POWER UPGRADING OF TRANSMISSION LINE BY COMBINING AC-DC TRANSMISSION.

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***Abstract*: The basic proof justifying the simultaneous ac–dc power transmission is explained in reference. In the above references, simultaneous ac–dc power transmission was first proposed through a single circuit ac transmission line. In these proposals Mono-polar dc transmission with ground as return path was used. There were certain limitations due to use of ground as return path. Moreover, the instantaneous value of each conductor voltage with respect to ground becomes higher by the amount of the dc voltage, and more discs are to be added in each insulator string to withstand this increased voltage. However, there was no change in the conductor separation distance, as the line-to-line voltage remains unchanged. In this paper, the feasibility study of conversion of a double circuit ac line to composite ac–dc line without altering the original line conductors, tower structures, and insulator strings has been presented.**

***Keywords*:-ac-dc power system, power upgradation by transmission line Etc.**

INTRODUCTION

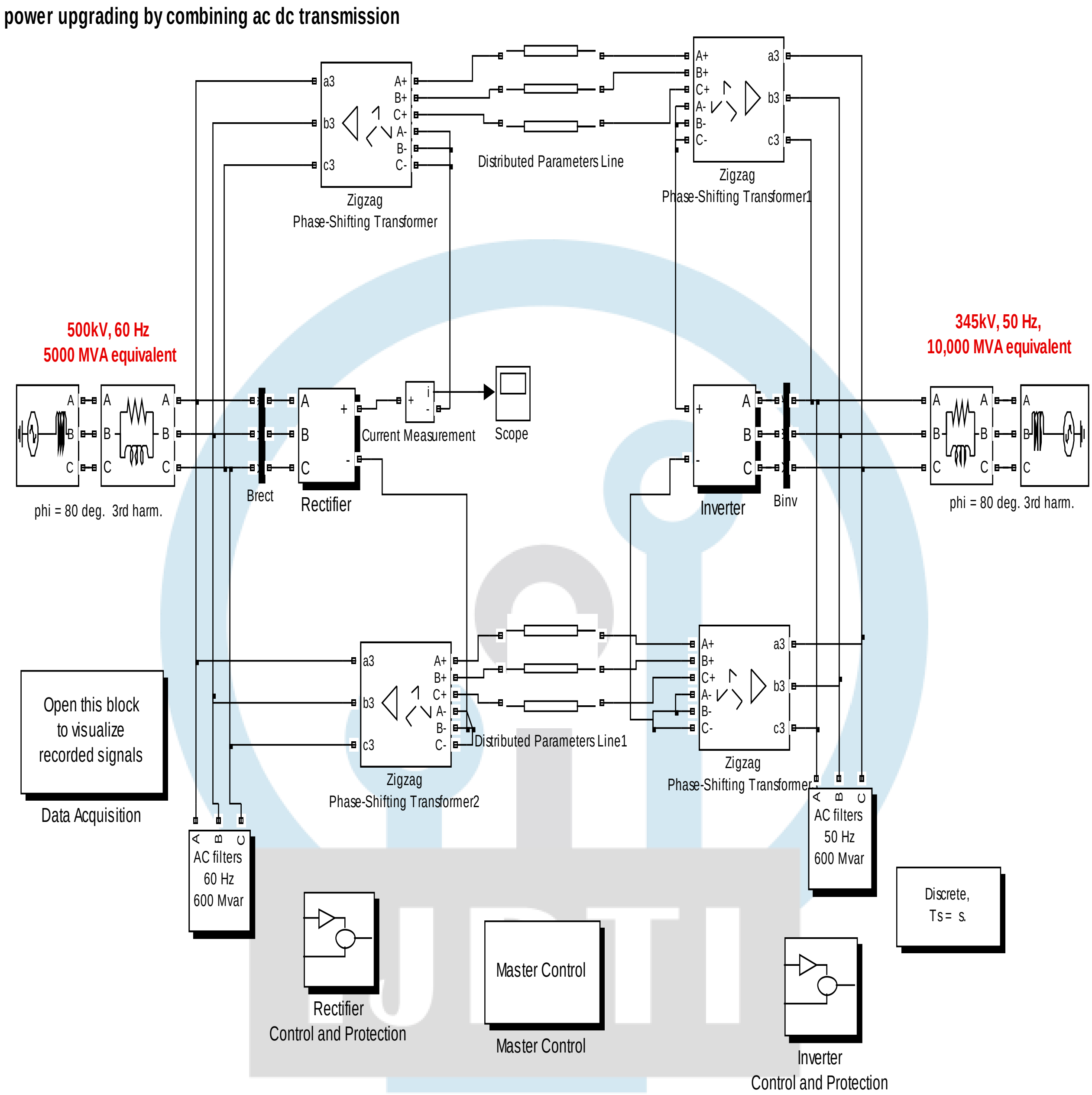
In recent years, environmental, right-of-way, and cost concerns have delayed the construction of a new transmission line, while demand of electric power has shown steady but geographically uneven growth. The power is often available at locations not close to the growing load centers but at remote locations. These locations are largely determined by regulatory policies, environmental acceptability, and the cost of available energy. The wheeling of this available energy through existing long ac lines to load centers has a certain upper limit due to stability considerations. Thus, these lines are not loaded to their thermal limit to keep sufficient margin against transient instability.

