A Novel Five Phase DSTATCOM for Industrial Loads

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Abstract

Now-a-days most of the industries want to earn more profit. It is possible with Five Phase Induction Machines. It attains the more efficiency because of its five phase winding arrangement. These machines are specially design for industries. Making the conversion of five phase supply from three phase supply with the help of transformer scheme which is specially designed. Generally, power quality problem like voltage sag occurs because of sudden changes in loads. In this paper, as a remedy, five phase DSTATCOM (Distribution Static Compensator) with PWM technique is opted to mitigate the voltage sag as power quality problem by injecting the currents in to the system. The MATLAB simulation results represent the effectiveness of five phase DSTATCOM with PWM technique.

Keywords: *Five Phase DSTATCOM; Five Leg Inverter; Controlling Mechanism.*

1. Introduction

In present scenario the multiphase systems playing a vital role with their more benefits than three phase systems and researchers also are focusing on this multi phase system. The specially designed transformer scheme can be used to attain the five phase supply from already existed three phase system [1]. The usage of multi phase system is keep on increasing in electric power generation, transmission and distribution [2-5]. The research on this system has attained a momentum in the beginning of this century with the adequate accessibility of power electronics devices at cheap rates [6-12]. Now, it is required to give more emphasis on five phase DSTATCOM as it is more effective in improving power quality [13-17].

From literature, it is observed that the analysis of multiphase electric drive has been limited to controlling and modeling of supply side systems only [15-17]. In this paper, as an extension work, an effort has made to design a static transformation system to alter the no. of phase from 3 to n [17]. As 6 phase transmission can is smaller and more complex in design than traditional 3 phase double circuit lines, in this paper no. of phases considered are in odd numbering [12].

As per the literature available, even phase system like 6 and 12 phase system is well known to generate fewer ripples with higher level of frequencies in AC-DC rectifier system. These systems were designed to feed multi pulse rectifier system and 24 & 36 – phase transformer system also proposed for the same purpose [18-20].

The main reason for opting this even phase system is that designing of these systems is very simple. But, increasing the no. of phases will cause for more complexity in the system. It is observed that no such work has been carried out for odd no. of phases like 5, 7 & 11 [22-24]. A 5 phase DSTATCOM to enhance the power quality is proposed in this paper. A special connection

transformer is considered and simulation has done in using MATLAB/SIMULINK.

2. Distribution static compensator (DSTATCOM)

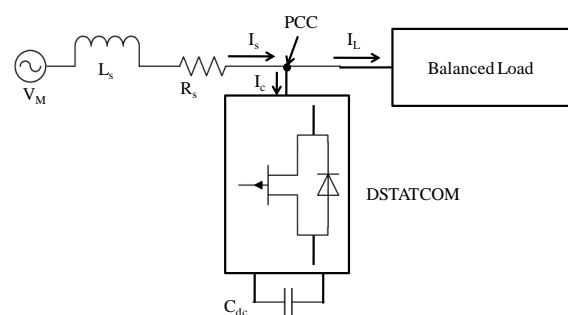A single line representation of a distribution system based on shunt connected DSTATCOM is shown in the Fig. 1.

Fig. 1: One Line Diagram of DSTATCOM.

A DC capacitor in the system can be used as a energy buffer and will provide the DC voltage for the successful operation of the DSTATCOM. To maintain the source current in phase with the voltage and to regulate the voltage the DSTATCOM will inject the current in system.

The MATLAB/SIMULINK diagram for DSTATCOM under sudden changes in load is shown in the Fig. 2. The 5 phase system consists of 5 single phase sources with phase shift of 72^0. An industry with 5 phase induction motor may be operated with a balanced 5 phase winding and for that it is assumed that the load is under balanced condition.

The DSTATCOM with 5 leg VSC is presented in the Fig. 3 and it can be used as a shunt active power conditioner with sinusoidal PWM technique. This system mainly consists of converter to change DC to AC and then a LC filter in each phase to change non

