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Elimination of Harmonics to Enhance the Power Quality by using SAPF

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ABSTRACT: The widespread use of power electronics devices such as rectifier, inverter etc. in power system causes serious problem relating to power quality. One of such problem is generation of current and voltage harmonics causing distortion of load waveform, voltage fluctuation, voltage dip, heating of equipment etc. Also presence of non-linear loads such as UPS, SMPS, speed drives etc. causes the generation of current harmonics in power system. They draw reactive power components of current from the AC mains, hence causing disturbance in supply current waveform. Thus to avoid the consequences of harmonics we have to compensate the harmonic component in power utility system. Among various method used, one of the effective method to reduce harmonic in power system is the use of Shunt Active Power Filter (SAPF). This Paper gives detail performance analysis of SAPF under two current control strategy namely, instantaneous active and reactive power theory (p-q) and synchronous frame reference theory (d-q) and their comparative analysis to justify one of the method better over other. Hardware module

KEYWORDS: Shunt Active Filter, Total harmonic Distortion, Power Quality

I.INTRODUCTION

Power quality is a term that means different things to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as “the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment.” As appropriate as this description might seem, the limitation of power quality to “sensitive electronic equipment” might be subject to disagreement. Electrical equipment susceptible to power quality or more appropriately to lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment, or a household appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems.

A simpler and perhaps more concise definition might state: “Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy.” This definition embraces two things that we demand from an electrical device: performance and life expectancy. Any power-related problem that compromises either attribute is a power quality concern.

Active power filters are simply power electronic converters, specially designed to inject Harmonic currents to the system. Classically, shunt passive filters, consist of tuned LC filters and/or high passive filters are used to suppress the harmonics and power capacitors are employed to improve the power factor. But they have the limitations of fixed compensation, large size and can also exile resonance conditions. Active power filters are now seen as a viable alternative over the classical passive filters, to compensate harmonics and reactive power requirement of the non-linear loads. The objective of the active filtering is to solve these problems by combining with a much-reduced rating of the necessary passive components.

The main objective of this Paper presents a compensating system for the harmonic currents of three-phase distribution system by using a shunt active filter. A shunt active filter is to inject into the system a compensating current so as to make the source current sinusoidal and in phase with the source voltage. A shunt active filter has been proposed for harmonic compensation. The voltage source inverter can thus be utilized as power converter. SRF and ID,IQ control techniques are compared. Hard ware model has been implemented

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II.HARMONICS

Harmonics is a term, used to describe the shape or characteristic of a voltage or current waveform, with respect to the fundamental frequency in an electrical distribution system. Harmonic distortion is a kind of pollution in the electrical supply.

Harmonics of complex current waveform is a way to define the current or voltage waveform. If no harmonics exist, then the waveform is described as the fundamental sine wave (50Hz).The harmonic frequencies are, exact multiples of the fundamental supply frequency (which is typically 50 Hz), thus a voltage with a frequency of 100Hz, would be the 2nd harmonic in a 50 Hz electrical system. Typical harmonics for a 50 Hz system are the 5th (250 Hz), the 7th (350 Hz) and the 11th (550Hz). A normal supply system operates at 50 Hz power frequency, However, due to any reason if voltage/current signal of higher frequencies (higher than 50 Hz), are introduced in the supply system, they are termed as harmonics, e.g. if a waveform of 250 Hz is introduced in a 50 Hz system, one can say that the system has 5th harmonic present in the system.

Truly speaking harmonics are a mathematical model of the real world. Any non- sinusoidal wave which is periodic in nature can be mathematically decomposed into sine waves of fundamental and higher frequencies, which are multiple of the fundamental frequency. Power system harmonics is an area that is always receiving a great deal of attention in Aluminum Smelters due to non-linear load of AC-DC converters as the load of AC-DC converters is very large portion of connected load.

Equipment	Problems
Generators	Overheating in coils & cores
Capacitors & Transductors	Overheating, burnout, resonance
MCCBs	Faulty operations due to excessive harmonic current
Power fuses	Blowing out due to excessive harmonic current
Neutral cables	Overheating of neutral lines
Rectifier controller	Faulty control due to phase shifting of control
signals Relays	Faulty operations due to phase variation
Watt-hour meter	Measuring error due to non-linear characteristics
Transformer	Reduction of capacitor due to copper losses

Table 1: Equipment and their problems due to harmonics

There are several measures used for evaluating the influence of harmonic current on the power system. One of the most common is the "Total Harmonic Distortion (THD)", which gives a measure of the effective (RMS) value of the harmonics relative to the fundamental component. The RMS value of a wave comprised of several harmonics is the square root of the sum of the squares of the individual harmonics.

