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Techno-Economic Analysis of HVDC Links for Inter-State Interconnection

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ABSTRACT

The design of an interregional high-voltage transmission system in the US is a revolutionary technological concept that will likely play a significant role in the planning and operation of future electric power systems. This paper presents techno economics analysis of HVDC link for interstate inter connected system. there are two type transmission system used for large power supply to long distance transmission 1- HVDC (high voltage dc transmission system) 2- (HVAC) high voltage ac transmission system in which HVDC is preferable due less power loss in transmissions but it need high installing charge at the starting moment. It need two type of installation block 1- rectifier block at the sending end 2- inverter block at receiving end these both block deal with high reactive VAR. In this paper we are going to analyze technology of HVDC installation, there control, how HVDC link deal with reactive VAR (reactive power compensation), how its economical (if it need high installing charge).In this paper we are using 2500 MVA, 230 volt, 60 grid after rectifying power transmitted to 100 km by 100 km cable then it invert at receiving end for distribution. Here we are calculating reactive power demand for both inverter and converter both, we comparing HVDC transmutation system with HVAC transmission system (economically) we also coverings the environmental advantages for HVDC system. My focus in this paper is, how to minimize installing charge of HVDC link, how to increase power carrying capacity of HVDC system and how to make it environment friendly.

KEYWORDS: *HVDC Transmission, HVDC Challenges, LCC-HVDC, VSC-HVDC, HVDC Outlook*

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1. INTRODUCTION

DC transmission is more economical than ac transmission; most of domestic equipment and industry are ac load that's why we need inverter at the receiving end. The main problem in dc transmission is reduction of harmonics. Researcher is focus on reduction on harmonics and how it become more economical. Fig-1 shows the block diagram of HV ac- dc link in which ac grid is connected to a rectifier by a phase reactor for long distance transmission we are using here dc supply at the receiving end ac supply required to drive ac load that's why an inverter should be placed at receiving end. After a phase reactor we can put this power on a bus the distribute to deferent load[1]. This paper presents techno economics analysis of HVDC link for interstate inter connected system. There are two type transmission system used for large power supply to long distance transmission 1- HVDC (high voltage dc transmission system) 2- (HVAC) high voltage ac transmission system in which HVDC is preferable due less power loss in transmissions but it need high installing charge at the starting moment. It need two type of installation block 1- rectifier block at the sending end 2- inverter block at receiving end these both block deal with high reactive VAR[2].In this paper we are going to analyze technology of HVDC installation, there control, how HVDC link deal with reactive VAR (reactive power compensation), how its economical (if it need high installing charge).In this paper we are using 2500 MVA, 230 volt, 60 grid after rectifying power transmitted to 100 km by 100 km cable then it invert at receiving end for distribution[3].

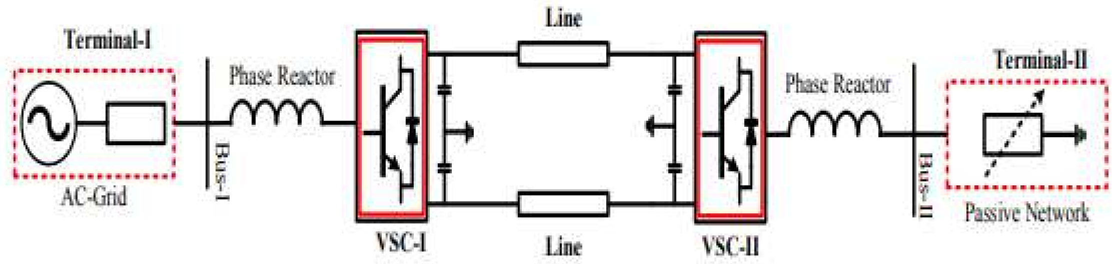

Fig-1 HVDC system with grid

DC transmission is more economical than ac transmission that's why dc supply used for transmission (for long distance) because it will be not economical for small distance transmission. Transmission has losses like corona loss, holmic loss, loss due to skin effect etc[4].