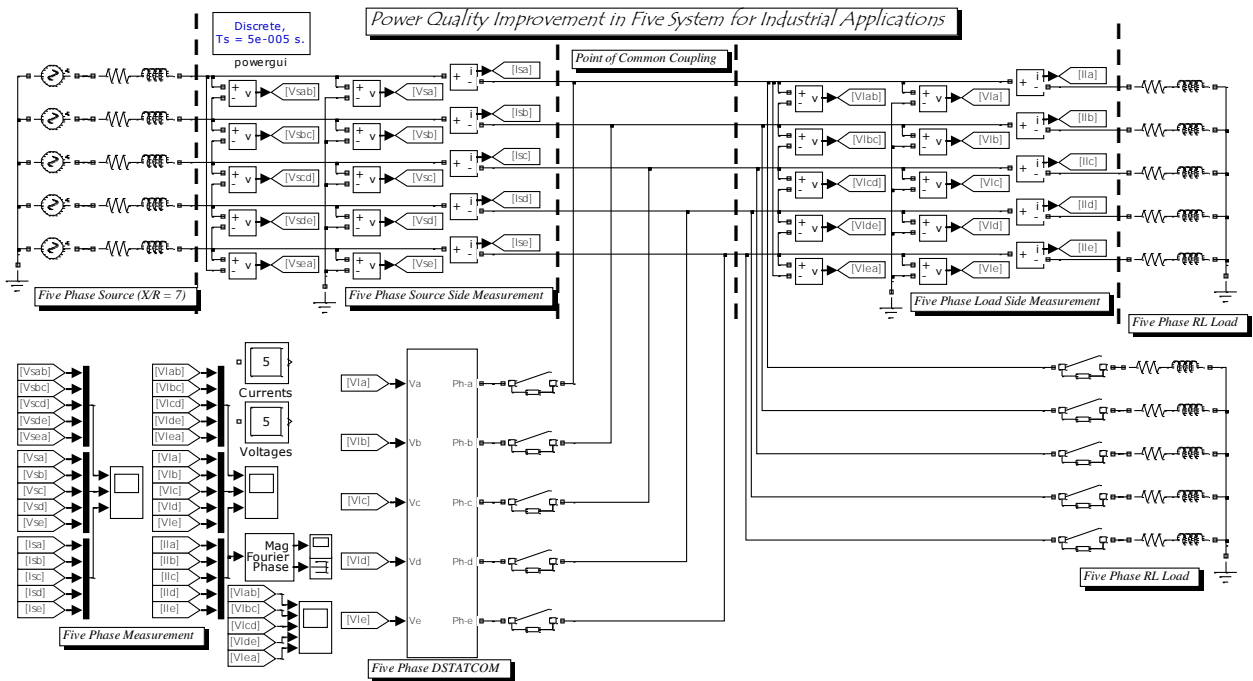sinusoidal waveform to sinusoidal. The data required for DSTATCOM is presented in Appendix.

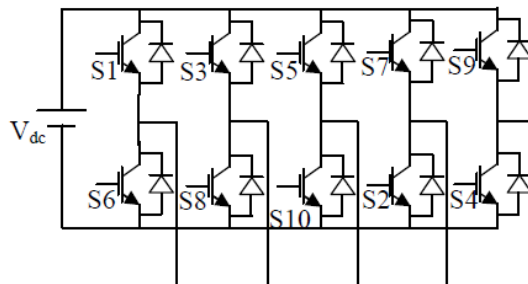**Fig. 2:** Five Phase DSTATCOM Model in MATLAB/SIMULINK.

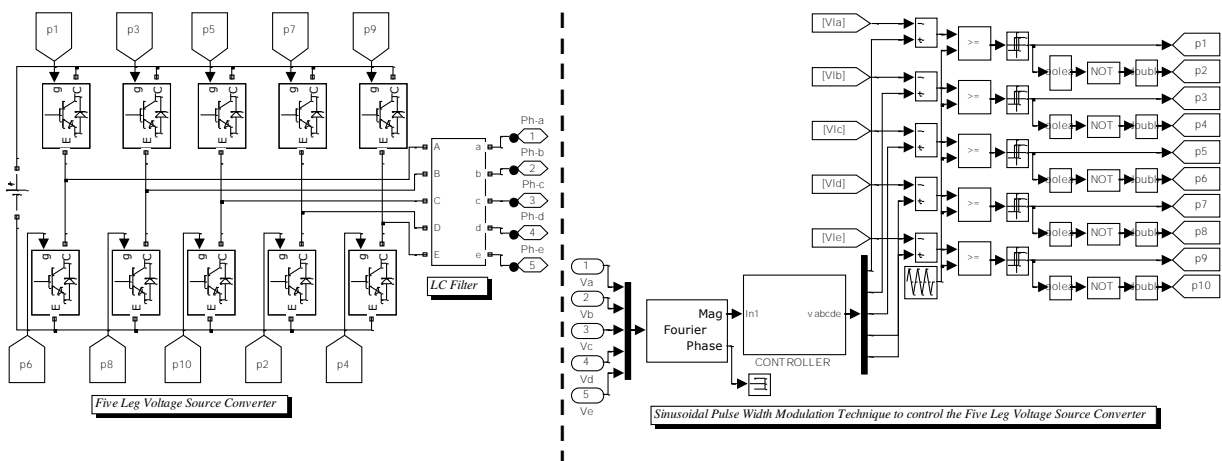**Fig. 3:** Five Leg Inverter (VSC) Used As DSTATCOM.

