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Three Phase Load Balancing and Harmonic Reduction using Distribution Static Compensator

Raghvendra Singh*, Dharmendra Singh**

* Mtech Student, Dr C.V. Raman Institute Of Technology Kota
** Faculty Electrical and Electronics Engg, Dr C.V. Raman Institute Of Technology Kota

Abstract- This paper presents a study of a D-STATCOM (Distribution Static Compensator) used for load balancing and harmonic reduction. The basic idea of the voltage sag mitigation, using a D-STATCOM is to dynamically inject a current of desired amplitude, frequency and phase into the grid line. The proposed method uses the instantaneous reactive power theory for generating reference values of current that need to be injected into the point of connection D-STATCOM in order to compensate the voltage errors. The proposed method offers structural simplicity and less calculation complexity. Simulation results indicate that this method is effective and D-STATCOM has good performance to balance the load and mitigate harmonic components of current.

Index Terms- load balancing, instantaneous reactive power theory, hysteresis controller, harmonic reduction.

I. INTRODUCTION

All the electrical and electronic equipments are affected by the power quality disturbances. On uneven distribution of loads in the three phases there occurs the problem of load unbalancing and the increase in the use of power electronic equipments results in increase of harmonic content in the power distribution system. A variety of custom power devices are developed and successfully implemented to compensate various power quality problems in a distribution system. The various custom power devices are the DSTATCOM (distribution static compensator), DVR (dynamic voltage restorer) and UPQC(unified power quality conditioner). The current related power quality problems are mitigated by a shunt connected device called DSTATCOM. The effectivenes of DSTATCOM depends upon the control algorithm used to obtain the reference current. In this paper a instantaneous reactive power theory is used as a control algorithm to obtain the reference current. The hysteresis controller is then used to generate the gate signals for firing of the IGBT used in DSTATCOM.

II. DESIGN OF DSTATCOM

A DSTATCOM is a device which is used in an AC distribution system where, harmonic current mitigation, reactive current compensation and load balancing are necessary. The building block of a DSTATCOM is a voltage source converter (VSC) consisting of self commutating semiconductor valves and a capacitor on the DC bus (Singh *et al*, 2008). The device is shunt connected to the power distribution network through a coupling inductance . In general, the DSTATCOM can provide power factor correction, harmonics compensation and load balancing. The major advantages of DSTATCOM compared with a conventional static VAR compensator (SVC) include the ability to generate the rated current at virtually any network voltage, better dynamic response and the use of a relatively small capacitor on the DC bus. The size of the capacitor does not play an important role in steady-state reactive power generation, which results in a significant reduction of the overall compensator size and cost .

Fig. 1 shows the schematic diagram of a DSTATCOM connected to a three phase AC mains feeding three phase loads. Three phase loads may be a lagging power factor load or an unbalanced load or non-linear loads or mixed of these loads. For reducing ripple in compensating currents, interfacing inductors (Lf) are used at AC side of the voltage source converter (VSC). A small series connected capacitor (Cf) and resistor (Rf) represent the ripple filter installed at PCC in parallel with the loads and the compensator to filter the high frequency switching noise of the voltage at PCC. The harmonics/reactive currents (Icabc) are injected by the DSTATCOM to cancel the harmonics /reactive power component of the load currents so that the source currents are harmonic free (reduction in harmonics) and load reactive power is also compensated.

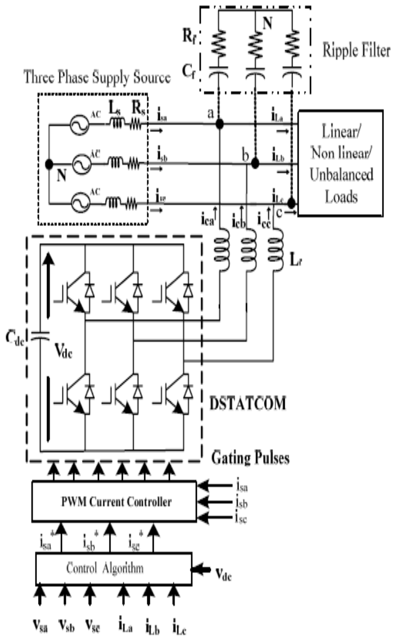

Figure 1. Schematic diagram of DSTATCOM

III. Control Algorithm of DSTATCOM

Hirofumi Akagi and his coworkers have described an instantaneous method of generating reference currents for shunt compensator .Since then various interpretations of this method have been presented. This method is applicable to a three-phase, four-wire system. To begin with, we transform the three-phase voltages from *a-b-c* frame to *a-β-O* frame and vice versa using the following power invariant transformation