The present situation demands the review of traditional power transmission theory and practice, on the basis of new concepts that allow full utilization of existing transmission facilities without decreasing system availability and security. The flexible ac transmission system (FACTS) concepts, based on applying state-of-the-art power electronic technology to existing ac transmission system, improve stability to achieve power transmission close to its thermal limit.

PROBLEM DEFINATION

The main object of my paper is to show that by superimposing DC in AC Transmission, the capacity of the transmission line can be increased by nearly 70 % of that if only AC is transmitted.
In our existing transmission system, 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 project, 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.

PROPOSED SYSTEM



simulink model using ac-dc transmissuion

BLOCKS FUNCTIONALITIE

Three-Phase Source

The Three-Phase Source block implements a balanced three-phase voltage source with an internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally grounded or made accessible. You can specify the source internal resistance and inductance either directly by entering R and L values or indirectly by specifying the source inductive short-circuit level and X/R ratio.

Three-Phase Parallel RLC Branch

The Three-Phase Parallel RLC Branch block implements three balanced branches consisting each of a resistor, an inductor, a capacitor, or a parallel combination of these. To eliminate either the resistance, inductance, or capacitance of each branch, the R, L, and C values must be set respectively to infinity (inf), infinity (inf), and 0. Only existing elements are displayed in the block icon. Negative values are allowed for resistance, inductance, and capacitance.

Three-Phase Transformer (Three Windings)

This block implements a three-phase transformer by using three single-phase transformers with three windings. You can simulate the saturable core or not simply by setting the appropriate check box in the parameter menu of the block. See the Linear Transformer and Saturable Transformer block sections for a detailed description of the electrical model of a single-phase transformer. The three windings of the transformer can be connected in the following manner: Y Y with accessible neutral (for windings 1 and 3 only) Grounded Y Delta (D1), delta lagging Y by 30 degrees Delta (D11), delta leading Y by 30 degrees.

Universal Bridge

The Universal Bridge block implements a universal three-phase power converter that consists of up to six power switches connected in a bridge configuration. The type of power switch and converter configuration are selectable from the dialog box. The Universal Bridge block allows simulation of converters using both naturally commutated (or line-commutated) power electronic devices (diodes or thyristors) and forced-commutated devices (GTO, IGBT, MOSFET). The Universal Bridge block is the basic block for building two-level voltage-sourced converters (VSC).

Connection Port

The Connection Port block, placed inside a subsystem composed of SimPowerSystems blocks, creates a Physical Modeling open round connector port on the boundary of the subsystem. Once connected to a connection line, the port becomes solid . Once you begin the simulation, the solid port becomes an electrical terminal port, an open square .You connect individual SimPowerSystems blocks and subsystems made of sim Power Systems blocks to one another with Sim Power Systems connection lines, instead of normal Simulink signal lines. These are anchored at the open, round connector ports . Subsystems constructed of SimPowerSystems blocks automatically have such open round connector ports. You can add additional connector ports by adding Connection Port blocks to your subsystem.

Breaker

The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external Simulink signal (external control mode), or from an internal control timer (internal control mode). The arc extinction process is simulated by opening the breaker device when the current passes through 0 (first current zero crossing following the transition of the Simulink control input from 1 to 0). When the breaker is closed it behaves as a resistive circuit. It is represented by a resistance Ron. The Ron value can be set as small as necessary in order to be negligible compared with external components (typical value is 10 m). When the breaker is open it has an infinite resistance. If the Breaker block is set in external control mode, a Simulink input appears on the block icon. The control signal connected to the Simulink input must be either 0 or 1: 0 to open the breaker, 1 to close it. If the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

If the breaker initial state is set to 1 (closed), SimPowerSystems automatically initializes all the states of the linear circuit and the Breaker block initial current so that the simulation starts in steady state. A series Rs-Cs snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

Distributed Parameter Line

Implement an N-phase distributed parameter transmission line model with lumped losses The Distributed Parameter Line block implements an N-phase distributed parameter line model with lumped losses. The model is based on the Bergeron's traveling wave method used by the Electromagnetic Transient Program (EMTP).In this model, the lossless distributed LC line is characterized by two values (for a single-phase line).

For multiphase line models, modal transformation is used to convert line quantities from phase values (line currents and voltages) into modal values independent of each other. The previous calculations are made in the modal domain before being converted back to phase values. In comparison to the PI section line model, the distributed line represents wave propagation phenomena and line end reflections with much better accuracy.