Fig. 4: Five Leg Voltage Source Converter Model and SPWM Technique in MATLAB Simulink.

Fig. 4. shows the schematic diagram of the five leg inverter with sinusoidal pulse width modulation to inject the reactive power in to the system when there is sudden changes happen in the load as well as supply system. The load voltages taken as input to the SPWM controller. This is converting into a dc form by using the magnitude - phase converter. This is passing through the PI controller and this will be converting as five phase waveform by using

the conversion mechanism. This five phase waveform is now going to compare with triangular waveform and generates the ten pulses to control the ten switches in five leg inverter.

The circuit whole explained with six steps. Throughout step-1, $0 \leq \omega t \leq \pi/5$, switches conducting 1, 8, 10, 7, 9. It's shown in Figure 4. 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

Fig. 5. shows the five phase load voltage waveforms when sag is happened in the system because of sudden change (increased) in load demand. In normal operating mode the load supplied with 400V (=~420V) and when sag is happened the voltage comes down to 320V in all the phases.
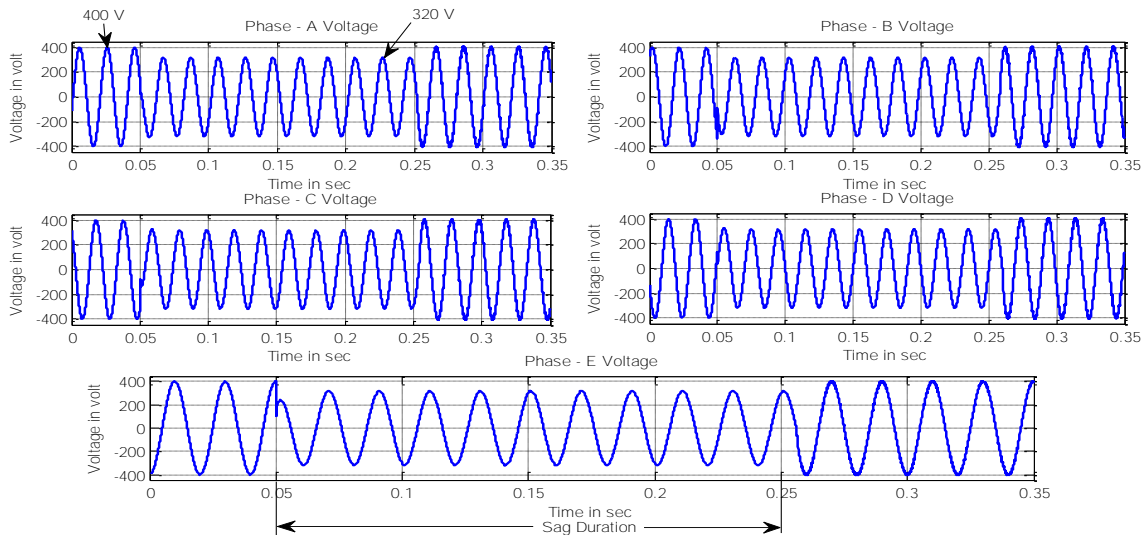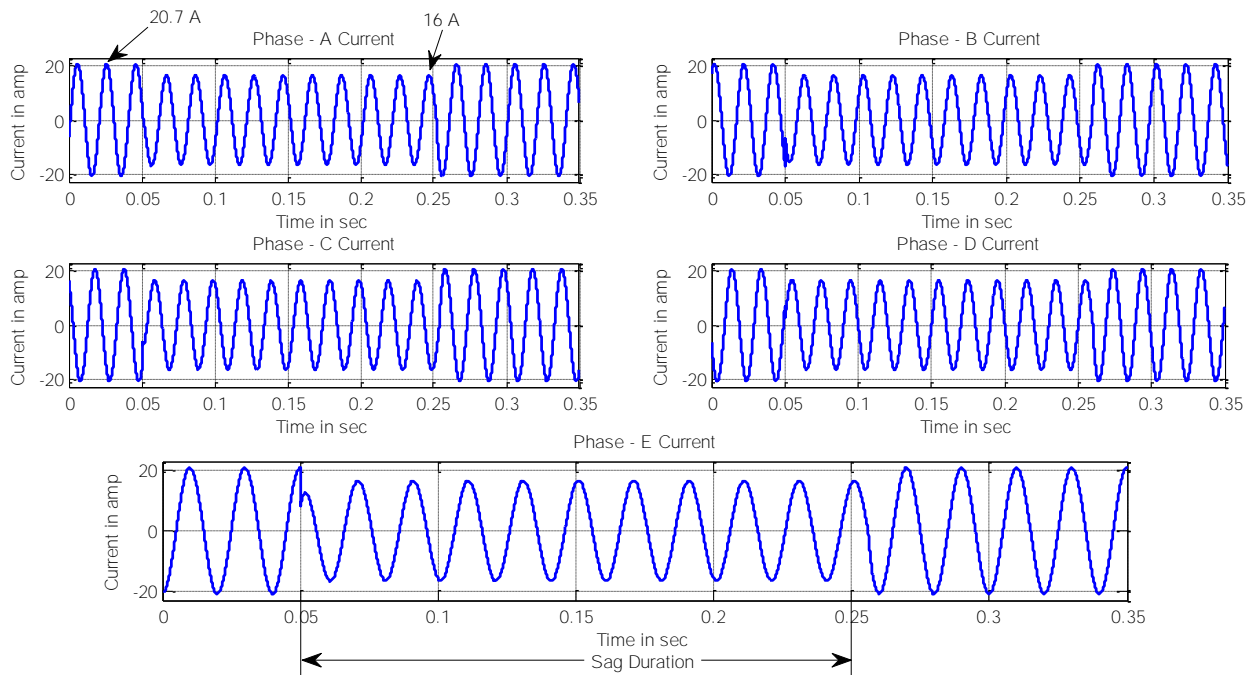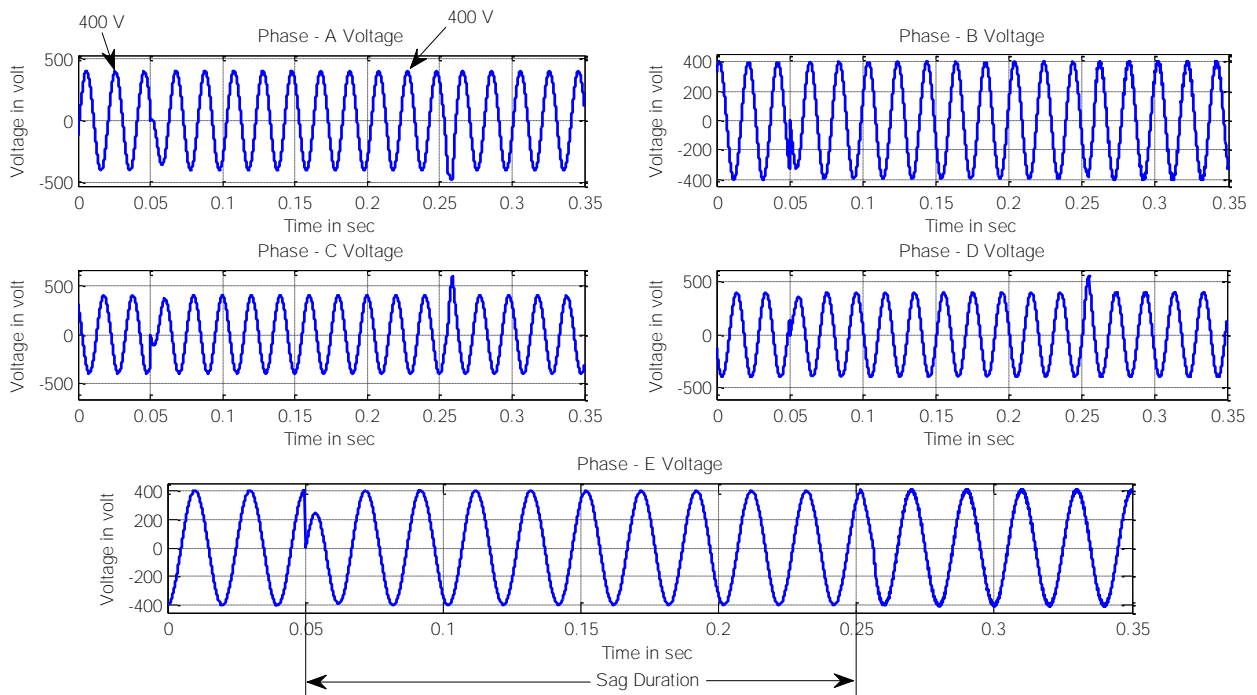

