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Five Phase Distribution Static Compensator in Five Phase Distribution System

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ABSTRACT

The present world look into the renewable energy conversion techniques with high efficiency. In this context, this paper gives the some remedial point for effective conversion of Solar Energy in to useful form of Electrical Energy. The Five Leg Inverter is the best solution for converting the Solar to Electrical Energy with high efficiency. For this, the author used the PWM control technique to operate the power electronics / controlled switches in MATLAB Simulink.

Key Words: Multiphase Inverter, Multiphase DSTATCOM.

1. INTRODUCTION

There are several advantages having the multiphase systems compared to 3 phase systems. So, now a days engineers are more concentrated this more than three phase systems. The normal three phase supply can be converted in to five phase supply with specially designed transformer [1-4]. This multiphase concept will be implemented by the engineers in electric power generation, transmission and distribution [5-7]. With the less cost of power electronic devices, starting of this century, the engineers concentrated on this system [8-14]. The 5 phase system utilized by the industry or domestic people, then power quality problems will come and this will be solved by introducing the DSTATCOM [15-20]. Based on the previous research done by the engineers, the analysis of multiphase drives controlling and modeling of supply system has been limited [21-27].

As per the previous analysis, the 6 phase system is smaller and much complex design by comparing with 3 phase double circuit system [28]. 6 and 12 phase system generates the less ripples with high frequency, so it will convert AC to DC by using rectifier. The same design is used to feed multiphase rectifier for 24 and 36 phase with the help of transformer and it is proposed [29-34].

The above mentioned work preferred by the engineers, it is very simple to develop with this complexity will increase particularly in even phase system. This type of analysis was not happened in odd phase systems of 5, 7 and 11 etc [35-41]. The 5 phase converter has been proposed in this paper as DSTATCOM for improving the power quality.

2. DISTRIBUTION STATIC COMPENSATOR (DSTATCOM)

The Figure 1, shows the Distribution system with Distribution STATic COMpensator (DSTATCOM). C_{dc} is the capacitor at DC bus of the converter, working as energy buffer and for normal operation of the system, it establish a DC Voltage. For pf (power Factor) correction or voltage regulation, need to compensate the reactive power in system with the proposed compensator. The proposed compensator like DSTATCOM injects a current of reactive component, such that the source current is in-phase with voltage.

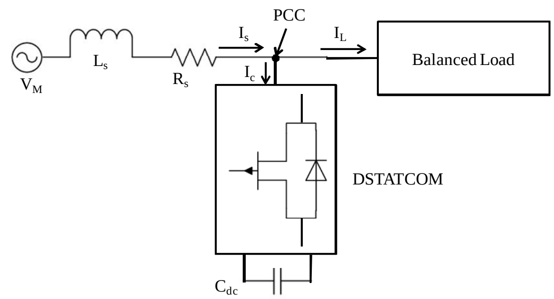

Figure 1: One line diagram of DSTATCOM

The following Figure 2, shows the schematic diagram of the above mentioned line diagram for operation of DSTATCOM to manage the voltage and current profile intern for active and reactive power compensation for sudden change in load. The five phase supply with 72^0 phase shift of each and balanced load is assumed. Because, induction motors in industry with five phase winding is of balanced and also provide the balanced distribution of mmf.

The following Figure 3, shows the Five Leg Inverter like Voltage Source Converter, acts as DSTATCOM in the proposed distribution system along with Sinusoidal Pulse Width Modulation (SPWM). This topology have the ten IGBT's and one LC filter used with five inductors and capacitor for converting the square or rectangular output of converter into sinusoidal wave by eliminating the selected harmonic content. Rating of VSC is depends on the required compensation provided by DSTATCOM. The data of DSTATCOM system considered for analysis is shown in the Appendix.