Description of the Control and Protection Systems

The control systems of the rectifier and of the inverter use the same Discrete HVDC Controller block from the Discrete Control Blocks library of the SimPowerSystems Extras library. The block can operate in either rectifier or inverter mode. At the inverter, the Gamma Measurement block is used and it is found in the same library. The Master Control system generates the current reference for both converters and initiates the starting and stopping of the DC power transmission.

The protection systems can be switched on and off. At the rectifier, the DC fault protection detects a fault on the line and takes the necessary action to clear the fault. The Low AC Voltage Detection subsystem at the rectifier and inverter serves to discriminate between an AC fault and a DC fault. At the inverter, the Commutation Failure Prevention Control subsystem [2] mitigates commutation failures due to AC voltage dips. A more detailed description is given in each of these protection blocks.

HVDC Controller Block Inputs and Outputs

Inputs 1and 2 are the DC line voltage (VdL) and current (Id). Note that the measured DC currents (Id_R and Id_I in A) and DC voltages (VdL_R and VdL_I in V) are scaled to p.u. (1 p.u. current = 2 kA; 1 p.u. voltage = 500 kV) before they are used in the controllers.

The VdL and Id inputs are filtered before being processed by the regulators. A first-order filter is used on the Id input and a second-order filter is used on the VdL input.

Inputs 3 and 4 (Id_ref and Vd_ref) are the Vd and Id reference values in p.u.

Input 5 (Block) accepts a logical signal (0 or 1) used to block the converter when Block = 1.

Input 6 (Forced-alpha) is also a logical signal that can be used for protection purposes. If this signal is high (1), the firing angle is forced at the value defined in the block dialog box.

Input 7 (gamma_meas) is the measured minimum extinction angle of the converter 12 valves. It is obtained by combining the outputs of two 6-pulse Gamma Measurement blocks. Input 8 (gamma_ref) is the extinction angle reference in degrees. To minimize the reactive power absorption, the reference is set to a minimum acceptable angle (e.g., 18 deg).

Finally, input 9 (D_alpha) is a value that is subtracted from the delay angle maximum limit to increase the commutation margin during transient.

The first output (alpha_ord) is the firing delay angle in degrees ordered by the regulator. The second output (Id_ref_lim) is the actual reference current value (value of Id_ref limited by the VDCOL function as explained below). The third output (Mode) is an indication of the actual state of the converter control mode.

The state is given by a number (from 0 to 6) as follows:

0 Blocked pulses

1 Current control

2 Voltage control

3 Alpha minimum limitation

4 Alpha maximum limitation

5 Forced or constant alpha

6 Gamma control

Synchronization and Firing System

The synchronization and generation of the twelve firing pulses is performed in the 12-Pulse Firing Control system. Use Look under mask to see how this block is built. This block uses the primary voltages (input 2) to synchronize and generate the pulses according to the alpha firing angle computed by converter controller (input 1). The synchronizing voltages are measured at the primary side of the converter transformer because the waveforms are less distorted. A Phase Locked Loop (PLL) is used to generate three voltages synchronized on the fundamental component of the positive-sequence voltages. The firing pulse generator is synchronized to the three voltages generated by the PLL. At the zero crossings of the commutating voltages (AB, BC, CA), a ramp is reset. A firing pulse is generated whenever the ramp value becomes equal to the desired delay angle provided by the controller.

DESIGN OF SIMULTANEOUS AC–DC POWER TRANSMISSION

Fig. 4.2.1. depicts the basic scheme for simultaneous ac–dc power flow through a double circuit ac transmission line. The dc power is obtained through line commutated 12-pulse rectifier bridge used in conventional HVDC and injected to the neutral point of the zigzag connected secondary of sending end transformer and is reconverted to ac again by the conventional line commutated 12-pulse bridge inverter at the receiving end. The inverter bridge is again connected to the neutral of zig-zag connected winding of the receiving end transformer.

The double circuit ac transmission line carriers both three-phase ac and dc power. Each conductor of each line carries one third of the total dc current along with ac current.Resistance being equal in all the three phases of secondary winding of zig-zag transformer as well as the three conductors of the line, the dc current is equally divided among all the three phases.

The three conductors of the second line provide return path for the dc current. Zig-zag connected winding is used at both ends to avoid saturation of transformer due to dc current.Two fluxes produced by the dc current $(I_d/3)$ flowing through each of a winding in each limb of the core of a zig-zag transformer are equal in magnitude and opposite in direction. So the net dc flux at any instant of time becomes zero in each limb of the core. Thus, the dc saturation of the core is avoided. A high value of reactor X_d is used to reduce harmonics in dc current. In the absence of zero sequence and third harmonics or its multiple harmonic voltages, under normal operating conditions, the ac current flow through each transmission line will be restricted between the zigzag connected windings and the three conductors of the transmission line. Even the presence of these components of voltages may only be able to produce negligible current through the ground due to high value of X_d.

