double circuit line) through simulink in
MATLAB. A comparison between the sending end and receiving end voltages and sending end and receiving end current for the two cases have been done. The active and reactive power changes during existing and parallel AC-DC conditions are also observed.
Earlier it was proposed through a single circuit AC transmission line i.e. uni polar DC link with ground as return path was used. The limitations of ground as return path is due to the fact that the use of ground may corrode any metallic material if it comes in its path. The instantaneous value of each conductor voltage with respect to ground becomes higher due to addition of DC voltage, hence more discs have to be added in each insulator string so that it can withstand this increased voltage. This thesis gives us the feasibility of converting a double circuit AC line into composite AC–DC. So we shifted towards a double linetransmission with 2 sending end stations and 2 receiving end stations making a more reliable and stronger system capable of overcoming any adversities or shortcomings. It is actually designed for a larger chunk of load transfer. It also guarantees continuous supply if one station is interrupted due to internal or external faults. The voltage, current and power profiles are studied during fault and without fault and it is found to have better transient response than single circuit.
The above fig 2. showing simulation model for simultaneous AC-DC transmission system. In this system we taking transmission line of 500 KV. The part of 500 KV voltage is get converted into DC by using 12 pulse line commutated rectifier and some part i.e approximately 500KV voltage was send through zig-zag transformer. And afterwards 1.3KA DC current is injected to the neutral winding of zig-zag transformer which get further distributed to the three transmission line as (Id/3). And this DC current again recovers back by using inverter which also connected to the receiving end zig-zag transformer. The waveforms for sending and receiving end voltages, current and power are shown in results.
The AC power transmission can be calculated by formula given as,

$$Pac=(Va^2*\sin\delta/X)\text{……..………………………}(1)$$

And DC power can be calculated by formula given as, $PDC=Vd*Id$………………………………..……(2)

Power loss of the transmission line is calculated by, $Ploss=3*Ia^2*R$…………………………………..(3)

III. SIMULATION RESULTS

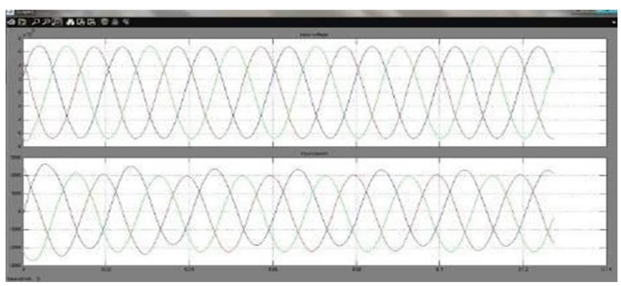


Fig 3. Input AC voltage and current waveforms

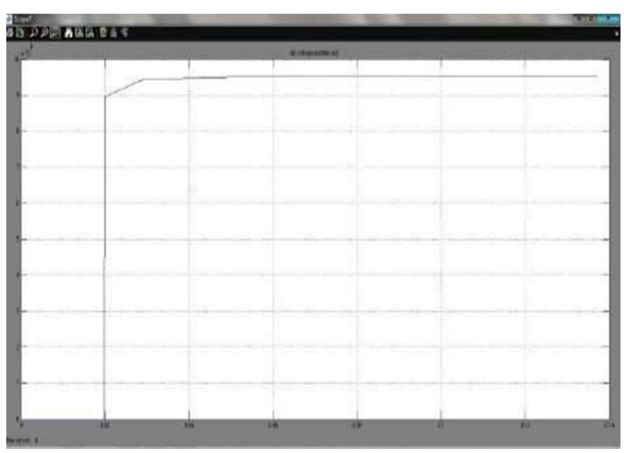
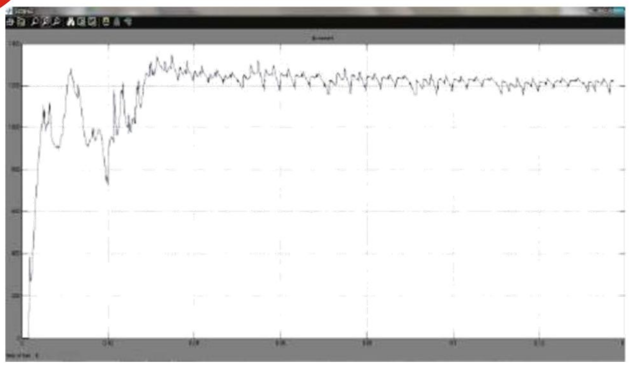