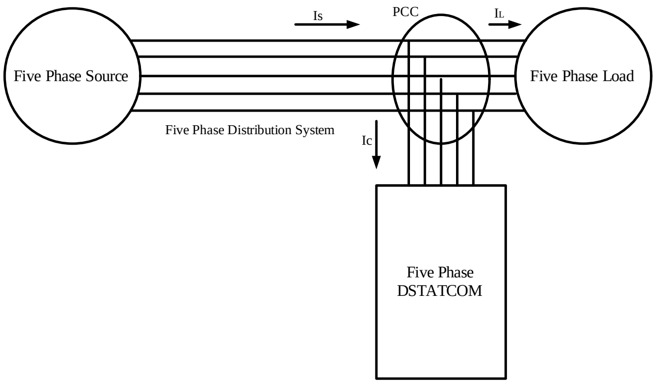

Figure 2: Schematic Diagram of Five - Phase Distribution System with Compensator like DSTATCOM

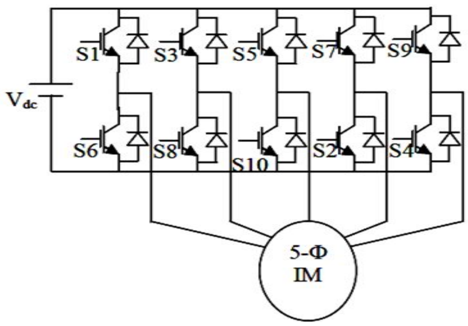

Figure 3: Five Leg Inverter (VSC) used as DSTATCOM.

With-in six steps the total operation can explained with the following analysis. Step: 1, $0 \le \omega t \le \pi/5$, conducting switches are 1, 8, 10, 7, 9. If winding of the Induction motor impedance consider as Z, all impedances are same and Z1, Z4, Z5 are parallel having +ve sign and Z2, Z3 are parallel having –ve sign and they are in series one combination to other combination.

Current,

$$i_1 = \frac{V_s}{5z/6} = \frac{6}{5} * \frac{V_s}{z}$$

Phase Voltages,

$$v_{ao} = v_{do} = v_{eo} = i_1 * \frac{z}{3} = \frac{2}{5} V_s$$

$$v_{ob} = -v_{bo} = v_{oc} = -v_{co} = i_1 * \frac{z}{2} = -\frac{3}{5} V_s$$

Similarly, step – 2: $\pi/5 \le \omega t \le 2\pi/5$

Current,

$$i_2 = \frac{V_s}{5z/6} = \frac{6}{5} * \frac{V_s}{z}$$

Phase Voltages,

$$v_{bo} = v_{co} = v_{do} = -\frac{2}{5} V_s$$

$$v_{ao} = v_{eo} = \frac{3}{5} V_s$$

Similarly, step – 3: $2\pi/5 \le \omega t \le 3\pi/5$

Current,

$$i_3 = \frac{V_s}{5z/6} = \frac{6}{5} * \frac{V_s}{z}$$

Phase Voltages,

$$v_{ao} = v_{bo} = v_{eo} = \frac{2}{5} V_s$$

$$v_{co} = v_{do} = -\frac{3}{5} V_s$$

Similarly, step – 4: $3\pi/5 \le \omega t \le 4\pi/5$

Current,

$$i_4 = \frac{V_s}{5z/6} = \frac{6}{5} * \frac{V_s}{z}$$

Phase Voltages,

$$v_{co} = v_{do} = v_{eo} = -\frac{2}{5} V_s$$

$$v_{ao} = v_{bo} = \frac{3}{5} V_s$$

Similarly, step – 5: $4\pi/5 \le \omega t \le \pi$

Current,

$$i_5 = \frac{V_s}{5z/6} = \frac{6}{5} * \frac{V_s}{z}$$

Phase Voltages,

$$v_{ao} = v_{bo} = v_{co} = \frac{2}{5} V_s$$

$$v_{do} = v_{eo} = -\frac{3}{5} V_s$$

Similarly, step – 6: $\pi \le \omega t \le 6\pi/5$

Current,

$$i_6 = \frac{V_s}{5z/6} = \frac{6}{5} * \frac{V_s}{z}$$

Phase Voltages,

$$v_{ao} = v_{do} = v_{eo} = -\frac{2}{5} V_s$$

$$v_{bo} = v_{co} = \frac{3}{5} V_s$$

3. RESULTS & DISCUSSIONS

The following Figure 4, shows the voltage waveform at load side if sag is happened for sudden increase in load. In healthy condition of the system, the load supplied with 400V (=~ 420V) and if sag happened it became to 320V in all phases.

