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EFFECT OF VARIATION OF LOADING CONDITION ON STATCOM CONTROLLER

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ABSTRACT.The Single Machine Infinite Bus (SMIB) power system installed with STATCOM is considered for the analysis. The static excitation system model type IEEE-ST1A has been considered along with a conventional PSS. The STATCOM is based on pulse width modulation (PWM) voltage source converter (VSC).It is used for Shunt compensation .Shunt compensation has the ability to automatically support the voltage level in a specific area of the power system. The voltage level is an immediate image of the reactive power balance – too high a voltage means a surplus of reactive power and vice versa. The systems react dynamically to changes in active and reactive power, influencing the magnitude and profile of the power systems voltage. Quite often it gives rise to a myriad of operational problems; the system operator has to intervene to try to achieve power flow redistribution, but with limited success .shunt compensator automatically and instantaneously adjusts the reactive power output smoothly as desired and thus improving the system stability.The dynamic performance of the system with/without the controllers Has been studied by taking different loading Conditions.

Keywords: STATCOM, Facts control, GEA, Matlab/Simulink

I. INTRODUCTION

A STATCOM is built up with power electronics devices with turn-off capabilities. VSC technology utilizing GTOs and IGBTs operates at a frequency in the kHz range. By connecting DC capacitors on one side of the converter, the STATCOM is able to vary its output voltage with respect to magnitude, frequency and phase angle. This means that the way the converter is operated; the STATCOM is automatically giving the requested output to provide decreased voltage and improve transient stability. Modified Heffron-Phillips model for a single machine infinite bus system installed with STATCOM is developed. AC and DC voltage regulator and Damping controller parameters are optimized and the dynamic performances of the system are analysed.

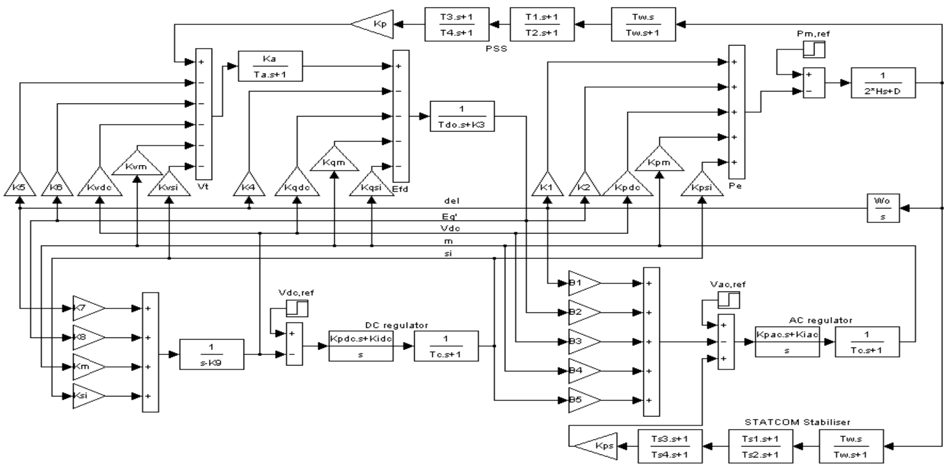

Fig-A-Simulation of the Linear Model Simulation Setup for SMIB installed with STATCOM

II. NOMINAL PARAMETERS

The nominal parameters and the operating conditions of the SMIB system with STATCOM are given below. All data are in per unit, except that of M and the time constants (in sec).

Generator : $M = 2H = 8.0$ MJ / MVA

$D = 0.0$ $T_{do}' = 5.044$ sec.

$x_d = 1.0$. $x_q = 0.6$
$x_d' = 0.3$

Excitation system : $K_A = 50$ $T_A = 0.05$ sec.
Transmission lines : $x_t = 0.3$ $x_b = 0.3$
$x_e = 0.1$
Operating condition : $P = 0.8$ $Q = 0.2676$
$f = 50$ Hz $V_t = 1.05$
$V_b = 1.0$ $V_o = 1.0$
STATCOM Parameters : $m = 0.5012$ $\psi = 56°$
DC link Parameters : $V_{dc} = 2$ $C_{dc} = 2$

