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Design And Simulation Of Series Active Power Filter To Improve Power Quality Conditioner By Reduction Of Harmonic

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Abstract-In this paper, a simplified control algorithm of athree-phase Series Active Power Filter (SAPF) as Power Quality Conditioner is presented. SAPF compensates supply voltage distortions/unbalance, supply voltage harmonics in a view as such they does not reach at the load end with very low THD in load voltage. The series APF is realized using a threephase, three leg VSI. A dynamic model of the SAPF is developed in the MATLAB/SIMULINK environment and the simulation results demonstrating the power quality improvement in the system are presented in terms of constant RMS Voltage at load.

index: Harmonics, PCC (point of common coupling), Series Active Power Filter (SAPF), Unbalance.

1. INTRODUCTION

'Reliability' is a key word for utilities and their customers in general, and it is crucial to companies operating in a highly competitive business environment, because it affects profitability, which definitely is a driving force in the industry. Although electrical transmission and distribution systems have reached a very high level of reliability, disturbances cannot be totally avoided. Any disturbances to voltage waveform can cause problems related with the operation of electrical and electronic devices. Users need constant sine wave shape, constant frequency and symmetrical voltage with a constant rms value to continue the production. This increasing interest to improve efficiency and eliminate variations in the industry has resulted more complex instruments sensitive to voltage disturbances such as voltage sag, voltage swell, interruption, phase shift and harmonics. Voltage sag is considered the most severe since the sensitive loads are very susceptible to temporary changes in the voltage. In some cases, these disturbances can lead to a complete shutdown of an entire production line, in particular at high-tech industries like semiconductor plants, with severe economic consequences to the affected enterprise. In the past, the solutions to mitigatethese power quality problems were through using conventional passive filters. But their limitations such as, fixed compensation, resonance with source impedance and the difficulty in tuning time dependence of filter parameters have ignited the need for active and hybrid filters. The rating of active filters is reduced through augmenting them with passive filters to form hybrid filters, which reduce overall cost. Also they can provide better compensation than either passive or active filters. Therefore, the development of hybrid filter technology has been from a hybrid of passive filters to a hybrid of active filters to provide a cost-effective solution and optimal compensation. For voltage related power quality problems and for systems supplying diode bridge converters with high dc link capacitive filters, series active or hybrid filter configurations are preferred. Series filters can eliminate voltage and current harmonics, but they are not suitable for maintaining zero voltage regulation at the PCC. In addition, for better rating utilization it is preferable to deal with voltage related problems with a series filter rather than a shunt filter. This paper presents a three-phase, SAPF configuration suitable for power distribution systems and a simple control algorithm for its control. The series AF is controlled to maintain voltage regulation and to eliminate voltage sag/swell, harmonics and unbalance from the load voltage.

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2. POWER QUALITY

The PQ issue is defined as "any occurrence manifested in voltage, current, or frequency deviations that results in damage, upset, failure, or disoperation of end-use equipment." Almost all PQ issues are closely related with PE in almost every aspect of commercial, domestic and industrial application. Equipment using power electronic device are residential appliances like TVs, PCs etc. business and office equipment like copiers, printers etc. Industrial equipment like programmable logic controllers (PLCs), adjustable speed drives (ASDs), rectifiers, inverters, CNC tools and so on.

The Power Quality (PQ) problem can be detected from one of the following several symptoms depending on the type of issue involved.

- Lamp flicker.
- Frequent blackouts.
- Sensitive-equipment frequent dropouts.
- Unexpected voltage drop to ground.

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- Communications interference.
- Overheated elements and equipment.

PE is the most important cause of harmonics, inter harmonics, notches and neutral currents. Harmonics are produced by rectifiers, ASDs, soft starters, electronic ballast for discharge lamps, switched-mode power supplies and HVAC using ASDs. Equipment affected by harmonics includes transformers, motors, cables, interrupters and capacitors (resonance). Notches are produced mainly by converters and they principally affect the electronic control devices. Neutral currents are produced by equipment using switched-mode power supplies such as PCs, printers, photocopiers and any triplet's generator. Neutral currents seriously affect the neutral conductor temperature and transformer capability. Interharmonics are produced by static frequency converters, cyclo-converters, induction motors& arcing devices.