Fig. 5: Voltage Waveforms of All the Phases under Power Quality Problem (I.E., with Sag).

Fig. 6. shows the five phase load current waveforms when sag is happened in the system because of sudden change (increased) in load demand. In normal operating mode the load supplied with 20.7A (=~20A) and when sag is happened the Current comes down to 16A in all the phases.

Fig. 6: Current Waveforms of All the Phases under Power Quality Problem (I.E., with Sag).
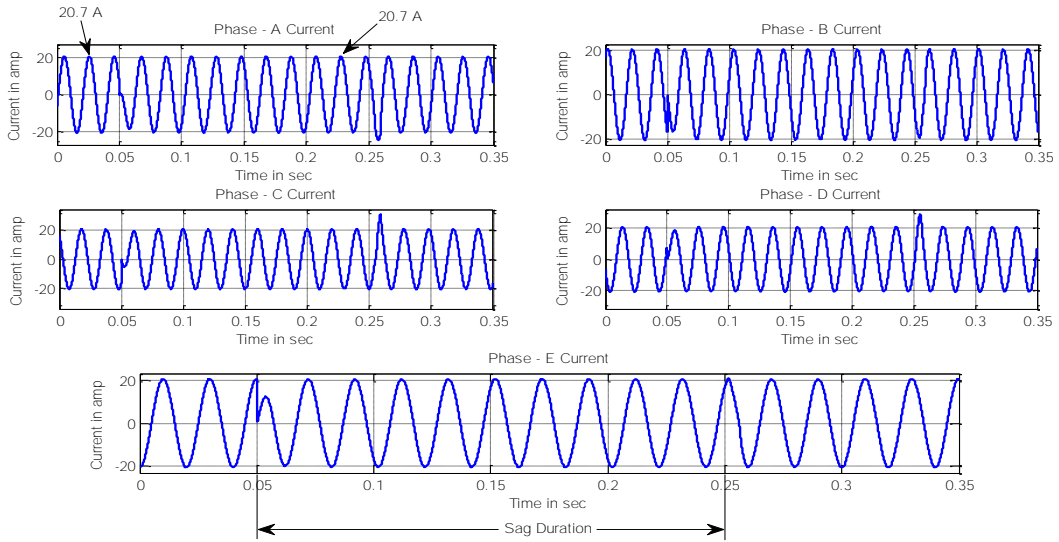

Fig. 7: Voltage Waveforms of All the Phases without Power Quality Problem (I.E., without Sag).