Assuming the usual constant current control of rectifier and constant extinction angle control of inverter [4], [8]–[10], the equivalent circuit of the scheme under normal steady-state operating condition is given in Fig. 2. The dotted lines in the figure show the

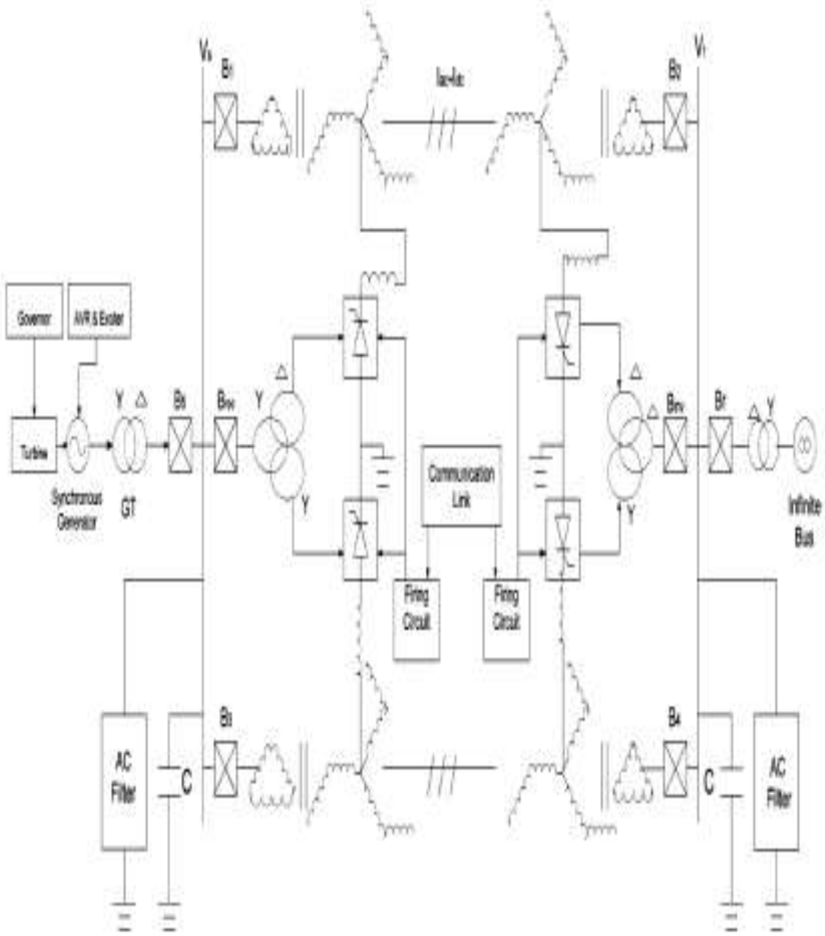


Fig. 1. Basic scheme for composite ac–dc transmission

path of ac return current only. The second transmission line carries the return dc current , and each conductor of the line carries $I_d/3$ along with the ac current per phase. and are the maximum values of rectifier and inverter side dc voltages and are equal to $(3\sqrt{2}/\pi)$ times converter ac input line-to-line voltage. R, L, and C are the line parameters per phase of each line. , R_{cr}, R_{ci} are commutating resistances, and α, γ are firing and extinction angles of rectifier and inverter, respectively. Neglecting the resistive drops in the line conductors and transformer windings due to dc current, expressions for ac voltage and current, and for active and reactive powers in terms of A, B, C, and D parameters of each line may be written as

$$E_s = AE_R + BI_R \quad (1)$$

$$I_s = CE_R + DI_R \quad (2)$$

$$P_s + jQ_s = -E_sE_R^*/B^* + D^*E_S^2/B^* \quad (3)$$

$$P_R + jQ_R = E_s^*E_R/B^* - A^*E_R^2/B^*. \quad (4)$$

Neglecting ac resistive drop in the line and transformer, the dc power P_{dr} and P_{di} of each rectifier and inverter may be expressed as

$$P_{dr} = V_{dr}I_d \quad (5)$$

$$P_{di} = V_{di}I_d. \quad (6)$$

Reactive powers required by the converters are

$$Q_{dr} = P_{dr}\tan\theta_r \quad (7)$$

$$Q_{di} = P_{di}\tan\theta_i \quad (8)$$

$$\cos\theta_r = [\cos\alpha + \cos(\alpha + \mu_r)]/2 \quad (9)$$

$$\cos\theta_i = [\cos\gamma + \cos(\gamma + \mu_i)]/2. \quad (10)$$

$$P_{st} = P_s + P_{dr} \text{ and } P_{rt} = P_R + P_{di} \quad (11)$$
$$Q_{st} = Q_s + Q_{dr} \text{ and } Q_{rt} = Q_R + Q_{di}. \quad (12)$$

