Power System Stability By Incorporating Closed Loop Controller as a Power Flow Controller in HVDC Links

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Abstract : In this paper we introduce a HVDC transmission between two buses of an IEEE 9bus system with transient and dynamic analysis of rotor angle deviation of the three synchronous generators. The deviation of the generators is maintained in synchronization during steady state and after fault transient. Comparison of HVDC VSCs with different controllers is presented with P, PI and PID controllers. Modeling and simulation is carried out in MATLAB software with graphical representations.

***IndexTerms* – HVDC links , Powerflow Controllers, Rotor angle deviation,VSCs**

I. INTRODUCTION

HVDC systems are used in for long transmission systems to reduce the power loss occurred due to high power transmission above 1500MW. In a simple interconnected system high power transmissions even with ultra high AC voltage may lead to high power loss as the conductor size has to be increased to handle large power transmission. With the increase in conductor size the transmission line the losses also increase which increases gradually with increase in distance. In a DC transmission the conduction of the current happens through all the cross section of the conductor which creates an advantage for transmission of large powers with lower size of conductors at higher voltages in the range of 500kV to 765kV. In this paper a HVDC transmission system in introduced in IEEE 9 bus system [1] which includes three synchronous generators feeding three AC loads at different locations with 220KV AC transmission lines.

As the IEEE 9 bus system is in synchronization the rotor angle deviation of the three generators are also in synchronization in steady state condition. Considering a fault at one of the buses on the IEEE 9 bus system, disrupts the rotor angle deviation of the synchronous generators [2]. And even after the fault is eliminated after a small transient time the rotor angle deviations of the synchronous generators will not get into synchronization creating harmonics and disruption in the transmission lines reducing the power quality of the bus system effecting the loads connected to it. To overcome this issue of non-synchronization of the rotor angel deviations of the synchronous generators after the fault a HVDC system is connected in between two busses controlling the voltage of the HVDC transmission system with the control of the VSCs (Voltage Source Converters). The adopted IEEE 9 bus system single line diagram can be seen in fig. 1 below.

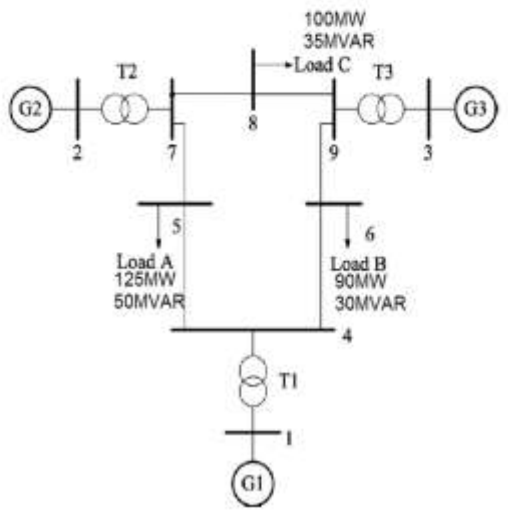

Fig. 1: IEEE 9 bus system single line diagram

The ratings of the generators, loads and transmission lines of the IEEE 9 bus system is given below in TABLE I.

TABLE I

Bus	V (kV)	P (MW)	Q (MVAR)
Bus1	16.5		
Bus 2	18		
Bus 3	13.8		
Bus 4	230		
Bus 5	230	125.841	50.327
Bus 6	230	87.705	29.235
Bus 7	230		
Bus 8	230	96.879	33.894
Bus 9	230		

The transmission line data between each bus with 230kV transmission voltage is given in TABLE II below.

TABLE II

Line	Bus	R	X	Y
Line 1	5 – 4	5.29	44.96	0.0003327
Line 2	6 – 4	8.99	48.66	0.0002987
Line 3	7 – 5	16.92	85.16	0.0005785
Line 4	9 – 6	20.63	89.93	0.0006767
Line 5	9 – 8	6.29	53.32	0.0003951
Line 6	8 – 7	4.49	38.08	0.0002817

II. MODELING OF IEEE 9 BUS SYSTEM

With the above parameters of the generator, load and transmission line R,X and Y data [3] the modeling of IEEE bus 9 bus system is done in MATLAB. The simulation of the IEEE 9 bus system with comparison of rotor angle deviation with total run time of 2sec with introducing a three phase to ground fault between bus 4 and bus 6from 0.4 to 0.45secs is shown below in fig. 2a, 2b and 3.