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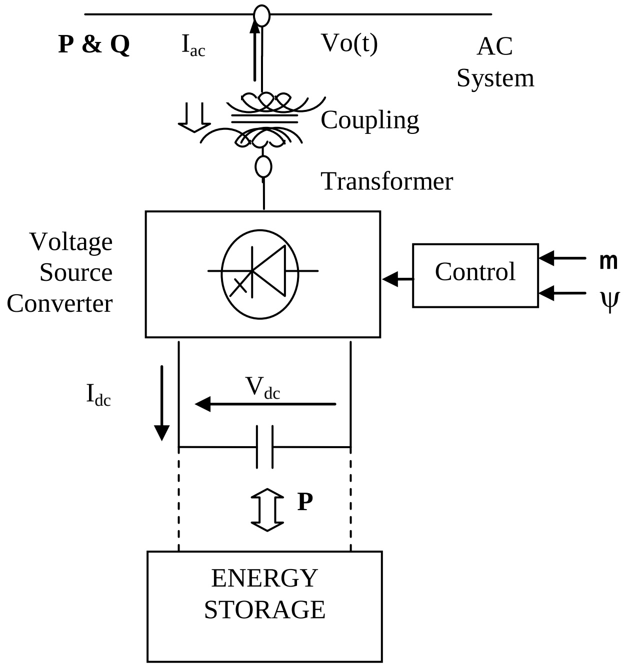

Fig-B:Funtional Diagram of STATCOM

The VSC generates a controllable AC voltage source $V_e(t)=mV_{dc}\sin(\omega t-\psi)$, where m is the modulation index. The magnitude and phase angle of the STATCOM AC side voltage are regulated by regulating *m* and ψ□.

III. CALCULATION OF INITIAL OPERATING CONDITIONS

Calculation of initial operating conditions for the SMIB system with STATCOM
Initially assumed inputs are Pe, Vt, Vo, Vb

$$\overline{V}_b = V_b \angle 0$$

$$\theta_1 = \sin^{-1}\left(\frac{P_e\, x_b}{V_o V_b}\right)$$

$$\overline{V}_o = V_o \angle \theta_1$$

$$\bar{I}_b = \frac{\overline{V}_o - \overline{V}_b}{j x_b} = I_b \angle \varphi_1$$

$$\theta_2 = \sin^{-1}\left(\frac{P_e\, x_t}{V_o V_t}\right)$$

$$\overline{V}_t = V_t \angle \theta_1 + \theta_2$$

$$\bar{I}_t = \frac{\overline{V}_t - \overline{V}_o}{j x_t} = I_t \angle \varphi_2$$

$$\bar{I}_e = \bar{I}_t - \bar{I}_b = I_e \angle \varphi_3$$

$$\overline{E}_q = \overline{V}_t + j x_q \bar{I}_t = E_q \angle \delta_0$$

$$\overline{E}' = \overline{V}_t + j x_d' \bar{I}_t = E' \angle \delta$$

$$E_q' = E' \cos(\delta_0 - \delta) \qquad E_q' = V_{tq} + x_d' I_{td}$$

$$V_{td} = V_t \sin(\delta_0 - \theta_1 - \theta_2) \qquad V_{tq} = V_t \cos(\delta_0 - \theta_1 - \theta_2)$$

$$I_{td} = I_t \sin(\delta_0 - \varphi_2) \qquad I_{tq} = I_t \cos(\delta_0 - \varphi_2)$$

$$I_{bd} = I_b \sin(\delta_0 - \varphi_1) \qquad I_{bq} = I_b \cos(\delta_0 - \varphi_1)$$

$$I_{ed} = I_e \sin(\delta_0 - \varphi_3) \qquad I_{eq} = I_e \cos(\delta_0 - \varphi_3)$$

$$\overline{V}_e = \overline{V}_o - j x_e \bar{I}_e$$

$$m = V_e / V_{dc} \qquad \Psi_e = \angle \overline{V}_e$$

$$\Psi = 90 - \delta_0 + \Psi_e$$

The initial d-q axes voltage and current components and torque angle computed for the nominal operating condition and system parameters are:

$V_{td} = 0.3730$ pu $\qquad V_{tq} = 0.9815$ pu.
$E_q' = 1.134$ pu $\qquad Q_e = 0.2676$ pu
$I_{td} = 0.5089$ pu $\qquad I_{tq} = 0.6217$ pu.
$I_{ed} = -0.0194$ pu $\qquad I_{eq} = 0.0131$pu
$\delta = 47.9°$ $\qquad \psi = 56°$ $\qquad m = 0.5012$.

Dynamic Performance of the different response with different controller are studied by taking 5% change of power.