Therefore the THD is computed as follows:

$$THD = [\ (I_2^2 + I_3^2 + \dots\dots\dots\dots + I_n^2)^{1/2}\ ] / I_1$$

III. SHUNT ACTIVE POWER FILTER

The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°. Fig 4.6 shows the connection of a shunt active power filter with a controller circuit.

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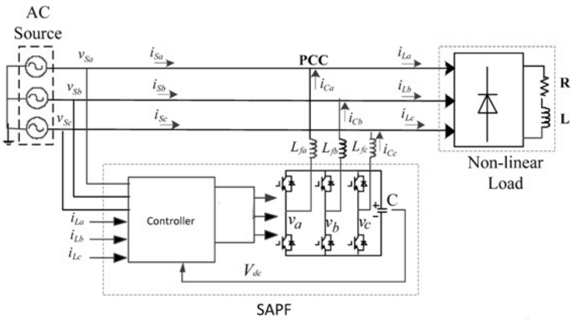

Fig. 1. Shunt active power filter topology

. It is controlled to draw / supply a compensating current ic from / to the utility, so that it cancels current harmonics on the AC side, and makes the source current in phase with the source voltage.

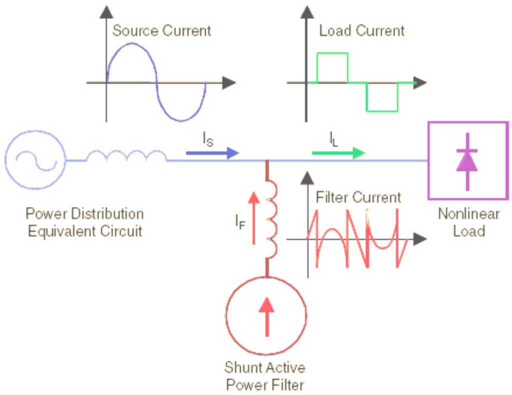

Fig 2.shows the basic compensation principle of a shunt active power filters

The instantaneous currents can be written as

$$i_s(t) = i_l(t) - i_c(t) \quad (1)$$

Source voltage is given by

$$v_s(t) = v_m \sin \omega t \quad (2)$$

If a non-linear load is applied, then the load current will have a fundamental component and harmonic components which can be represented as

$$i_L(t) = \sum_{n=1}^{\infty} I_n \sin(n\,\omega t + \emptyset_n) = I_1 \sin(n\,\omega t) + \sum_{n=2}^{\infty} \sin\,(n\,\omega t + \emptyset_n) \quad (3)$$

The instantaneous load power can be given as

$$P_L(t) = v_s(t) * I_1(t) = V_m I_l sin^2\,\omega t * cos\emptyset_1 + V_m I_1 sin\omega t * cos\omega t * sin\emptyset_1 + V_m sin\omega t *$$
$$= P_s(t) + P_\sigma(t) + P_h(t) \quad (4)$$

If the active filter provides the total reactive and harmonic power, then is(t) will be in phase with the utility voltage and purely sinusoidal. At this time, the active filter must provide the following compensation current

$$i_c(t) = i_L(t) - i_s(t) \quad (5)$$

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Instantaneous Power Theory or Active-Reactive (*p-q*) theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages in the *a-b-c* coordinates to the *α-β-0* coordinates, followed by the calculation of the p-q theory instantaneous power components. The theory is based on a transformation from the phase reference system 1-2-3 to the 0-α-β system. The instantaneous *p-q* method is achieved by previous calculation of the mains voltages and the nonlinear load currents in a stationary reference frames, i.e., in αβ0 components by using the Clarke transformation.