3. Power Quality Parameters

a)Voltage sag-sag occurs when the RMS voltage level drops below 90% of the typical RMS level, but is greater than 10% of the nominal voltage for duration of 0.5 cycles to 1 minute.

b)Very shor tinterruptions- Total interruption of electrical supply for duration from few milliseconds to one or two seconds.

c)Long interruptions-Total interruption of electrical supply for duration greater than 1 to 2 minutes.

d)Voltage spike - Very fast variation of the voltage value for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts even in low voltage.

e)Voltage swell– A swell occurs when the voltage increases to greater than 110% of the typical RMS voltage for duration of 0.5 cycles to 1 minute.

f)Harmonics-Harmonics are the voltages or currents waveforms with frequencies that are integral multiples of fundamental supply frequency (50 or 60 Hz).

g)Voltage fluctuation- Oscillation of voltage value amplitude modulated by a signal with frequency of 0 to 30 Hz.

i)Noise- Noise is unwanted electrical signals that produce undesirable effects in the circuits of control systems in which they occur.

j)Voltage Unbalance- A voltage variation in a three-phase system in which the three phase voltage magnitudes or the phase angle differences between them are not equal.

The above problem can be overcome by using three phase inverter with SPWM or SVPWM technique which work as a series shunt filter.

4. Simulation And Results

The three phase inverter is designed and simulated using MATLAB/SIMULINK as shown below

Table 3(a): Three Phase Voltage Source Inverter Conducting Modes

Interval	Three conducting switches								Leg state	Voltage vector
1	T_1	T_2	T_3						101	V_5
2		T_2	T_3	T_4					001	V_1
3			T_3	T_4	T_5				011	V_3
4				T_4	T_5	T_6			010	V_2
5					T_5	T_6	T_1		110	V_6
6						T_6	T_1	T_2	100	V_4

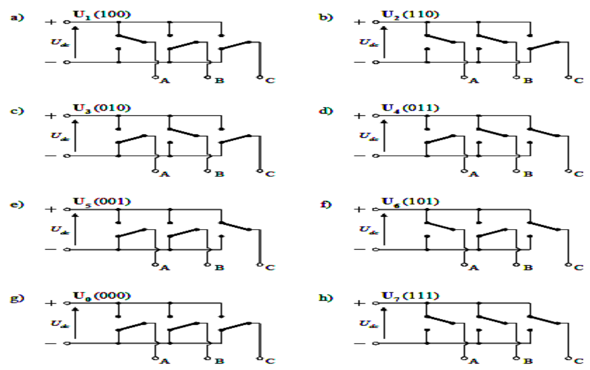

Fig 4(a) Switching Sequence Of Inverter

Considering eight switching sequence, as shown in fig 3(a) using the matrix in table 3(a). Effectively the resistors representing the three-phase load are sequentially cycled anticlockwise one at a time, being alternately connected to each supply rail. The output voltage is independent of the load, as it is for all voltage source inverters.Practical Inverter waveform contains harmonics. But the availability of high speedpower semiconductors devices reduce the harmonic contents of output voltage can be minimized or reduced significantly by switching techniques.With these theoretical background the three phase inverter is designed and simulated using MATLAB/SIMULINK as shown below.

a)Three phase inverter

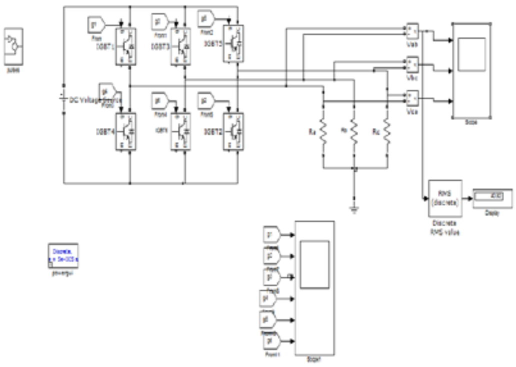

Fig 4(b) Simulation Circuit of Three-phase Inverter

The fig 4(b) shows the circuit diagram for single phase inverter. Here the input voltage is set a value of Vdc=50V. Inverter is feeding a resistive load of R=5Ω.