2. Technical issues Associated with AC grid interconnection:

AC grid has major disadvantage compare to dc, synchronization of grid is the challenging task in ac transmission where as dc transmission dos not need synchronization. AC transmission required transformer and there synchronization where as dc transmission don't need transformer, ac resistance is 1.6 time of dc resistance, that's why power loss in ac transmission is nearly 2.5 time of dc losses. Corona loss is the power loss in transmission line due to ionization of sounding air can be written as

$$P_{ufwc} = \frac{K}{\delta}(f+25)\sqrt{\frac{R}{d}}\left(\frac{V_L}{\sqrt{3}} - E_{dcv}\right)^2 L \times 10^{-5}\, KW/km/\, phase \quad (1)$$

Above equation shows that corona loss is directly proportional to (f+25) means if frequency is zero for dc supply corona loss will be very less compare to ac transmission line. Where as for ac if frequency is 60 Hz corona power loss will higher than dc transmission line [5].If power loss is more transmission will be costly. In ac transmission line minimum 3 line required where in dc 2 or 1 line required, resistance in line can be written by $R=\rho\frac{L}{A}$ where ρ is the resistivity of transmission line, L is the length of line A is the correction area of conductor, if line length will be large power loss will be more if in ac system there is minimum 3 conductors where as in dc system minimum 1 conductor that's why loss in ac will be nearly 3 time that of dc system power loss will be more if power loss is more electricity become costly[6]. Skin effect is phenomenon in which a time varying flux circulates the conductor due to skin effect current flow on the surface of conductor. Skin effect is possible only in ac conductor by considering all these parameter ac resistance is 1.6 time of dc resistance. Result of this power loss in ac conductor will be higher than dc resistance [5].

$$Skin\ Effect = \delta_s = \sqrt{\frac{2\rho}{2\pi f \mu_o \mu_r}} \quad (2)$$

δs is skin dept which is inversely proportional to(frequency) $^{0.5}$ and(permeability)$^{0.5}$, skin dept will be minimum for supper conductor nearly zero [7].DC supply where (f=0) skin dept will maximum it menace for dc supply current flow through whole conductor but in case of ac supply current only flow on the surface of conductor.

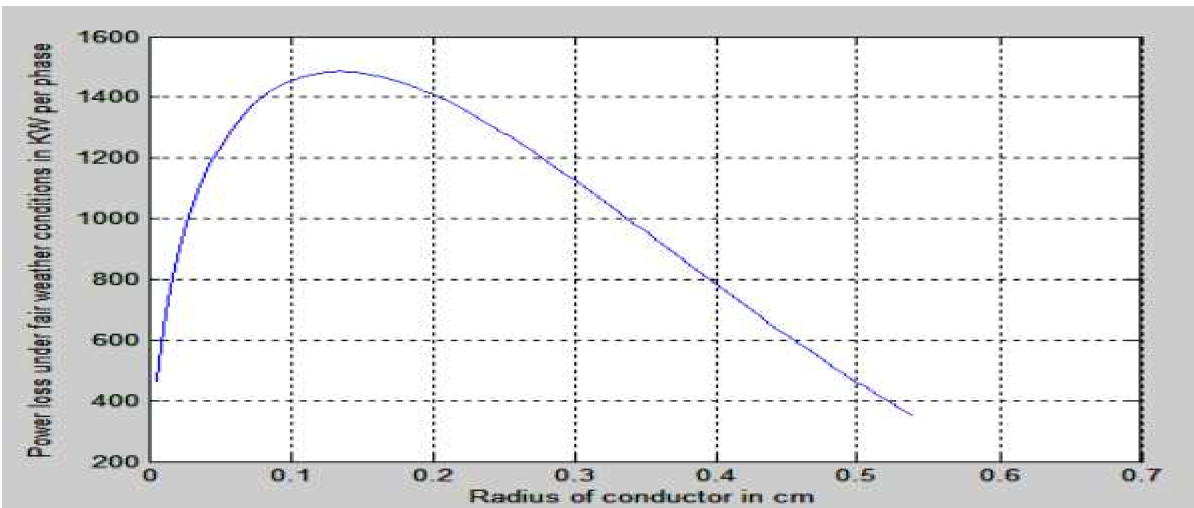

Fig-2 power loss in ac with respect to radius of conductor

Power loss in ac varies with respect to radios of conductor are shown in above fig-2which is increase with increase in radios but after a certain value of radios power loss decrees [8].