Transmission loss for each line is

$$P_L = (P_S + P_{dr}) - (P_R + P_{di}). \quad (13)$$

I_a being the rms ac current per conductor at any point of the line, the total rms current per conductor becomes

$$I = \left[I_a^2 + (I_d/3)^2\right]^{1/2}$$

Power loss for each line $= P_L \approx 3I^2R.$

The net current in any conductor is offsetted from zero. In case of a fault in the transmission system, gate signals to all the SCRs are blocked and that to the bypass SCRs are released to protect rectifier and inverter bridges. The current in any conductor is no more offseted. Circuit breakers (CBs) are then tripped at both ends to isolate the faulty line. CBs connected at the two ends of transmission line interrupt current at natural current zeroes, and no special dc CB is required. Now, allowing the net current through the conductor equal to its thermal limit (I_{th})

$$I_{th} = \left[I_a^2 + (I_d/3)^2\right]^{1/2}. \quad (14)$$

Let V_{ph} be per-phase rms voltage of original ac line. Let Also V_a be the per-phase voltage of ac component of composite ac–dc line with dc voltage V_d superimposed on it. As insulators remain unchanged, the peak voltage in both cases should be equal

equivalent circuit

Electric field produced by any conductor possesses a dc component superimpose on it a sinusoidally varying ac component. However, the instantaneous electric field polarity changes its sign twice in a cycle if $(V_d/V_a) < \sqrt{2}$ is insured. Therefore, higher creepage distance requirement for insulator discs used for HVDC lines are not required. Each conductor is to be insulated for , V_{max}, but the line-to line voltage has no dc component and . $V_{LL\,max} = \sqrt{6}V_a.$

Therefore, conductor-to-conductor separation distance of each line is determined only by rated ac voltage of the line. Allowing maximum permissible voltage offset such that the composite voltage wave just touches zero in each every cycle;

$$V_d = V_{ph}/\sqrt{2} \text{ and } V_a = V_{ph}/2. \qquad (16)$$

The total power transfer through the double circuit line before conversion is as follows:

$$P'total \approx 3V_{ph}{}^2 Sin\delta_1/X \qquad (17)$$

Where X is the transfer reactance per phase of the double circuit line, δ_1 and is the power angle between the voltages at the two ends. To keep sufficient stability margin, δ_1 is generally kept low for long lines and seldom exceeds 30 . With the increasing

length of line, the load ability of the line is decreased [4]. An approximate value of δ_1 may be computed from the load ability curve by knowing the values of surge impedance loading (SIL)

and transfer reactance X of the line $P'_{total} = 2.M.SIL$ (18)

where M is the multiplying factor, and its magnitude decreases with the length of line. The value of M can be obtained from the load ability curve . The total power transfer through the composite line

$$P_{total} = P_{ac} + P_{dc} = 3V_a^2 Sin\delta_2/X + 2V_d I_d. \qquad (19)$$

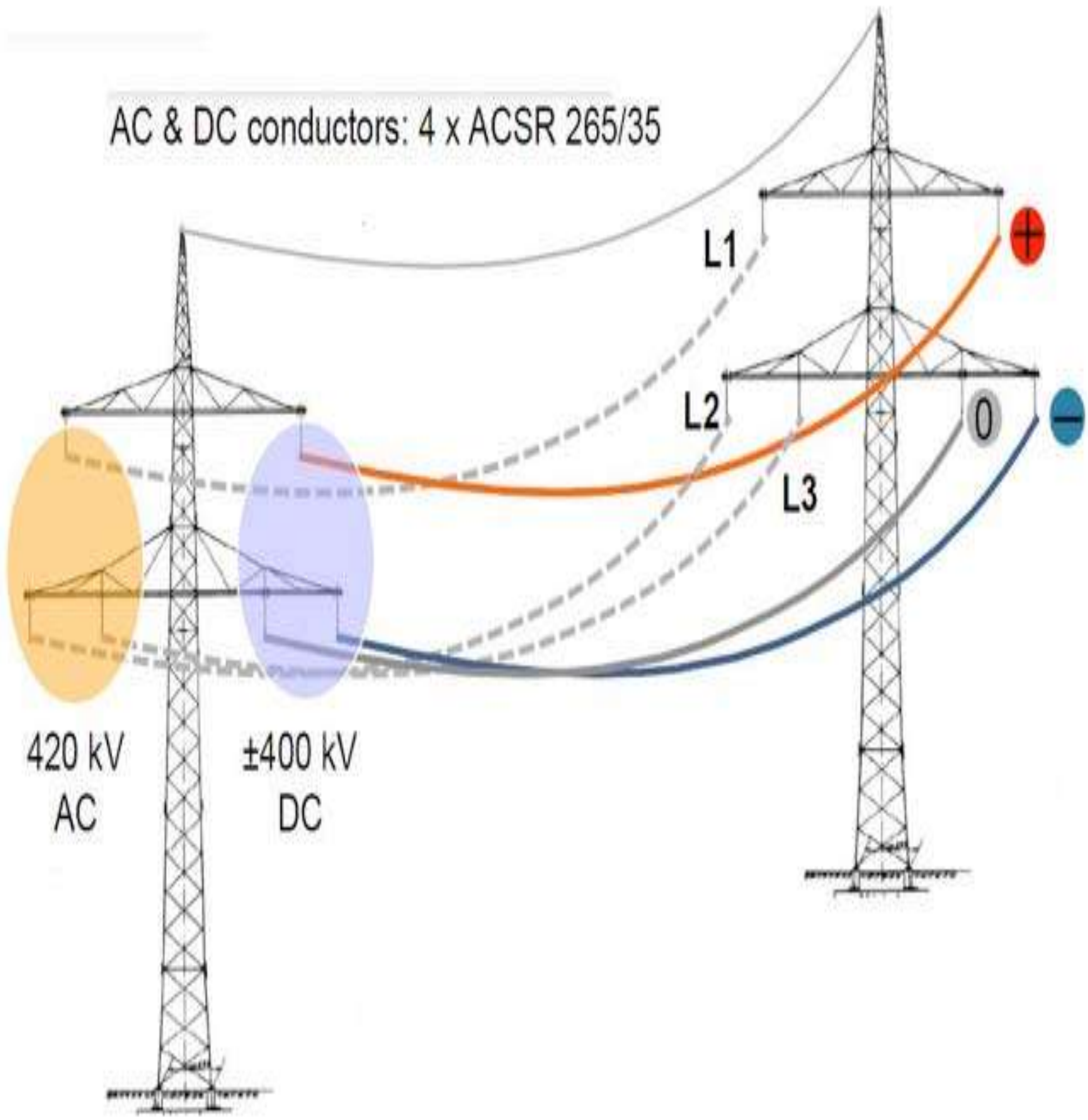
The power angle δ_2 between the ac voltages at the two ends of the composite line may be increased to a high value due to fast controllability of dc component of power. For a constant value of total power, P_{ac} may be modulated by fast control of the current controller of dc power converters. Approximate value of ac current per phase per circuit of the double circuit line may be computed as