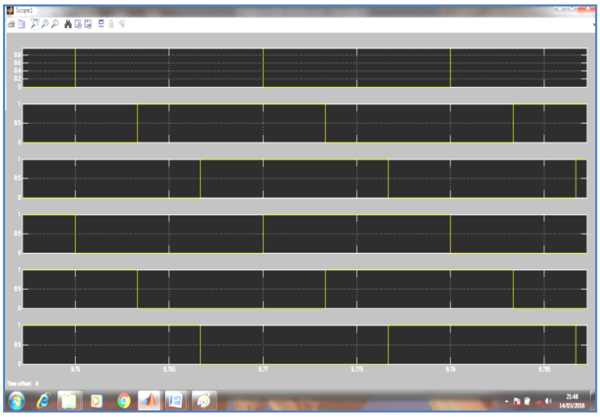

Fig 4(c) Gating signal

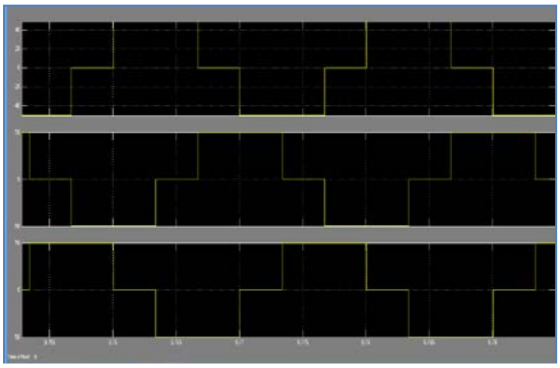

Fig 4(d) Output Voltage Waveform Of Three Phase Inverter

The fig 4(d) shows output voltage of three phase inverter. It has a peak voltage of 50V and rmsvalue of output voltage of 40.92V. Here the output voltage is a square wave and contains more number of harmonics. The fig 4(e) shows the FFT analysis of three phase inverter where the fundamental output voltage has a magnitude of 55.29V with total harmonic distortion of30.90%.

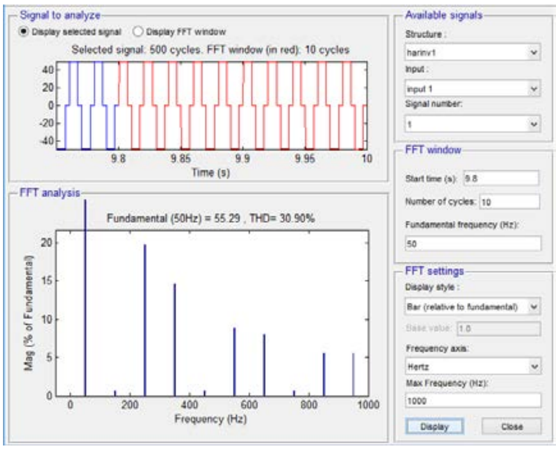

Fig 4(e) FFT Analysis Of Three Phase Inverter

5. SPWM THREE PHASE INVERTER

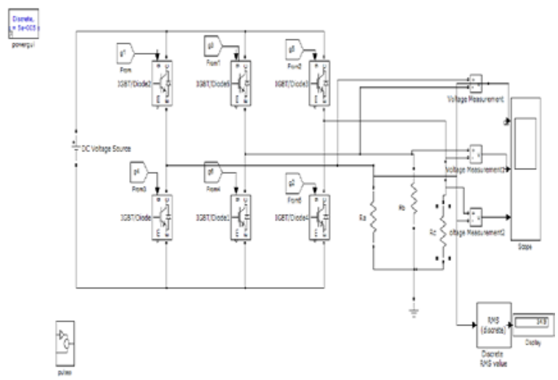

Fig 5(a)
Simulation Circuit Of Three Phase SPWM Inverter

The figure 5(a) shows the circuit diagram for three phase PWM inverter. Here the input voltage is set a value ofVdc=50V. Inverter is feeding a resistive load of R=5Ω. The SPWM technique is chosen as a PWM controller to minimise the harmonics and to control the output voltage and frequency of the inverter. In SPWM technique the reference signal with magnitude 100V and frequency 50Hz is compared with the carrier signal of type triangular signal with carrier frequency 1080Hz to obtain output of desired magnitude and frequency. The modulation index can be varied to vary the inverter output voltage. The modulation index can be varied from 0 to 1. In this model the modulation index value of 0.9 is used to obtain the required output voltage (0.9Vorms). in order to vary the frequency of the output voltage, frequency of the reference voltage need to vary.