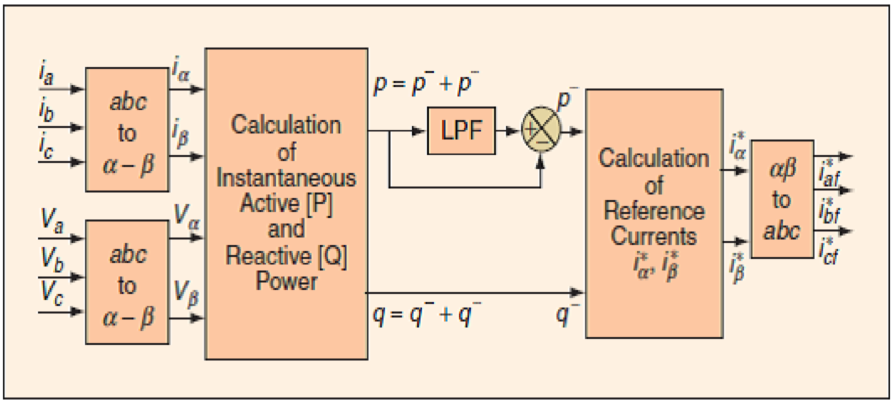

Fig 3.block diagram of Instantaneous Power Theory or Active-Reactive (*p-q*)

This based on Reference Frame transformation i.e. the transformation of coordinates from a three-phase *a-b-c* stationery co-ordinate system to the 0-*d*- *q* rotating coordinate system. All positive sequence fundamental quantities will appear as dc in d-q frame, and other harmonics will appear as ripples. A low-pass filter (LPF) is used to extract the fundamental component.

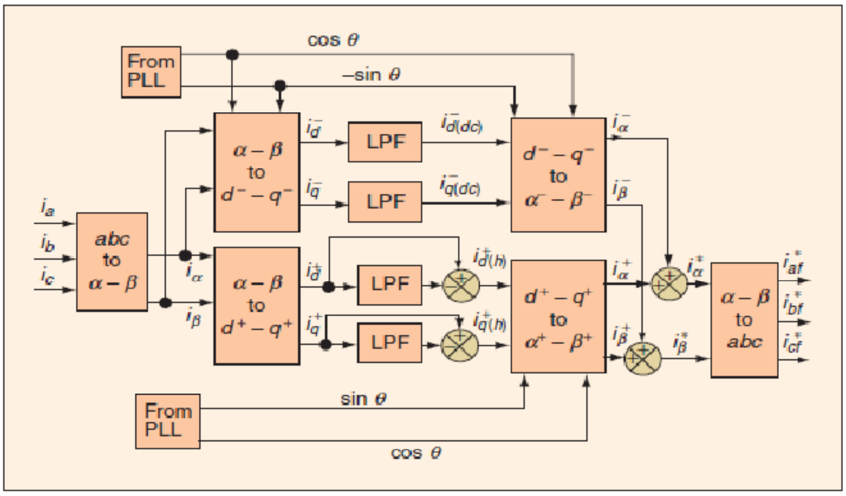

Fig 4.block diagram of Reference Frame transformation

IV. RESULTS ANALYSIS

The Matlab/Simulink simulation tool was used to develop a model that allowed the simulation and testing of the p-q theory calculation, which were implemented in the controller of shunt active power filter for three phase, three wire systems. The controller used in this project is PQ theory it consists in the algebraic transformation of the current and voltage of the system from the abc system to 0αβ system using the Clarke transformation. After filtering the

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harmonic content again the 0αβ system is transformed into abc reverse Clarke transformation. The hysteresis current controller was developed to generate the switching pulses to control VSI switches by comparing the real current to the reference current. The control scheme gives the switching pattern of active filter switches in order to maintain the real injected current within desired hysteresis band (HB)

Shunt active filters injects the compensating current into the line hence corrects the source current into sinusoidal. The following waveform shows the source current and load current before injecting shunt active filter compensating current. In this method we use non-linear load, hence load is distorted with harmonics.

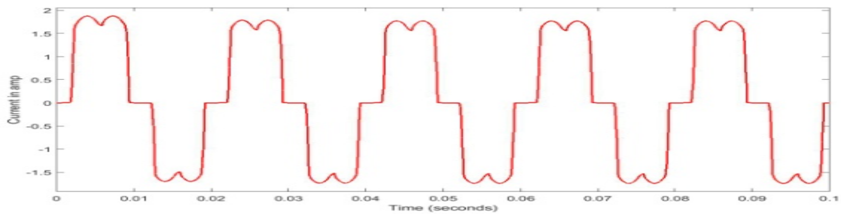

Fig. 5 Single phase source and load current waveform without SAP filter

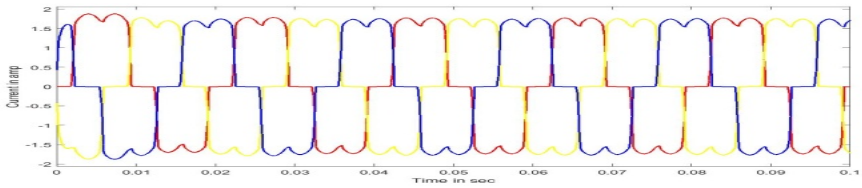

Fig. 6 Three phase source and load current waveform without SAP filter

The fig 5 and fig 6 shows the three phase source current and single phase source current waveforms after connecting shunt active filter.