$$I_a = V(Sin\delta/2)/X. \qquad (20)$$

The rectifier dc current order is adjusted online as

$$I_d = 3\sqrt{I_{th}^{*2} - I_a^{*2}}. \qquad (21)$$

Preliminary qualitative analysis suggests that commonly used techniques in HVDC/AC system may be adopted for the purpose of the design of protective scheme, filter, and instrumentation network to be used with the composite line for simultaneous ac–dc power flow. In case of a fault in the transmission system, gate signals to all the SCRs are blocked and that to the bypass SCRs are released to protect rectifier and inverter bridges. CBsare then tripped at both ends to isolate the complete system. A surge diverter connected between the zig-zag neutral and the ground protects the converter bridge against any over voltage.



Sample of AC-DC transmission line

RESULT

SYATEM RESULTS

AC Configuration only

The laudability of Moose (commercial name), ACSR, twin bundle conductor, 400-kV, 50-Hz, 450-Km single circuit line has been computed.

The parameters of line are Z=0.6054+j0.66172 Z/km/ph/ckt Y=j6.67594*10-6s/km/ph/ckt Current carrying capacity of each sub conductor =.9kA ,Ith = 1.8 kA/ckt.

SIL = 511MW/ckt , x=74.4435 ohms/ph.

Using (17)–(20), the computed power at receiving end and conductor current is

P'total =1124.2 MW Iph/ckt = 0.803 kA.

Conversion of the Conventional Double Circuit AC line into Composite AC-DC Power Transmission line

Let Vph be per-phase rms voltage of original AC line. Let also Va the per-phase voltage of AC component of composite AC-DC line with DC voltage Vd superimposed on it. As insulators remain unchanged, the peak voltage in both cases should be equal in a cycle if (Vd/Va) < √2 is insured.

Therefore, higher creepage distance requirement for insulator discs used for HVDC lines are not required. Each conductor is to be insulated for,Vmax but the line-to line voltage has no DC component and VLLmax = √6Va.

Therefore, conductor-to-conductor separation distance of each line is determined only by rated AC voltage of the line.

Allowing maximum permissible voltage offset such that the composite voltage wave just touches zero in each every cycle;

Vd = Vph/√2 and Va= Vph/2 . Va = 120 KV/ph (208kVLL ; Vd = 160 kV.

COMPARISON OF RESULTS

AC Configuration only

Table 5.2.1 shows Simulation results of ac configuration

Table 5.2.1

POWER ANGLE, δ	**30°**
LINE LENGTH	**450kms**
AC CURRENT	**Iac 0.76kA**
AC VOLTAGE	**Vph 230kV**
POWER TRANSFER	**P′total 1090MW**