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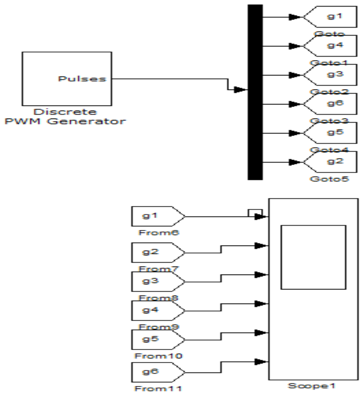

Fig 5(b).PWM Generator

The figure 5(b) shows PWM generator circuit to generate gating pulses for the single phase inverter. The 180 degree conduction control strategy is used along with SPWM technique in order to generate the gating pulses.

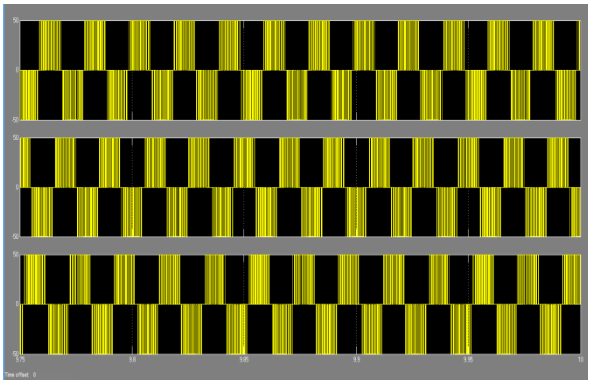

Fig 5(c) Output Voltage Waveform Of Three Phase PWM Inverter

The figure 5(c) shows PWM output voltage of single phase inverter. It has a peak voltage of 50V and rmsvalue of output voltage of 34.9V with modulation index 0.9 which is acceptable value of output voltage. The figure 5(d) shows the FFT analysis of single phase PWM inverter where the fundamental output voltage has a magnitude of 38.9V with total harmonic distortion of 19.35% which is less than the total harmonic distortion obtained by simulation of single phase inverter without PWM.

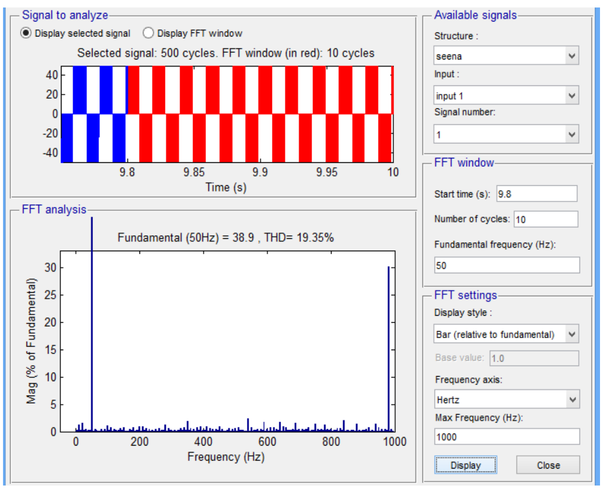

Fig 5(d) FFT Analysis Of Three Phase PWM Inverter

6. SVPWM THREE PHASE INVERTER

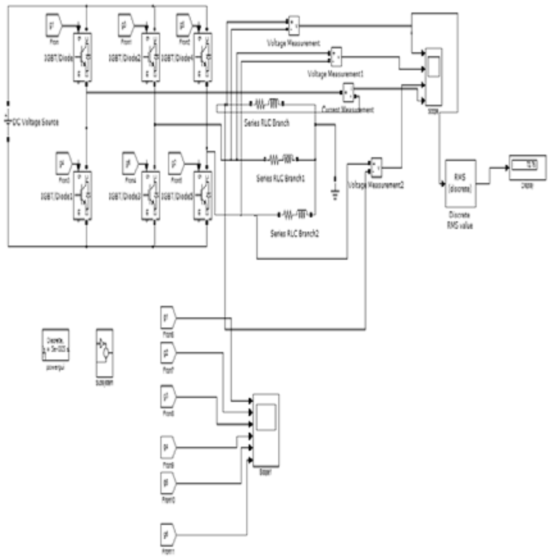

Fig 6(a) Simulation Circuit Of Three Phase SVPWM Inverter

The figure 6(a) shows the circuit diagram for three phase SVPWM inverter. Here the input voltage is set a value of Vdc=50V. Inverter is feeding a resistive load of R=5Ω. The SPWM technique is chosen as a SVPWM controller to minimise the harmonics and to control the output voltage and frequency of the inverter.