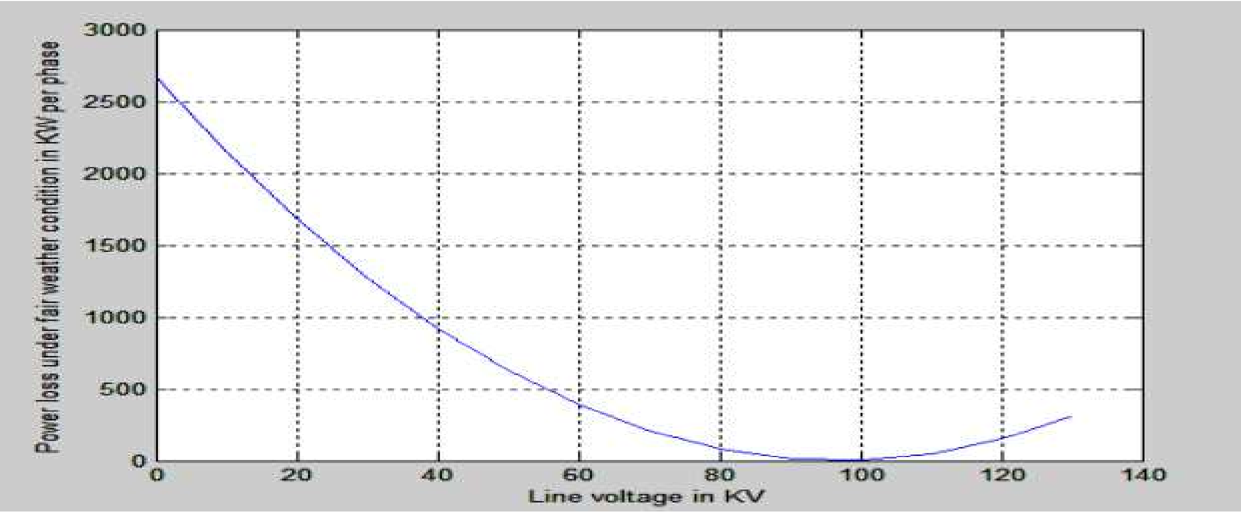

Fig-3 power loss with line voltage

Above fig 3 shows the variation of power loss with respect to line voltage in which shows that at 100 KV power losses will be zero below this voltage power loss will be high and increase up to zero voltage. When voltage increase beyond 100 KV power loss increase again gradually [7].

$\delta s =$ Skin depth (meter)

$\rho =$ Resistivity of the electrical conductor (Ohm Meter)

f= frequency in hertz

$\mu 0 =$ Permeability constant

μ_r= Relative permeability of medium.

Cost variation of ac and dc power transmission shown in fig -1.4 (a) it indicate ac loss as well as dc varies linearly with distance, but slope of dc loss line is less than slope of ac loss line it menace rate increase of ac loss is higher than rate of increase of dc loss, at staring ac power loss is less but rate of increase of loss is very high that's why it meat very soon to dc loss line at distance d show in fig beyond distance d ac loss increase at high rate[9].For small distance dc transmission is not economical but for large distance is much economical.