Composite AC-DC Configuration

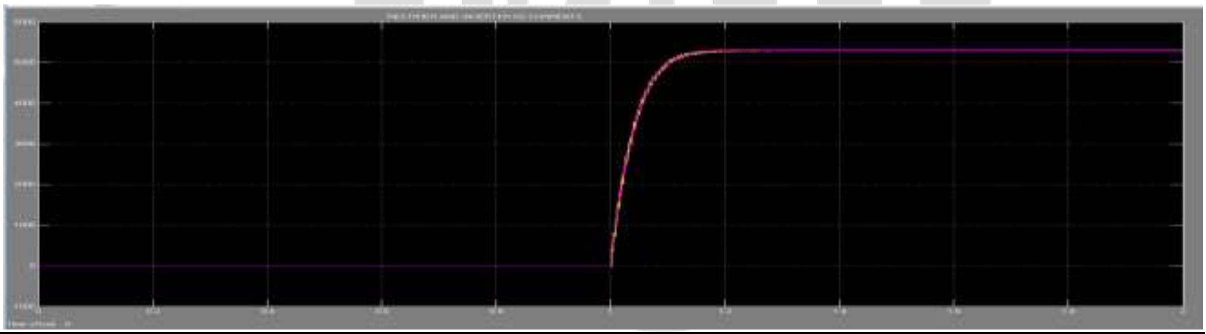
Table 5.2.2 showes Simulation results of composite ac-dc configuration

Table 5.2.2

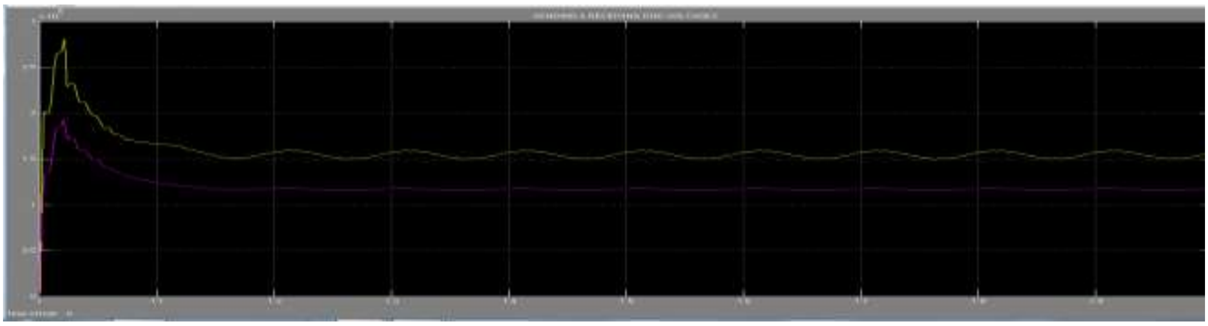
POWER ANGLE, δ	**30°**
LINE LENGTH	**450kms**
AC CURRENT	**Ia 400A**
DC CURRENT	**Id 5.3kA**
CONDUCTOR DC CURRENT	**Id/3 1.740kA**
CONDUCTOR CURRENT	**Iac-dc 1.785kA**
AC VOLTAGE	**Va 120kV**
DC VOLTAGE	**Vd 160kV**
AC POWER	**Pac 300MW**
DC POWER	**Pdc 1735MW**
TOTAL POWER TRANSFER	**Pac-dc 1935MW**

DIGITAL SIMULATION RESULT OF THE PROPOSED SCHEME

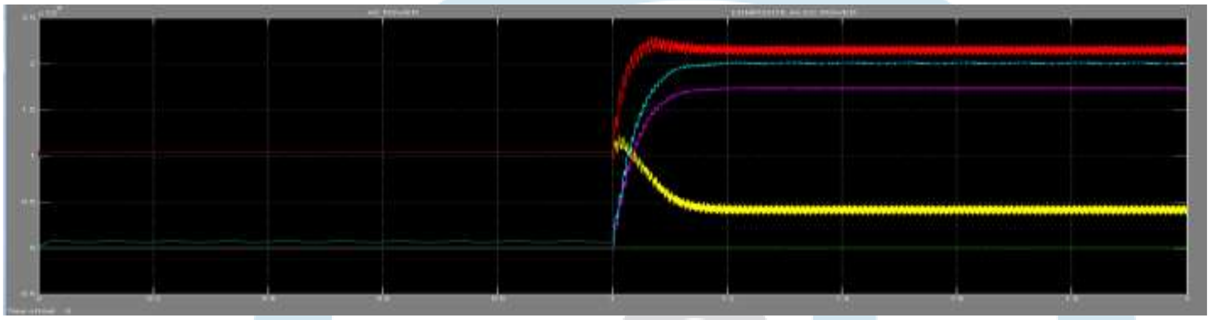
In order to examine the feasibility of the proposed scheme for enhanced power transfer and to observe the performance of the composite ac-dc power transmission system under various operating conditions, the MATLAB simulation is used. The simulated results in steady state are shown in bellow graphs.