Fig 4. DC voltage waveform across rectifier



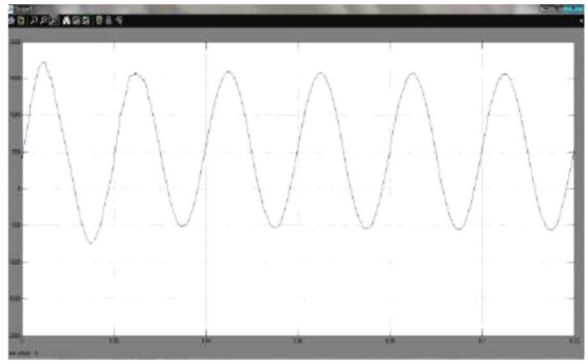


Fig 5. DC current waveform

Fig 6. Waveforms of power

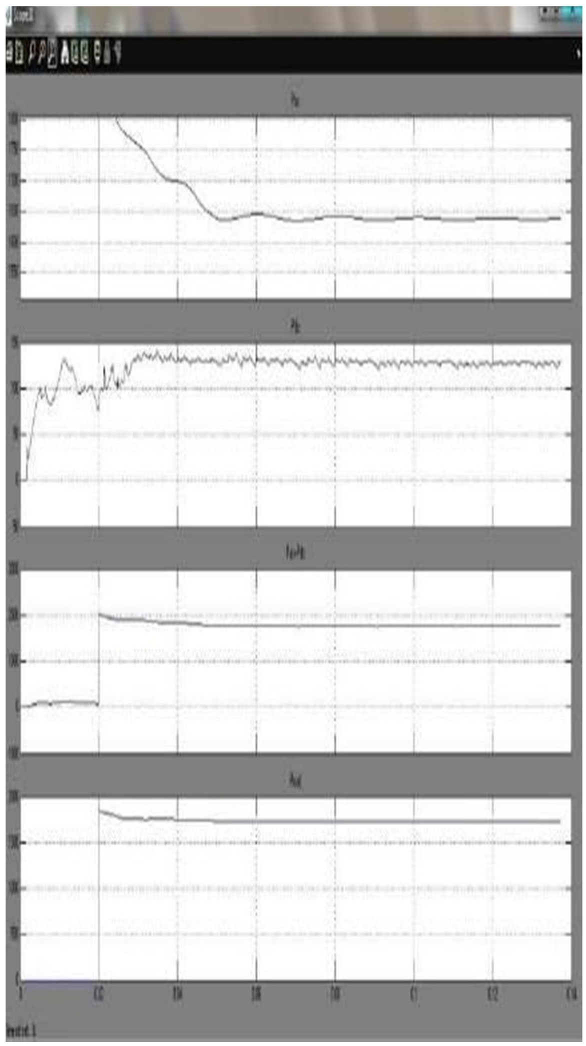


Fig 7. Combined AC-DC current waveform

AC power waveform
DC power waveform
Combined AC-DC power waveform
Load power

PHASE ANGLE Degree	AC POWER P_{AC} MW	DC POWER P_{DC} MW	TOTAL POWER $(P_{AC} + P_{DC})$ MW	% INCREASE IN POWER
30	1700	140	1850	8.82
45	1640	135	1770	7.92
60	1637	128	1765	7.82
75	1665	95	1760	5.70
80	1690	93	1785	5.62
90	1690	75	1785	4.01

Table showing percentage increase in power at different power angle

IV. CONCLUSION

Necessity of additional DC power transmission will be experienced maximum during peak load period which is characterized with lower than rate voltage. If DC power is injected during the peak loading period only with V d being in the range of 5% to 10% of E ph, the same transmission line without having any enhanced insulation level can be allowed to be used, 5.1% or 10.2% more power can be transmitted. By adding a few more discs in insulator strings of each phase conductor with appropriate modifications in cross arms of towers insulation level between phase to ground may be increased to a high value, which permits proportional increase in Emax, Therefore higher value of Vd may be used to increase DC and total power flow through the line. This modification in the exiting AC lines is justified due to high cost of a separate HVDC line.

V. FINDINGS FROM SIMULATION

When simultaneous AC-DC power is send and the load requirement is less than or equal to DC power in the line then only DC power flows through the line .

If load power requirement is greater than DC power in the line then AC power fulfills the additional power requirement.

Simultaneous AC and DC power transfer increases the power transfer capability of line.

The variation in phase angle and the corresponding percentage increase in power illustrate that maximum power is available at 30 degree.

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