Fig 7 shows the five phase load voltage waveforms when sag is cleared in the system because of injecting the reactive power into the system. In normal operating mode the load supplied with 400V (=~420V) and when sag is cleared the voltage comes up to 400V (=~420V) in all the phases.
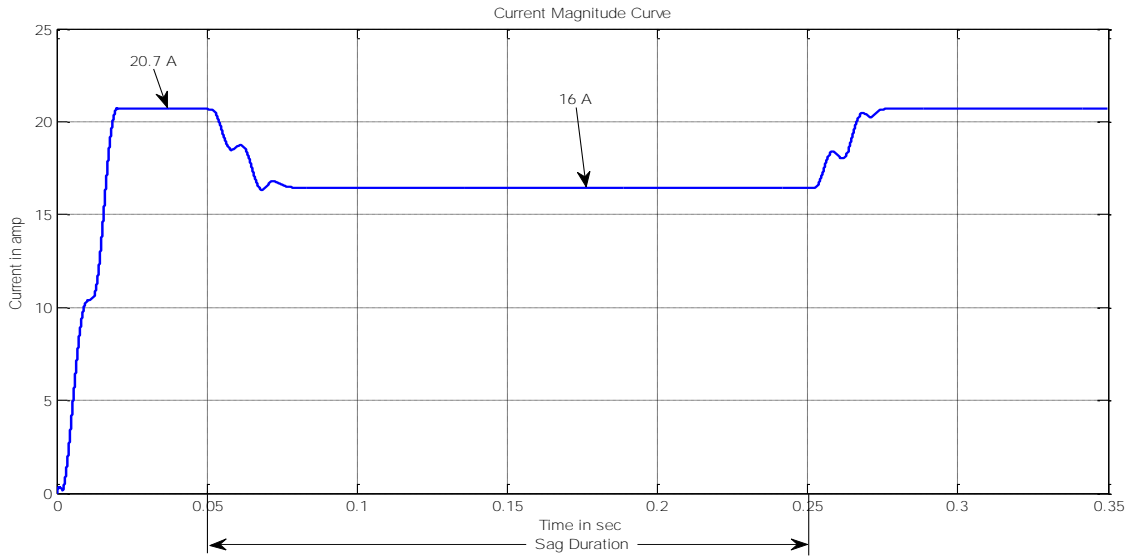
Fig. 8. shows the five phase load current waveforms when sag is cleared in the system because of injecting the reactive power into the system. In normal operating mode the load supplied with 20.7A (=~20A) and when sag is cleared the current comes up to 20.7A (=~20A) in all the phases.

Fig 9 shows the five phase load current magnitude when sag is happened in the system because of sudden change (increased) in load demand. In normal operating mode the load supplied with 20.7A (=~20A) and when sag is happened the Current comes down to 16A.

Fig. 8: Current Waveforms of All the Phases without Power Quality Problem (I.E., without Sag).

Fig. 9: Current Magnitude Curve with Power Quality Problem (I.E., with Sag).

Fig. 10. shows the five phase load current magnitude when sag is cleared in the system because of injecting the reactive power into the system. In normal operating mode the load supplied with 20.7A (=~20A) and when sag is cleared the current comes up to 20.7A (=~20A).
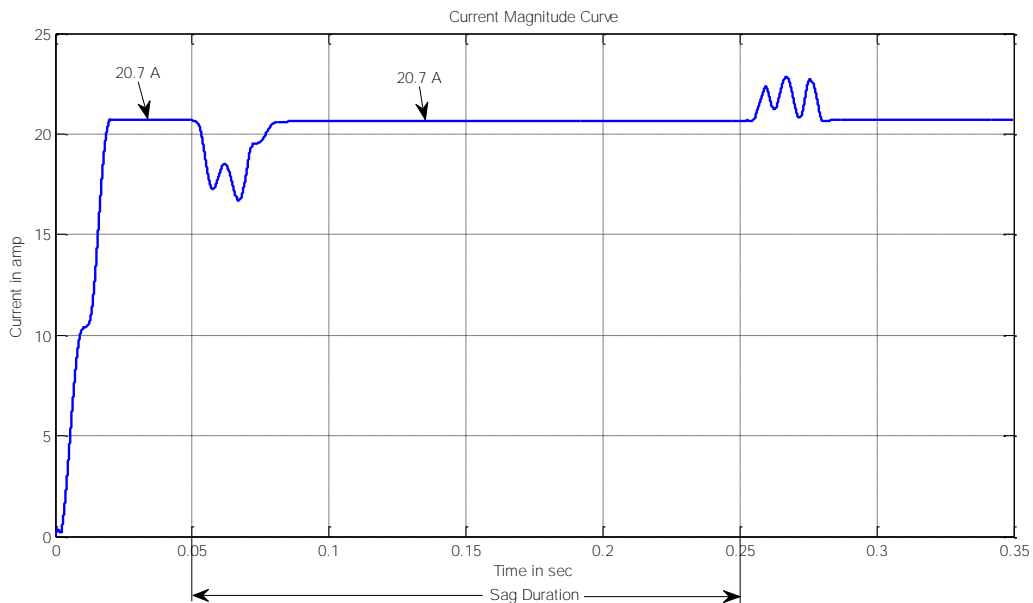
Fig. 10: Current Magnitude Curve without Power Quality Problem (I.E., without Sag).

4. Conclusion

The five phase DSTATCOM is used to mitigate the voltage sag in the five phase supply system if any changes happen in the system because of sudden load changes or fault happened. The MATALB simulation result clearly shows the operation of the distribution static compensator when the load is suddenly changes. This has done by using 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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