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Design of the Pole Placement Controller for D-STATCOM in Mitigating Three Phase Fault

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Abstract-This paper presents a design of pole placement controller for D-STATCOM in mitigation of three phase fault. In the pole placement method the existing poles are shifted to the new locations of poles at the real-imaginary axes for better response. This type of controller is able to control the amount of injected current or voltage or both from the D-STATCOM inverters to mitigate the three phase fault by referring to the currents that are the input to the pole placement controller. The controller efficiency was tested in the different percentage of voltage sag that occurs during the three phase fault. The controller and the D-STATCOM were designed using SIMULINK and Power System Blockset toolbox available in MATLAB program.

I. INTRODUCTION

The Distribution Static synchronous compensator (D-STATCOM) is a shunt connected device that generates a balanced set of three phase sinusoidal voltages or current at the fundamental frequency [1]. The D-STATCOM consists of voltage source inverter such as Gate Turn Off (GTO) thyristor, a DC link capacitor and a controller [2]. It has been proven that the D-STATCOM is a device capable of solving the power quality problems at the distribution system.

One of the power quality problems that always occur at the distribution system is the three phase fault caused by short circuit in the system, switching operation, starting large motors and etc. This problem happens in milliseconds and because of the time limitation, it requires the D-STATCOM that has continuous reactive power control with fast response [3].

Various topologies for the controllers can be designed such as Proportional Integration (PI), pole placement and Linear Quadratic Regulator (LQR) to give high response to the system and steady operating point. The PI controller depends on the reactive power, which is the input to the controller for injection of the currents from the D-STATCOM and cause the controller to have slow response [3]. For the pole placement method, the controller is based on dynamic model rather than phasor diagram [3], which produces a fast response to the system. The pole placement is also known as a discrete time control technique with close loop poles [4] and has met the requirement of the stability for operating points [5]. In LQR controller method, it is able to give a fast response, but the problem is in selecting the positive semi definite and positive definite matrix value to give a better performance.

In this work, the pole placement controller has been selected because it can operates with fast response, capable of controlling two outputs from the D-STATCOM and gives better ride through stability to the distribution system. The pole placement method is a combination of input–output feedback linearization and DQ transformations of the reference currents from the distribution system. Pole placement controller is used to shift the initial pole from the right to the left of the complex diagram, in order to increase the stability of the system and damping response which makes the inverter in the D-STATCOM to inject voltage or current to compensate the three phase fault [1]. This technique has been applied by [1, 4] and it shows that it is suitable in D-STATCOM control. The difference from the previous studies is that, the pole placement controller was designed referring to signal flow diagram which consists only a branch, which represents the system and the nodes of the state space equation that is obtained from the D-STATCOM circuit. In this pole placement controller the combination between DQ transformation of the current from the distribution has been applied to minimize the D-STATCOM state space equation. This DQ transformation will give all information about three phase set, steady state unbalance, harmonic waveform distortions and transient components [6].

II. MODELING OF D-STATCOM

In designing the pole placement controller, the state space equations from the D-STATCOM circuit must be introduced. The theory of DQ transformation of currents has been applied in the circuit, which makes the d and q components as independent parameters. Fig.1 shows the circuit diagram of a typical D-STATCOM. The D-STATCOM is connected in shunt with the power system and the capacitor on the left hand side is used to supply the voltage to the inverter to solve the power quality problems.

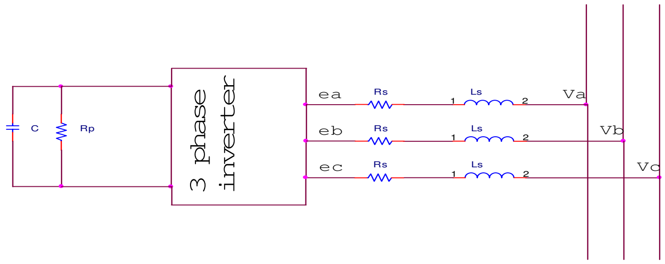

Fig.1. Equivalent circuit of STATCOM.

The resistance ‘Rs’ in series with the inverter represents the sum of the transformer winding resistance losses and inverter conduction losses. The inductance ‘Ls’ represents the leakage inductance of the transformer. The resistance ‘Rp’ in shunt with the capacitor ‘C’ represents the sum of the switching losses of the inverter and power losses in the capacitor [1]. The inverter block represents an ideal transformer. The voltage ‘ea’, ‘eb’ and ‘ec’ are the inverter AC side phase voltage suitably stepped up. The circuit for the D-STATCOM without the capacitor in single line diagram is shown in Fig.2.