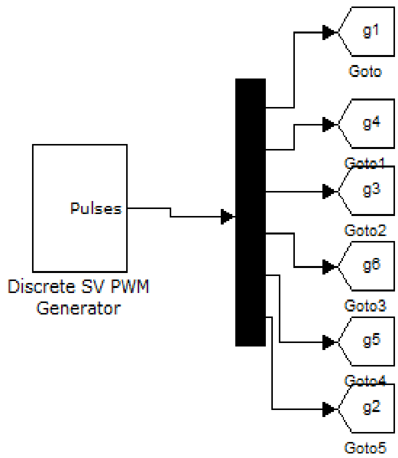

Fig 6(b) Pulses of Three phase inverter with SVPWM

The figure 6(b) shows SVPWM generator circuit to generate gating pulses for the single phase inverter. The 180 degree conduction control strategy is used along with SPWM technique in order to generate the gating pulses.

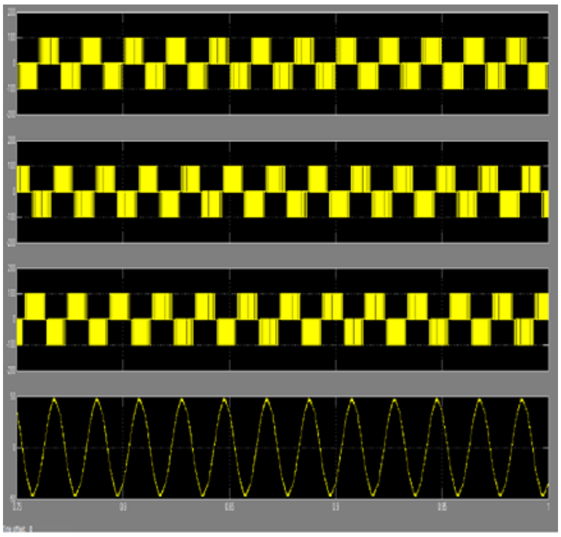

Fig.6(c)Simulation of three phase inverter with SVPWM

The figure 6(c) shows SVPWM output voltage of single phase inverter. It has a peak voltage of 50V and rms value of output voltage of 34.9V with modulation index 0.9 which is acceptable value of out put voltage.

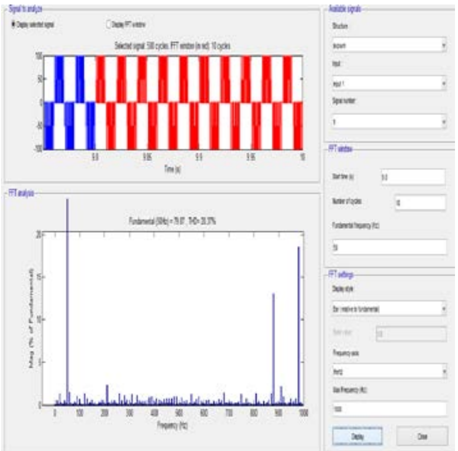

Fig 6(d) FFT Analysis Of Three Phase SVPWM Inverter

The figure 6(d) shows the FFT analysis of single phase SVPWM inverter where the fundamental output voltage has a magnitude of 38.9V with total harmonic distortion of 20.37% which is less than the total harmonic distortion obtained by simulation of single phase inverter without SVPWM.

7. Conclusion

Three phase inverter with SPWM and SVPWM technique which will be used as series active power filter to control voltage, to minimize reactive power and harmonics is designed and simulated using MATLAB/SIMULINK. In this paper an attempt is made to compare SVPWM and SPWM based three phase inverter performance which will be used as series active filter to mitigate harmonics is done. From the simulation results we can conclude that SVPWM three phase inverter mitigate harmonics effectively compared to SPWM three phase inverter.

8. References

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