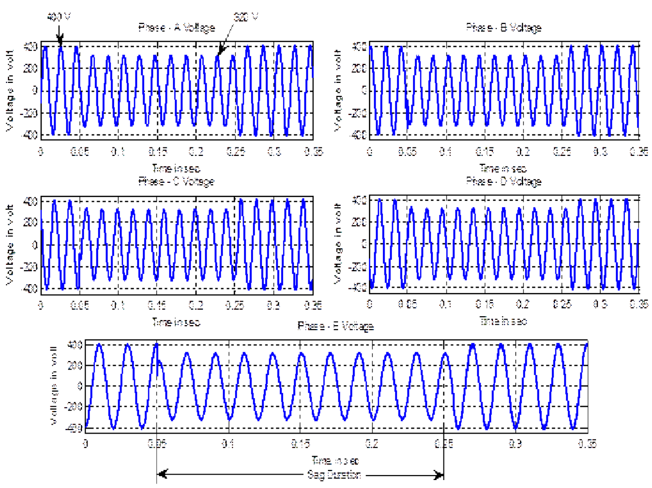

Figure 4: Voltage waveforms of all the Phases under power quality problem (i.e., with Sag)

The following Figure 5, shows the load current if sag happened in the system. In healthy condition of the system, the load supplied with 20.7 A (= ~ 20 A) and if sag happened it became to 16 A in all phases.

The following Figure 6, shows the load voltage when sag is cleared by the compensator because of introducing the reactive component in system. In healthy condition of the system, the load supplied with 400 V (= ~ 420 V) and if sag cleared it became 400 V (= ~ 420 V) in all phases.

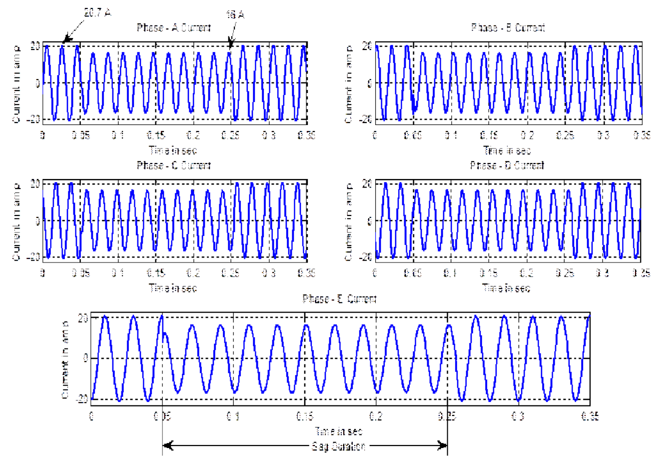

Figure 5: Current wave forms of all the Phases under power quality problem (i.e., with Sag)

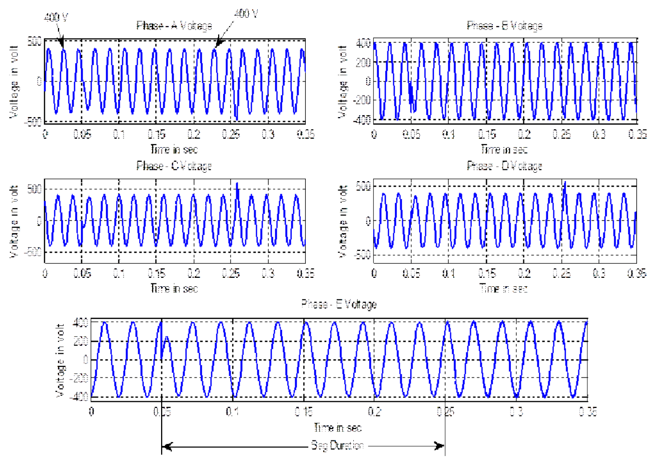

Figure 6: Voltage wave forms of all the Phases without power quality problem (i.e., without Sag)

The following Figure 7, shows the load current when sag is cleared by the compensator because of introducing the reactive component in system. In healthy condition of the system, the load supplied with 20.7 A (= ~ 20 A) and if sag cleared it became to 20.7 A (= ~ 20 A) in all phases.

The following Figure 8, shows the load current magnitude if sag happened in the system. In healthy condition of the system, the load supplied with 20.7 A (= ~ 20 A) and if sag happened it became to 16 A in all phases.