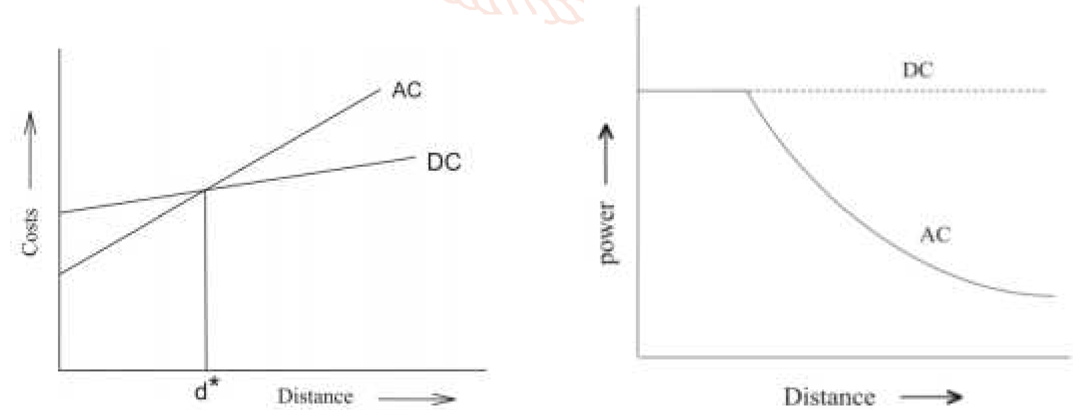

Fig-4 (a) cost versus distance **(b) Power transfer capacity**

3. **Power carrying capacity:**

Power carrying capacity is define as P= $\frac{EV}{X} sin\delta$ (3)

X is impedance of line and δ is torque angle (angle between receiving and sending end voltage), for large X power carrying capacity will be low in ac transmission[10]. Power loss increase sharply for large distance that's why power carrying capacity decrease for large distance.

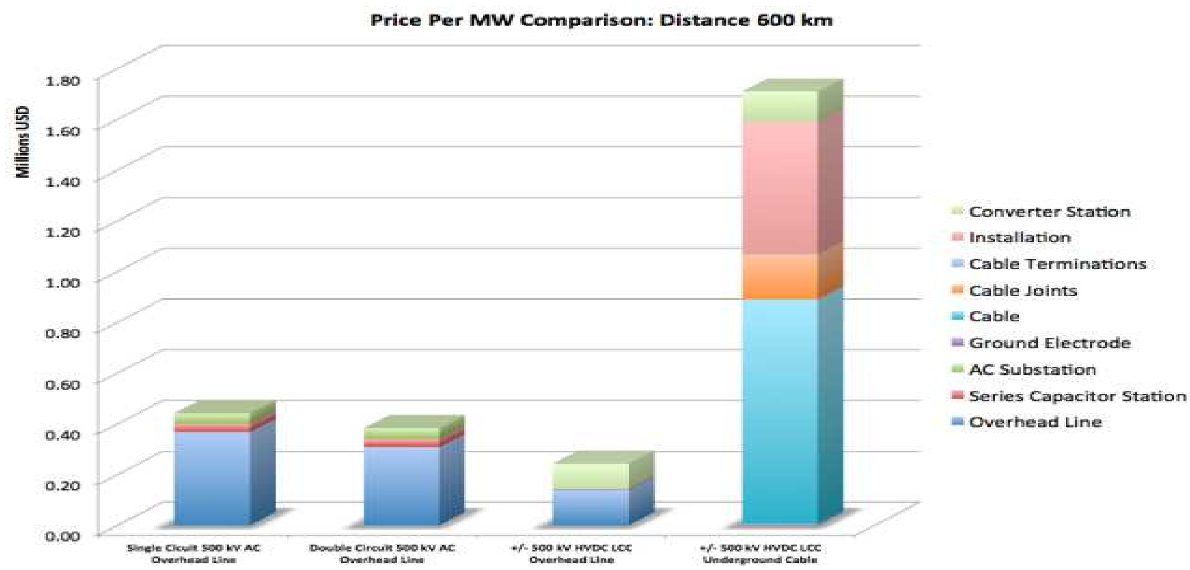

Fig-5 Price comparison per MW cost

Fig-5 shows the variation of cost with respect to deferent type of transmission dc power can be transmit by over head line and with help of underground cable, underground power transmission cost showing maximum cost where as single line overhead dc power transmission showing the minimum cost ac transmission cost is higher than dc transmission cost but less than underground dc transmission cost. Electrical can be transmit with help of overhead transmission line, underground cable or by using wireless power transmission (not used), HVDC transmission normally done on over head transmission line with high voltage. Conceder a 2 bus power system network where V1 is the voltage at bus- 1, V2 is the voltage at bus 2, $\delta 1$ is the torque angle at bus -1, $\delta 2$ is the torque angle at bus -2, For ideal transmission line (no power losses in lines) receiving end (voltage at bus-1) should be equal to sending voltage (voltage at bus -2)[11].