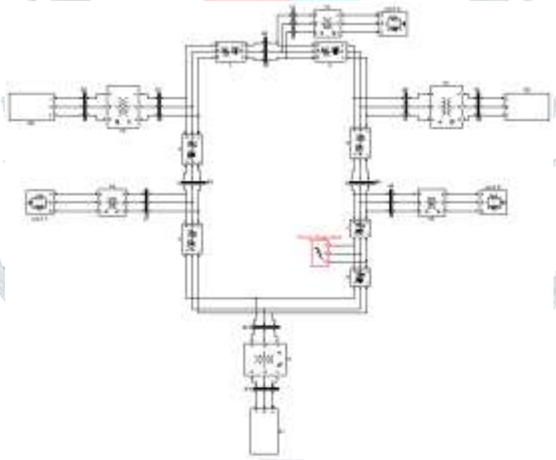

Fig. 2a: Simulink model of IEEE 9 bus system

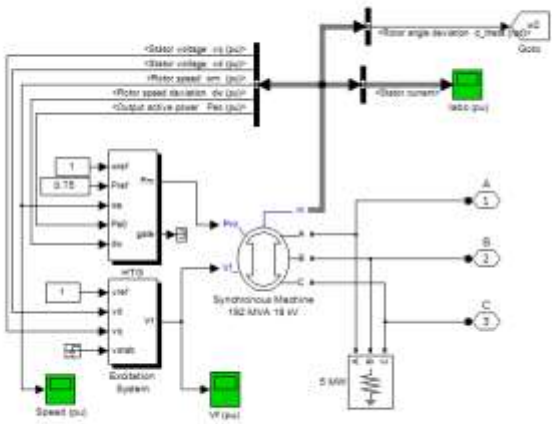

Fig. 2b: Synchronous generator modeling

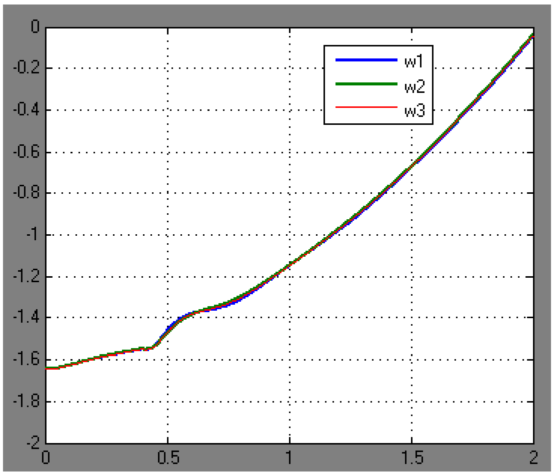

Fig. 3: Rotor angle deviation of G1 G2 and G3 with fault

With the above graphical representations from the simulation of IEEE 9 bus system with fault at 0.4sec it is observed that the even after the fault the rotor angle deviation of the generators are in synchronization. For lower transmission loss in the bus system a HVDC transmission system is introduced between Bus 4 and Bus 5. The modeling of the HVDC system [4] in IEEE 9 bus is shown below in fig. 4 and 5.

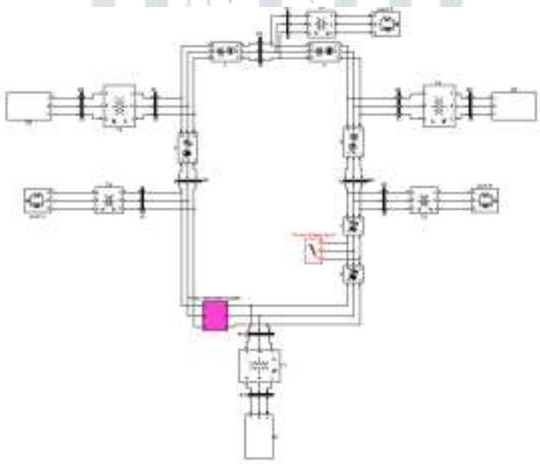

Fig. 4: IEEE 9 bus system modeling with HVDC transmission system between bus 4 and 5

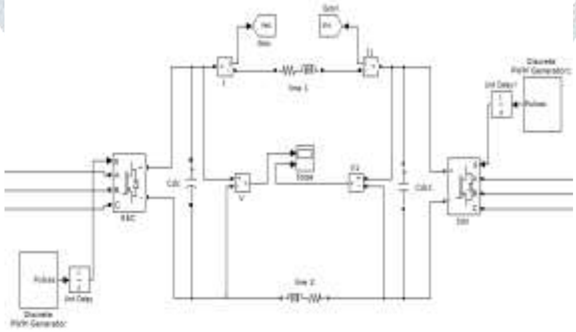

Fig. 5: HVDC transmission system with open loop PWM control

After the HVDC transmission system is introduced in the IEEE 9 bus system a fault is introduced from 0.7 to 0.75 sec with total simulation time of 3sec in MATLAB Simulink. The rotor angle deviation of the each generator are compared which is shown in fig. 6.