The following Figure 9, shows the load current magnitude when sag is cleared by the compensator because of introducing the reactive component in system. In healthy condition of the system, the load supplied with 20.7 A (= ~ 20 A) and if sag cleared it became to 20.7 A (= ~ 20 A) in all phases.

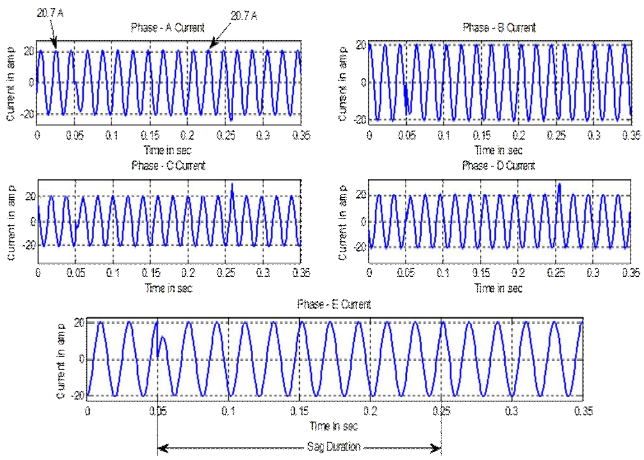

Figure 7: Current wave forms of all the Phases without power quality problem (i.e., without Sag)

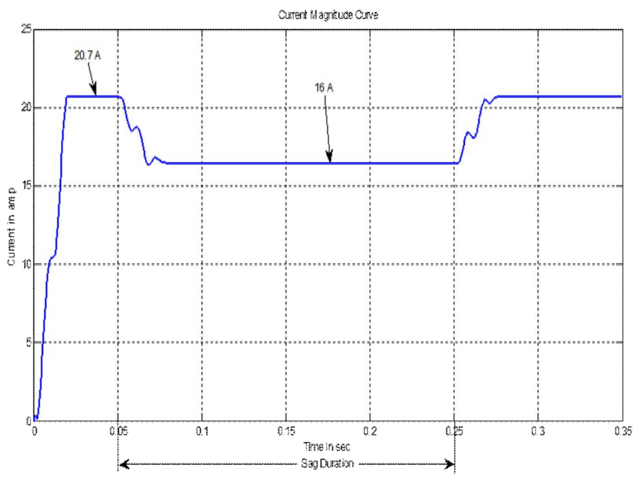

Figure 8: Current Magnitude curve with Power Quality problem (i.e., With Sag)

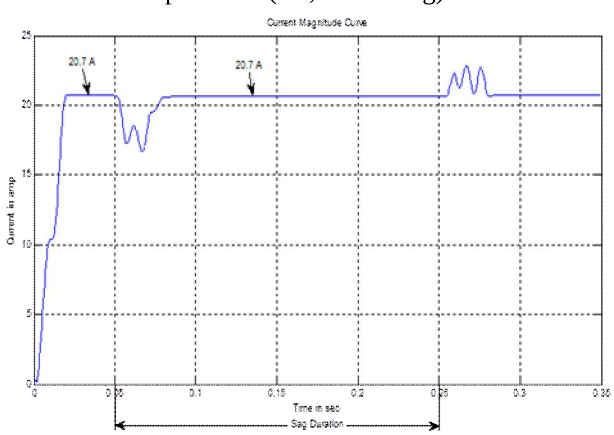

Figure 9: Current Magnitude curve without Power Quality problem (i.e., Without Sag)

4. CONCLUSION

The five phase distribution system along with distribution static compensator is explained how to mitigate the power quality problem for industrial need by change in load suddenly or a fault occurred in system. The simulation results explain clearly the DSTATCOM operation with the help of MATLAB-Simulink environment. The controlling of Static Compensator explain with sinusoidal pulse width modulation technique.

Appendix:

Parameters	Values
Line Frequency	50Hz
Switching frequency	2000Hz
Load Voltage	420V
DC bus voltage	50V
Filter Inductance & Capacitance	22.5e-2H & 27.5e-5F
Load: 1	10e3 W & 100 VAR
Load: 2	15e3 W & 10 VAR

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