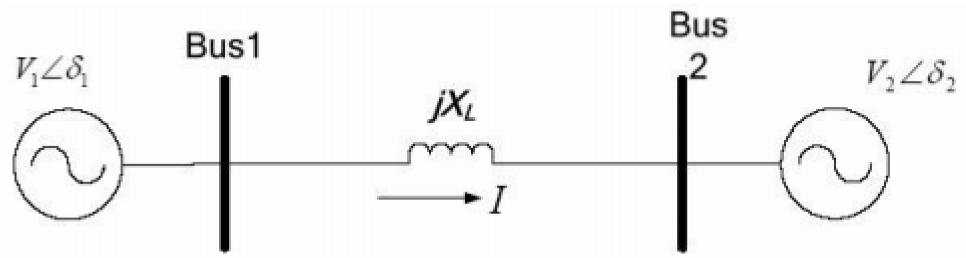

Fig-6 Transmission line

Current in transmission line can be written as:

$$I = \frac{V1<\delta1-V2<\delta2}{XL} \quad (4)$$

Where X_L is the inductance of transmission line, from above equation we can conclude that current in transmission line is inversely proportional to line reactance X or load carrying capacity is inversely proportional to line reactance X so if u want control variation in load (receiving end voltage) we have control line reactance[12].

4. Traditional method of Reactive voltage control.

Synchronous phase modifier is ideal source having capacitor can inject or absorbed reactive VAR it has many limitations but it give fast response and trouble free service[13]. It's a reactor connected in shunt to transmission line with mechanical switch. it has some advantages

1. less cost
2. installation free
3. no require strong foundation
4. Very less maintenance problem.
5. long life

The disadvantages are:
1. cant remove harmonics
2. not possible to vary reactive power with load variation
3. possibility of resonance

Reactive power also known as imaginary power, it means it is a kind of power which will be present always in system but it cannot participate practically to load, but reactive power has significant role in power quality it can improve power quality for proper management of reactive VAR. Assume we have load which can generate Q unit of reactive VAR at same time if another power equipment observe that Q unit of reactive VAR then power quality of power system will be better system will operate safely[14]. But what happen if there is large amount of reactive VAR present in system in that case power quality will be very poor and power factor will be low very less than unity, load draw high current result of this it possible that load may burn (if induction motor connected at as load it is possible that armature winding of motor may damage) because load produce very large high energy if motor is higher rating produce heat will responsible for global warming, result of this nature will damage. So we are strongly recommended that to avid these we have to improve power quality of power system, make Pf=1, it has only one wave that is compensation of reactive VAR [15].

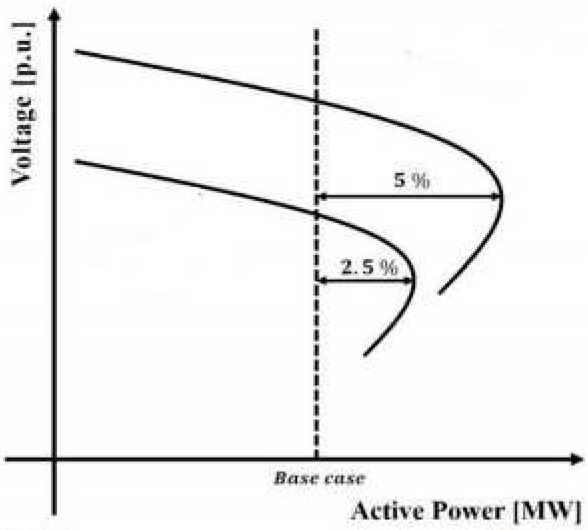

Fig-9 variation of active power with bus voltage

The variation of load voltage with active power are shown in above fig, the curve shows that load voltage decreases with increase in active power of load. Similarly if load decreases voltage across load will increase[16].