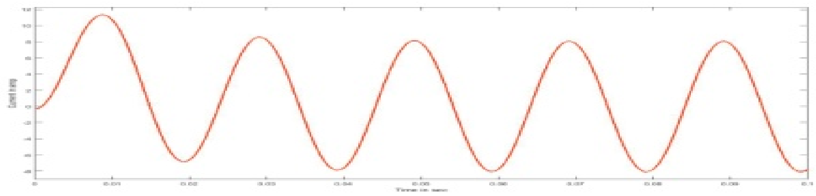

Fig. 7 Single phase source current waveform with SAP filter

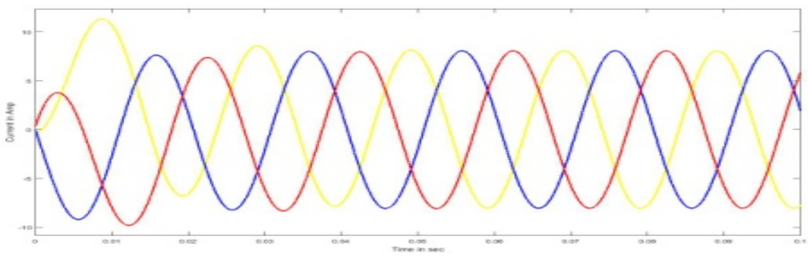

Fig. 8 Three phase source current waveform with SAP filter

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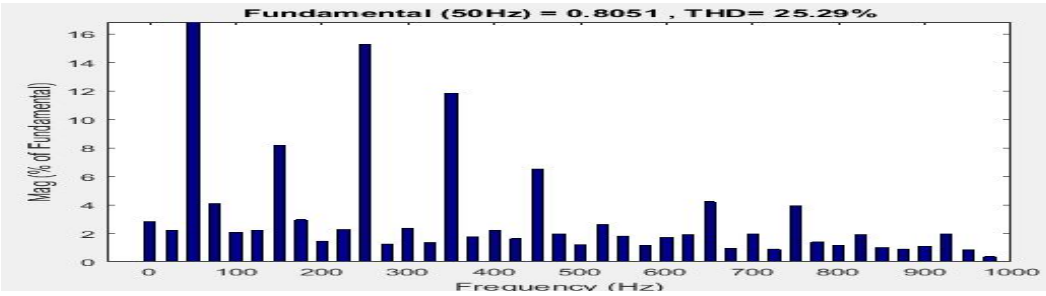


Fig. 9 THD at source side without SAP filter

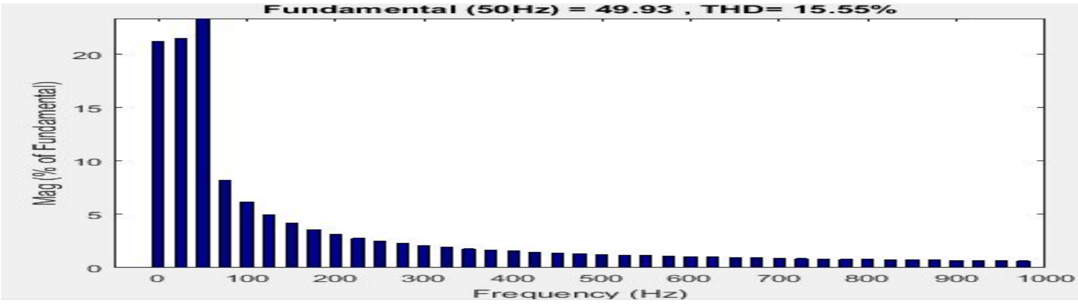


Fig. 10 THD at source side with SAP filter

In the fig 9 it is observed that the source current THD is 25.29% before the shunt active filter get activated. In the fig 10 the source current THD is 15.66% after the injection of compensating current into the power system. Hence the power quality is improved.