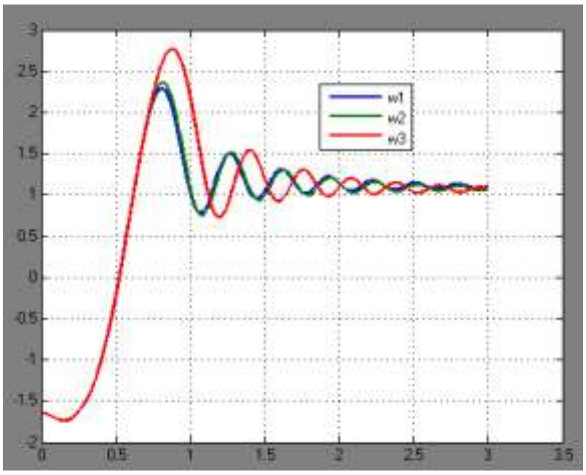

Fig. 6: Rotor angle deviation of G1,G2 and G3 with open loop HVDC transmission system

The above graph of the angles of G1 G2 and G3 denote that they are in synchronization until the fault and after the fault is introduced at 0.7sec the G3 rotor deviation angle is completely out of synchronization leading to harmonics in the IEEE 9 bus system damaging the loads connected to the generator.

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III. CLOSED LOOP CONTROL OF HVDC SYSTEM

To overcome the above state problem in section II of the non-synchronization of rotor angle deviation of the generators, the HVDC [5] system has to be controlled with a closed loop controller which can control the VSCs in turn controlling the voltage of transmission and reducing the effect of fault. The block diagram of the closed loop control with PI control [6] is given in fig. 7.

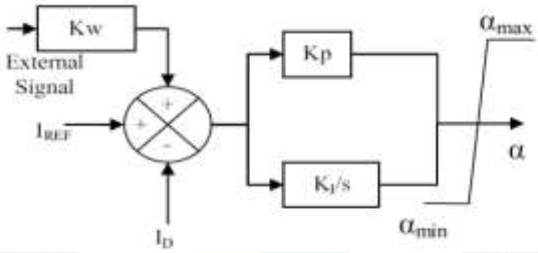

Fig. 7: Closed loop control of HVDC VSCs with Iref feedback

In the controller feedback measured external signal is taken from Bus 5 voltage magnitude through a conversion gain 'Kw' added with Iref and Id which are reference AC current and reference DC current respectively.

$I^* = Kw|V_{BUS5}| + I_{ref} + I_d$ ……………...…(1)

The I* (reference current) signal is fed to PI controller with Kp and Ki gains 0.01 and 0.02 respectively converting the SI unit value to pu representation. The magnitude of the reference current signal I* is multiplied with a sinusoidal wave by which PWM signals are generated.

$V_{ref} = I^* \sin(wt)$ ………………………..(2)

The V_{ref} waveform is compared to triangular wave with a frequency of 2kHz by which the VSCs are operated. The modeling of the control system with PI control is shown in fig. 8.

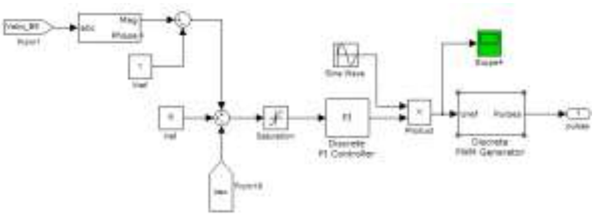

Fig. 8: Modeling of feedback PI control of VSCs in HVDC system

With the above feedback control of the VSCs [7] with feedback from sending end and receiving end voltages of the buses (Bus 5 and Bus 4) after the fault the rotor angle deviation of the generators G1 G2 and G3 are synchronized with a small deviation and better as compared to open loop control system.

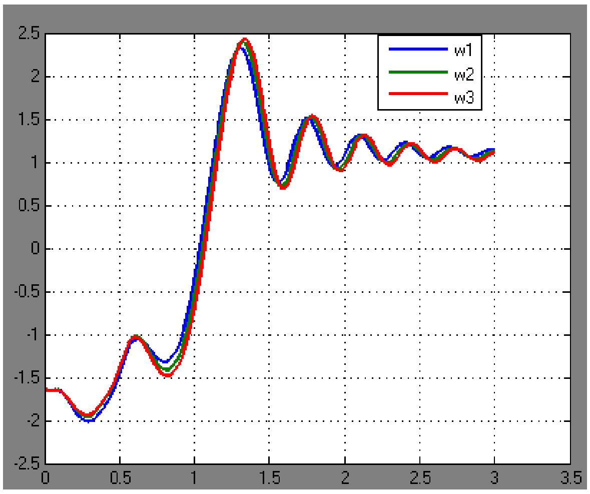

Fig. 9: Rotor angle deviation of G1 G2 G3 with feedback control system of VSCs with respect to time in secs

IV. CONCLUSION

With the above results of comparing rotor angle deviations w1 w2 w3 of all the three generator G1 G2 G3 respectively it is clear that the synchronization is maintained even after the fault for closed loop PI control of VSCs where as the angles are deviated after the fault for open loop control of VSCs. The complete results are validated with modeling of the modules in MATLAB Simulink software with comparison through graphs with respect to time.

V. REFRENCES

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