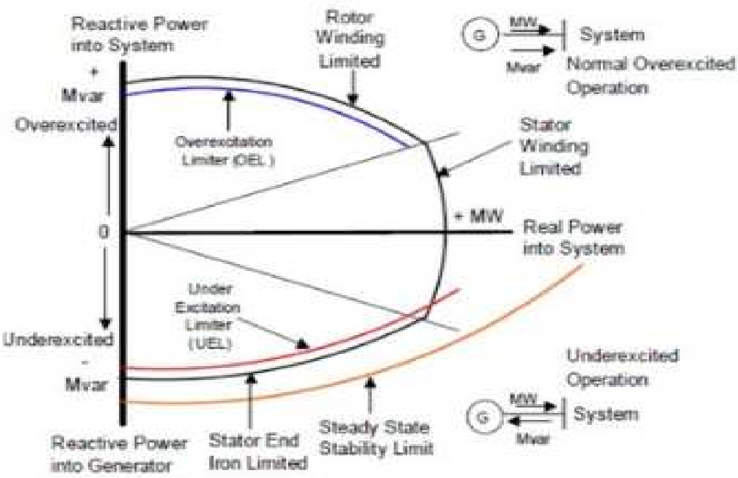

Fig -10 variation of reactive power with active power

5. MATLAB/SIMULINK:

The economical way for long distance power transmission is the HVDC transmission, HVDC transmission reduces the transmission loss same time it increase the power carrying capacity and stability of power system but same it increase the harmonics component in power system. To reduce harmonics components in power system we have use filters and other techniques line higher level inverter. In the conversion and inversion process semiconductor devices SCR, MOSFET, TRICK etc are used when ever these component are used an extra power component added by the junctions of semiconductor device. Semiconductor devices generate reactive power in power supply system some time it absorbed reactive power too, so we have to proper arrangement of reactive VAR compensation.