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

And

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix}$$

We can also use the same transform matrix for transforming currents. The instantaneous three-phase power is then given by

$$P_{3\phi} = V_a I_a + V_B I_B + V_C I_C = V_\alpha I_\alpha + V_\beta I_\beta + V_0 I_0 = P + P_0$$

where p is the total instantaneous real power **in** the three phase wires and $P_0 = V_0 I_0$ is the instantaneous power in the zero-sequence network. Let us define the following variable

$$q = V_\alpha I_\beta - V_\beta I_\alpha = \frac{1}{3} \{ I_a (V_c - V_b) + I_b (V_a - Vc) + Ic (v_b - v_a) \}$$

the quantity q given in (7.9) is the reactive power absorbed by a circuit when both voltages and currents contain only the fundamental frequency. However, this quantity can be used in a much broader context when either voltages or currents or both have many frequency components. Akagi et al called this term the instantaneous imaginary power [7]. We can write from (7.8) and (7.9)

$$\begin{bmatrix} P \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix}$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & -V_\beta \\ V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} P \\ q \end{bmatrix}$$

To compensate the unbalanced load and harmonic component the compensating current in $\alpha, \beta, 0$

$$\begin{bmatrix} I_{c\alpha} \\ I_{c\beta} \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & -V_\beta \\ V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} P_{osc} \\ Q_l \end{bmatrix}$$

Where p_{osc} is the oscillating active power also termed as the harmonic content of active power and q is the reactive power taken from the source.

IV. Problem Statement and Simulation Diagram

The load unbalancing problem and its simululation is illustrated in the the following simulation diagram. The proposed control topology is being adopted and the system performance with a and without the controller is being analysed. The simulink model is shown in figure 2

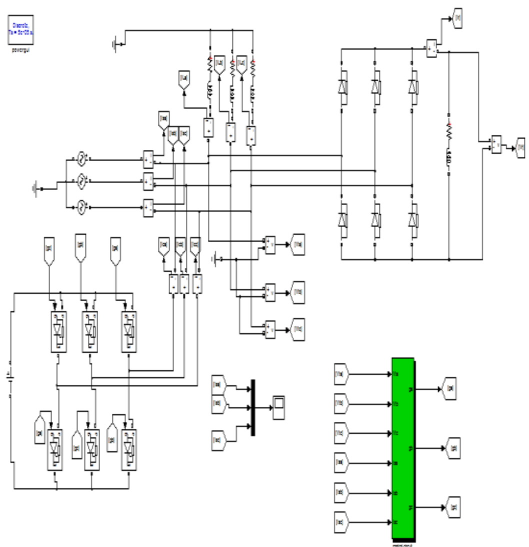

Figure 1 simulink model of the distribution power system

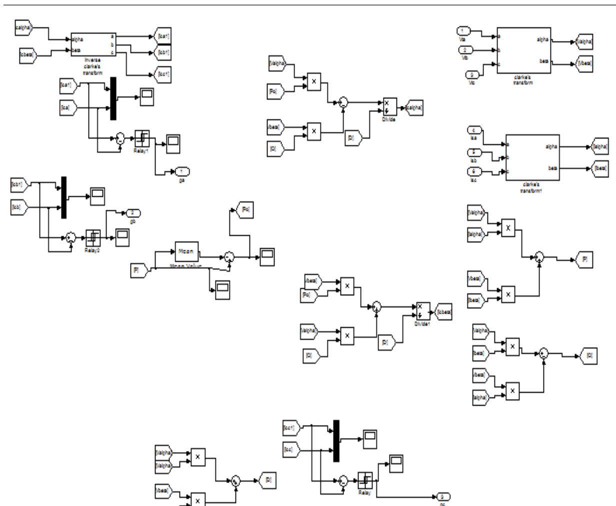

Figure 3 control circuit

V. Results and Discussion

In the simulink diagram its is been shown that with a proposed control method the load unbalancing is been reduced considerably and also the THD thet is total harmonic distortion has been reduced considerably. The two waveforms obtained with a and without compensator has been shown in figure 4 and figure 5.