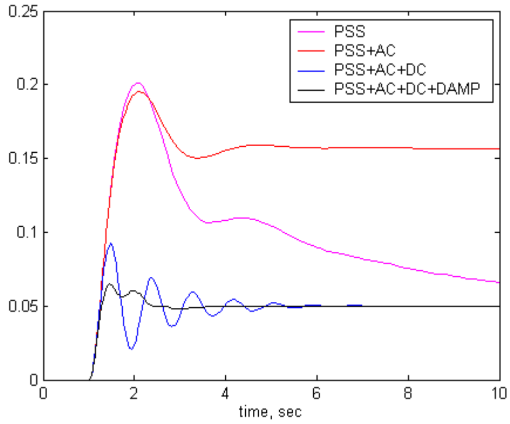

Fig 1:Dynamic response of Δdeltafor ΔP_m = 5%

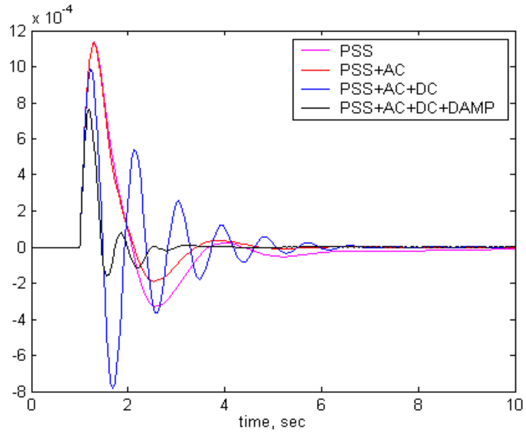

Fig.2 : Dynamic response of Δwfor ΔP_m = 5%

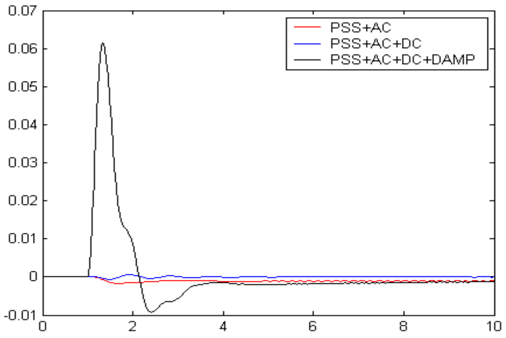

Fig 3 :Dynamic response of ΔV_o for ΔP_m = 5%

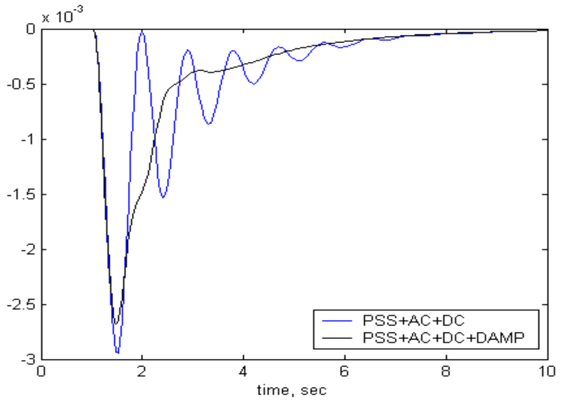

Fig.4 : Dynamic response of $\Delta V_{dc}$for ΔP_m = 5%

From the simulation ,it is seen that

a)The STATCOM AC-voltage control has little influence on the system damping. (ζ changes from 0.388 to 0.447)

b)The STATCOM DC-voltage control has negative influence on the system damping. (ζ reduces from 0.447 to 0.112)

c)To combat the negative damping effect, of DC regulator, damping controller is used to improve system damping. (ζ increases from 0.112 to 0.627)

V. EFFECT OF VARIATION OF LOADING CONDITION

In any power system, operating load varies over a wide range. In order to examine the effectiveness of damping controller at different loading condition, dynamic responses for the following three loading conditions are obtained (Fig 5) considering 5% step increase in mechanical power input to the generator (i.e. ΔP_m = 0.05 pu).
Fig 5 to 7 shows the dynamic responses for Δw, ΔV_o(i.e. ΔVac), ΔV_{dc}following 5% step increase in mechanical power P_m (i.e. ΔP_m=5%) considering different loading.

1. Light loading (Pe = 0.4 pu Qe = 0.1979 pu)
2. Nominal loading (Pe = 0.8 pu Qe = 0.2677 pu)
3. Heavy loading (Pe = 1.2 pu Qe = 0.3871 pu)

Optimum Parameter for Different Loading:

Different Load	Controller	Optimizimizing Value
LIGHT LOADING Pe=0.4,Qe=0.1979	PSS	Tp1=0.456
		Tp2=0.1663
		Kps=12.53
	AC REGULATOR	Kpac=1.2
		Kiac=23
	DC REGULATOR	Kpdc= -23
		Kidc= -10
	DAMPING CONTROLLER	T1=0.0751
		T2=0.2021
		T3=T1
		T4=T2
		Kstab=175.8
NOMINAL LOADING,Pe=0.8,Qe=0.2677	PSS	Tp1=0.367
		Tp2=0.1863
		Kps=11.58
	AC REGULATOR	Kpac=1.36
		Kiac=20
	DC REGULATOR	Kpdc= -20
		Kidc= -10
	DAMPING CONTROLLER	T1=0.0861
		T2=0.2321
		T3=T1
		T4=T2
		Kstab=181.8
HEAVY LOADING ,Pe=1.2,Qe=0.0.3871	PSS	Tp1=0.143
		Tp2=0.1263
		Kps=16.21
	AC REGULATOR	Kpac=1.9
		Kiac=20
	DC REGULATOR	Kpdc= -20
		Kidc= -9
	DAMPING CONTROLLER	T1=0.0463
		T2=0.1129
		T3=T1
		T4=T2
		Kstab=170.5

Optimization values of different controller has been found out by using GEA technique and Phase compensation Technique which is implemented on the simulation work of the system shown in fig-A. Dynamic response are represented for different controller by considering different loading..

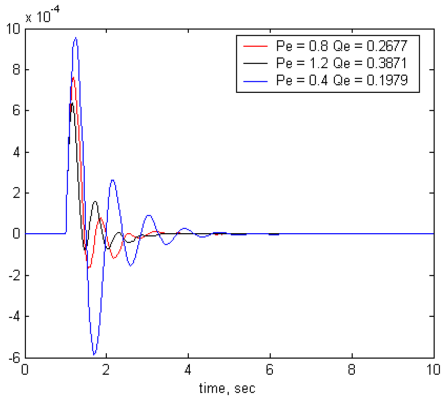

Fig.5 : Dynamic response of Δw for ΔPm = 5% at different loading condition

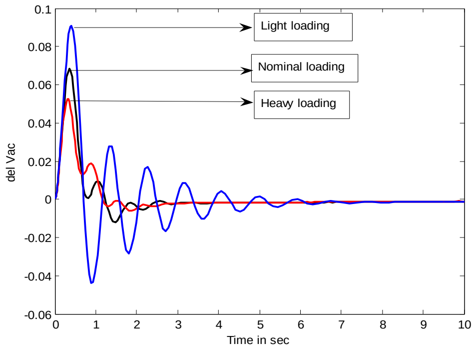

Fig 6: Dynamic response of ΔVac for ΔPm = 5% at different loading condition

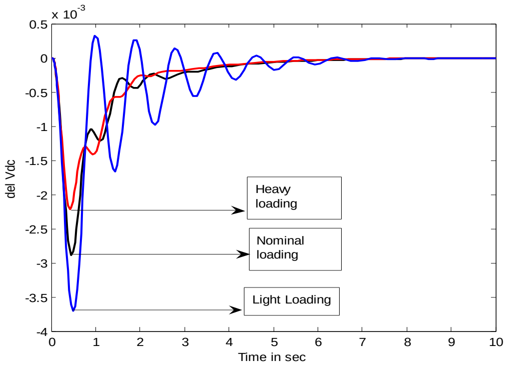

Fig 7: Dynamic response of ΔVdc for ΔPm = 5% at different loading condition

Critically examination of clearly shows that STATCOM AC voltage regulator has little influence on system damping. With the installation of STATCOMDC voltage regulator, the voltage level of V_{dc} is maintained which ensures the normal operation of the STATCOM. However, system oscillation damping is degraded due to negative effect of STATCOMDC voltage regulator on power system oscillation damping. With properly designed damping controller, system damping improves. Examination of Fig 3 shows that midpoint voltage (V_o) of the bus is regulated to a desired value, i.e. under steady state condition the midpoint voltage deviation is regulated to zero. However, with damping controller the midpoint voltage is modulated to damp the system oscillations. Examination of Fig..4 shows that DC link voltage (V_{dc}) is regulated to a desired value, i.e. under steady state condition the DC link voltage deviation is regulated to zero.

VI. CONCLUSIONS

In this Paper all the controller parameters are and the dynamic performances of the system is analyzed.AC voltage at the bus can be regulated so as to improve the voltage profile of the power system.AC voltage control has little influence on system damping. DC voltage across capacitor can be regulated to maintain voltage level V_{dc}. However, system oscillation damping is affected. Damping controller is added into the STATCOM for enhancing power system oscillation stability. Investigations in liner model reveals that midpoint AC voltage and DC link voltages can be effectively regulated. Investigations also reveal that the STATCOM based damping controller enhance the system dynamic stability. Its examined by taking the different loading conditions.

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