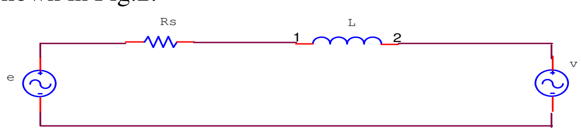

Fig.2. Single line diagram.

The equation for the single phase diagram can be written as,

$$R_s + L\frac{di}{dt} + v = e \qquad (1)$$

$$L\frac{di}{dt} = e - v - R_s i \qquad (2)$$

$$\frac{di}{dt} = \frac{e-v}{L} - \frac{R_s}{L} i \qquad (3)$$

The loop equation for the circuit can be written in vector as,

$$\frac{d}{dt} i_{abc} = -\frac{R_s}{L} i_{abc} + \frac{1}{L}\left(e_{abc} - v_{abc}\right) \qquad (4)$$

Equation 4 indicates the D-STATCOM circuit without DQ transformation. After the DQ transformation and linearization process to Equation 4, the state space for D-STATCOM is shown in Equation 5 [6],

$$\frac{d}{dt}\begin{bmatrix} i'_d \\ i'_q \\ v'_{dc} \end{bmatrix} = [A_\nabla]\begin{bmatrix} i'_d \\ i'_q \\ v'_{dc} \end{bmatrix} + [B_\nabla]\begin{bmatrix} v' \\ \alpha \end{bmatrix} \qquad (5)$$

where,

$$[A_\nabla] = \begin{bmatrix} \frac{-R'_s \omega_b}{L'} & \omega_b & \frac{\omega_b k}{L'}\cos(\alpha) \\ -\omega_b & \frac{-R'_s \omega_b}{L'} & \frac{\omega_b k}{L'}\sin(\alpha) \\ -\frac{3}{2}kC'\omega_b\cos(\alpha) & \frac{3}{2}kC'\omega_b\sin(\alpha) & \frac{-C'\omega_b}{R'_p} \end{bmatrix}$$

$$[B_\nabla] = \begin{bmatrix} \frac{-\omega_b}{L'} & \frac{-k\omega_b v'_{dc}}{L'}\sin(\alpha) \\ 0 & \frac{-k\omega_b v'_{dc}}{L'}\cos(\alpha) \\ 0 & \frac{3}{2}kC'\omega_b(i'_d\sin(\alpha) - i'_q\cos(\alpha)) \end{bmatrix}$$

The primed parameters indicate the p.u value. The D-STATCOM parameters (in p.u.) used in the following discussion are given as,

$\alpha = 0$, $V'_{dc} = 1.35$, $L' = 0.1$, $R'_s = 0.01$, k=1.273, ω_b=314, C’ = 2.275, $i'_d = 0.082$, $i'_q = -0.048$

Equation 5 shows the state space equation for the D-STATCOM. This equation will give the initial poles which are highly damp and has high frequency oscillation at the operating point and is shown in Fig.3. The initial poles of D-STATCOM are shown as,

$$S = \begin{bmatrix} -16 - 2356\ j \\ -16 + 2356\ j \\ -30.8 \end{bmatrix} \qquad (6)$$

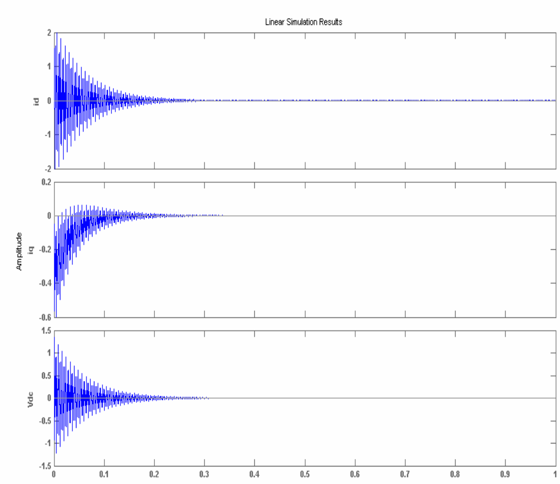

Fig.3. Initial poles response of D-STATCOM.