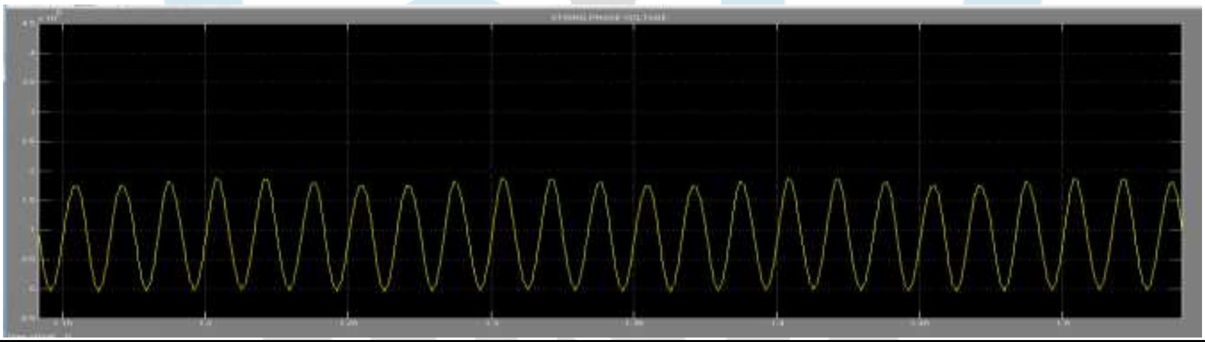
Rectifier and Inverter DC currents.



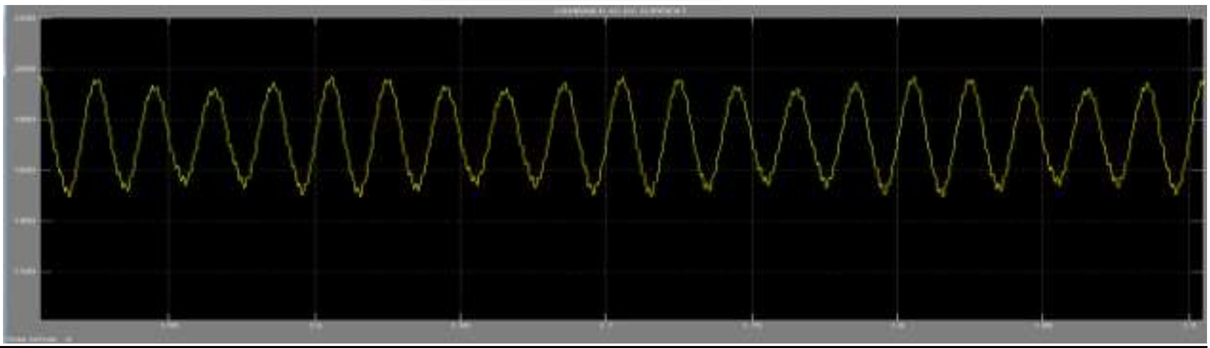
Sending & receiving end voltages.



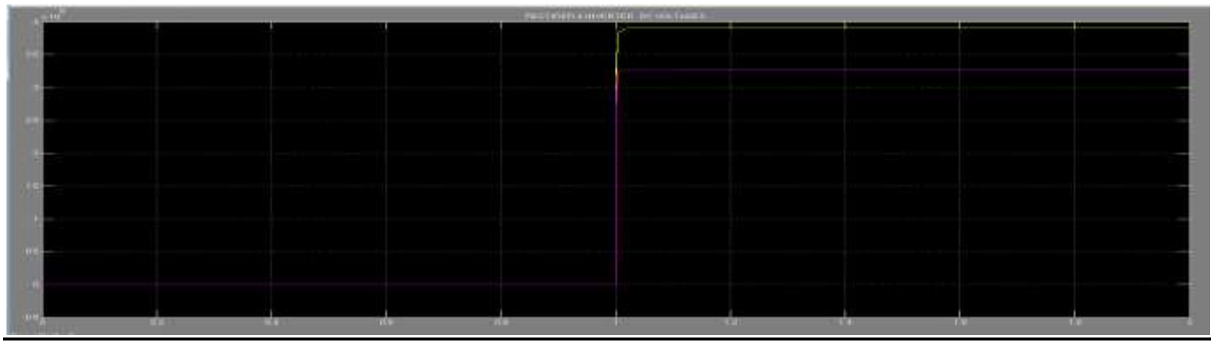
Sending end (Ps), ac (Pac), dc(Pdc), and total transfer.(Ptotal_tr) power



String phase voltage



Combined AC-DC Current (Iac-dc=1.785kA)



Converter voltages (Vdcr=375kV;Vdci=325kV)

CONCLUSION

The feasibility to convert ac transmission line to a composite ac–dc line has been demonstrated. For the particular system studied, there is substantial increase (about 83.45%) in the load ability of the line. The line is loaded to its thermal limit with the superimposed dc current. The dc power flow does not impose any stability problem.

The advantage of parallel ac–dc transmission is obtained.

Dc current regulator may modulate ac power flow. There is no need for any modification in the size of conductors, insulator strings, and towers structure of the original line. The optimum values of ac and dc voltage components of the converted composite line are 1/2 and times the ac voltage before conversion, respectively.

FUTURE SCOPE

In this paper, it is shown that by injecting DC power in AC power transmission lines; we can improve the transmission capacity of the line by 2 to 4 times without altering the physical equipment.

This work can be extended for analyzing the effect of faults on this type of transmission. This work is done on double circuit AC transmission lines but it can be extended to other types of transmission methods

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