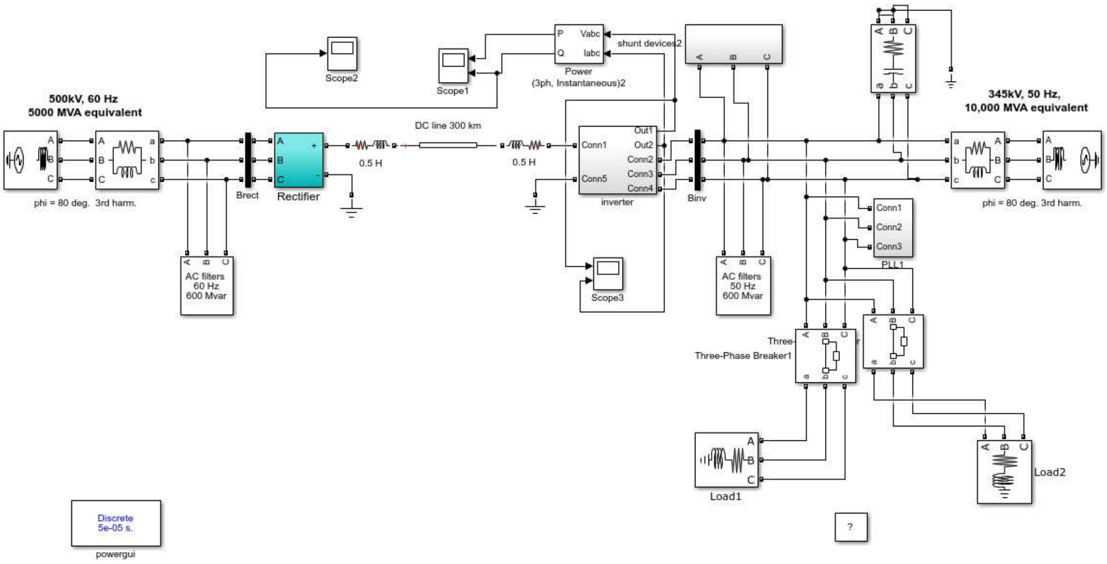

Fig-11 MATLAB/SIMULINK of proposed HVDC system

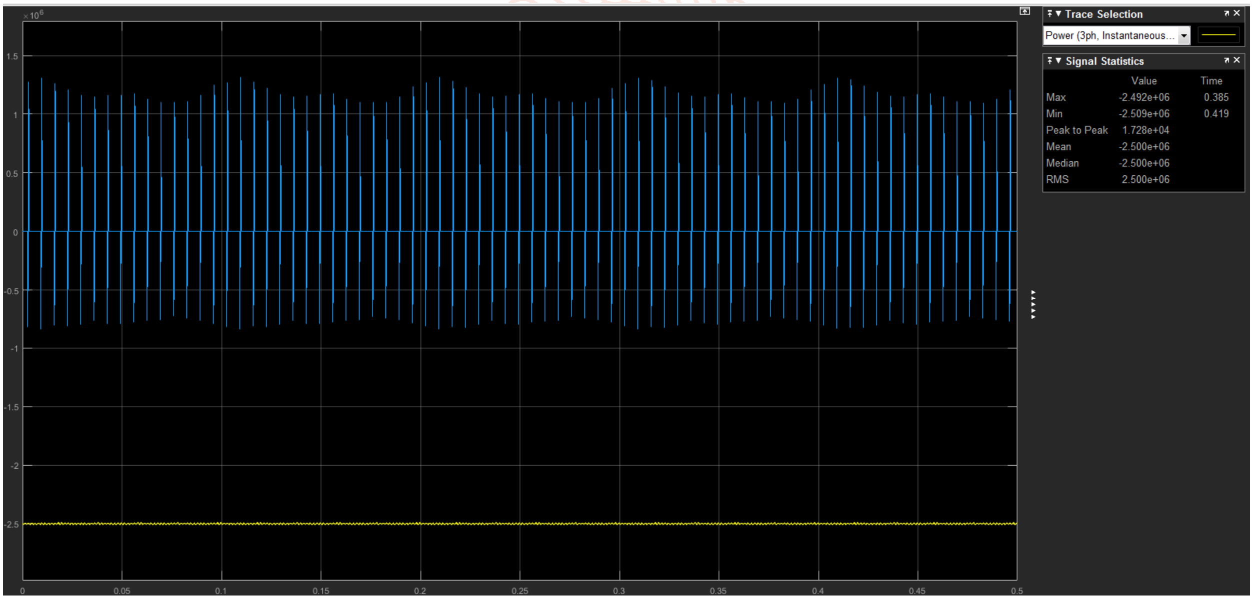

Fig- 12 Active and reactive power of dc link

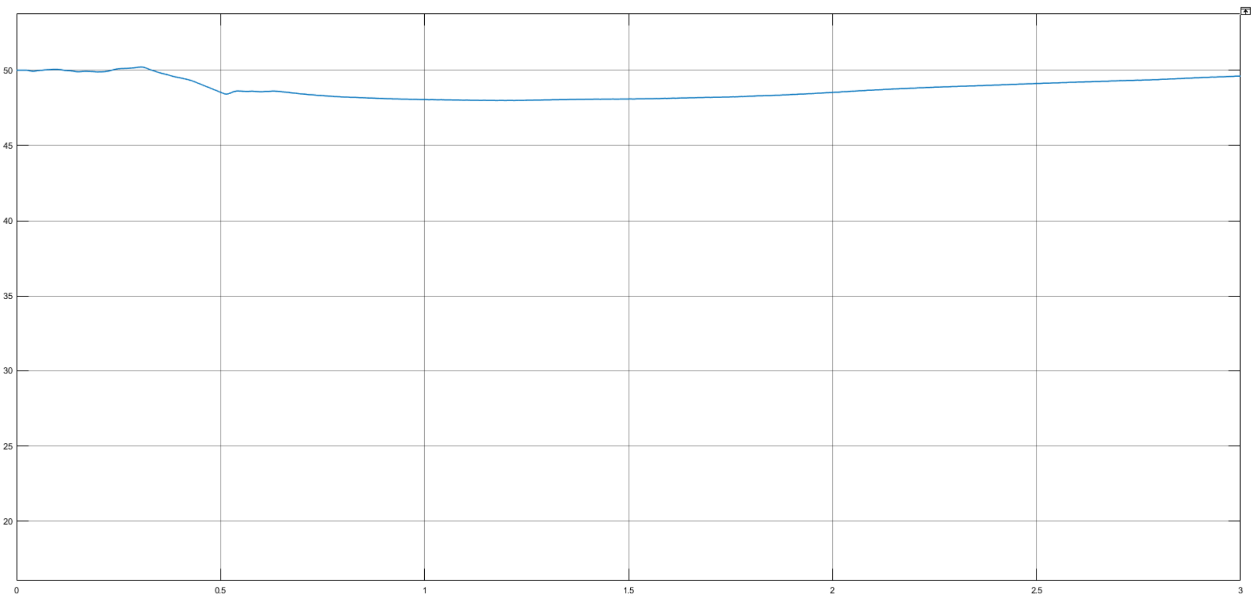

Fig-13 frequency of AC supply of proposed HVDC system

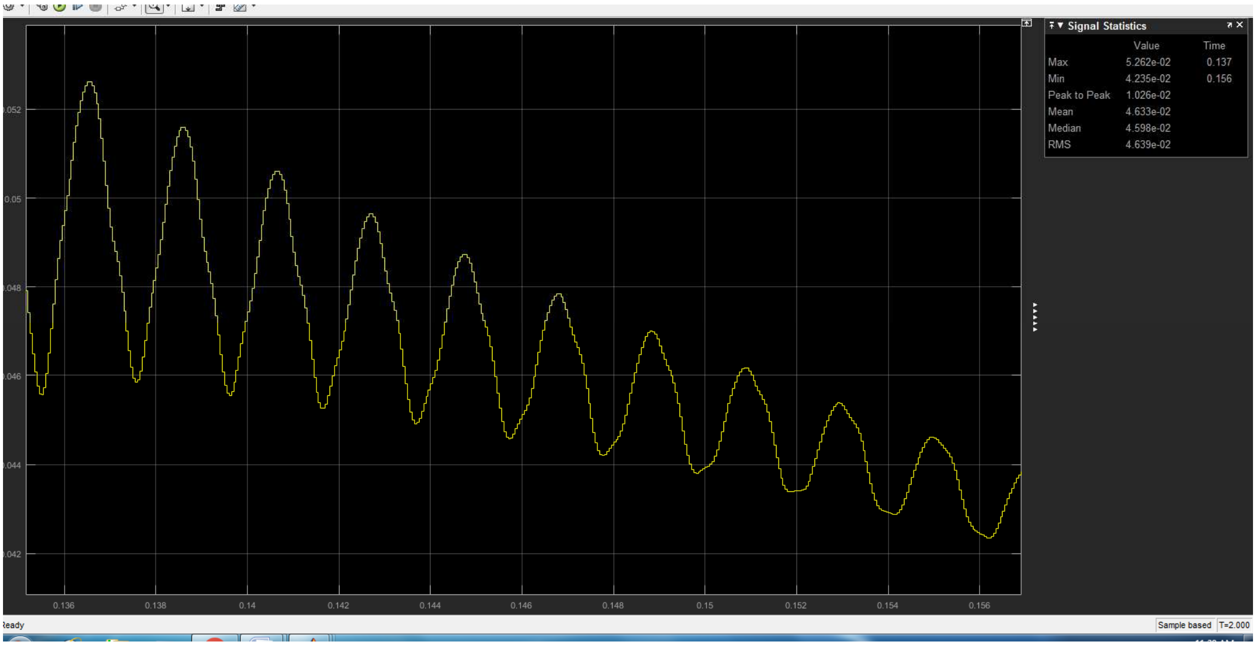

Fig-14 DC current DC link of proposed HVDC system

Result and conclusion: HVDC transmission technique is effective technique to transmitted power long distance with reduce loss, better efficiency the main problem of this transmission is reactive power compensation and reduction of harmonics. The effect of HVDC on system voltage is lower, and presents a voltage profile within the allowable limits, close to unity. From published works, voltage stability of a congested line can be achieved by converting the HVAC line to an HVDC. Congestion relieve is thus achieved by converting line 4-5 from AC to a DC line and hence controlling power flow resulting to more of the cheaper generation being dispatched.

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