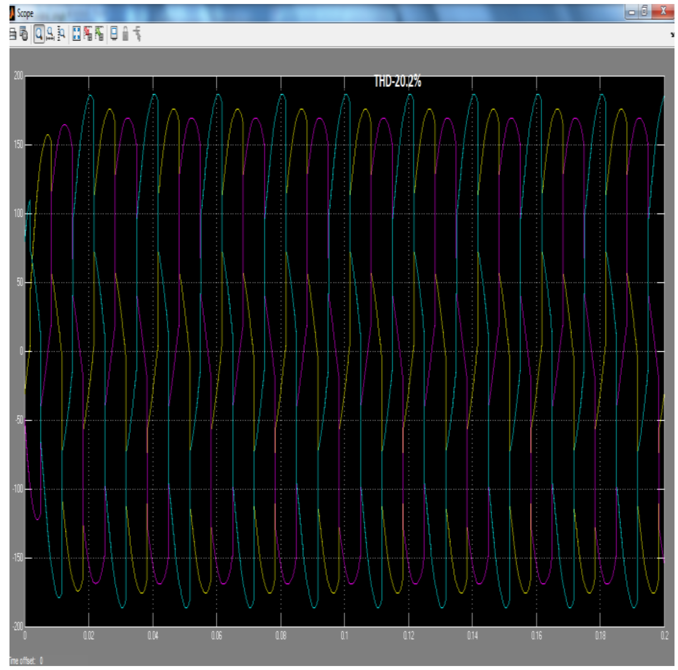

Figure 4: Three Phase Source Current Without Compensator

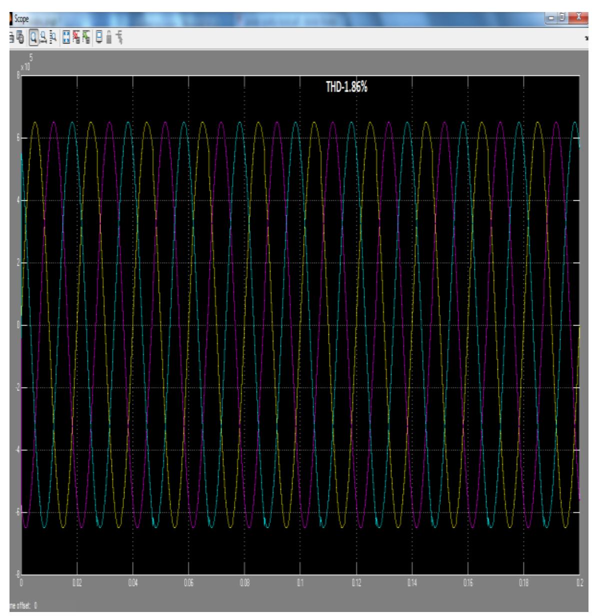

Figure 5: Three Phase Load Current With Compensator

VI. Conclusion and Future Works

From the results and waveforms shown in this paper as a results it can be concluded that on using the above controlling method a large amount of power quality problems can be eliminated and the on balancing the loads the voltage fluctuation problems associated with the phase having large load burden can be eliminated. In the future prospect research can be done on modeling a STATCOM with the energy storing elements like inductors or capacitors.

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AUTHORS

First Author – Raghvendra Singh, Mtech Student, Dr C.V. Raman Institute Of Technology Kota
Second Author – Dharmendra Singh, Faculty Electrical and Electronics Engg, Dr C.V. Raman Institute Of Technology Kota