The hardware model of the active power filters incorporating the major components are shown in fig.11. it contains step down Transformer(230v to 100v), Transmission system, Load, arduino nano, Driver circuit, Inverter circuit with four MOSFET's.

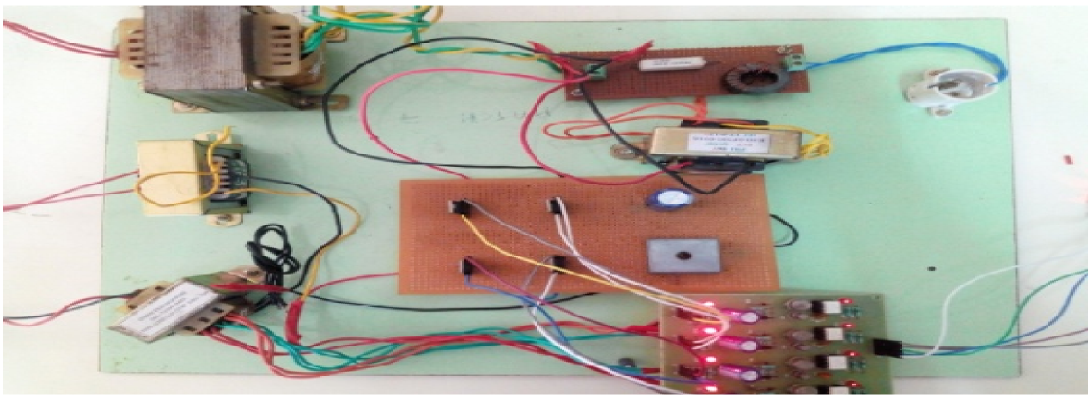
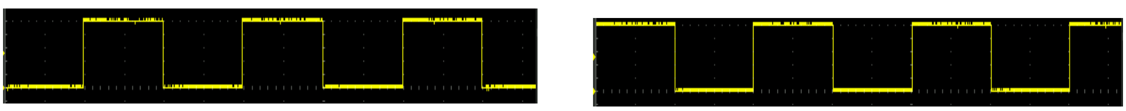


Fig. 11 Hardware implementation

In fig 12 it is observed the driver circuit input pulses. The input pulses are generated by the aurdino nano.



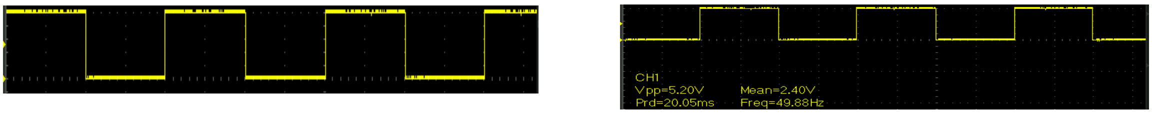


Fig. 12 Input pulses for gate driver

In fig 13 it is observed that driver circuit output pulses. In this the pulses are generated by the driver circuit which helps to switch ON the MOSFET's.

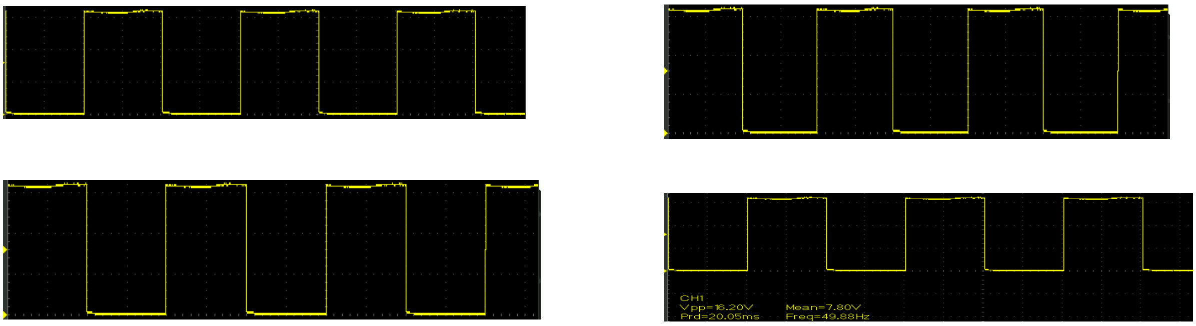


Fig. 13 Output pulses from gate driver

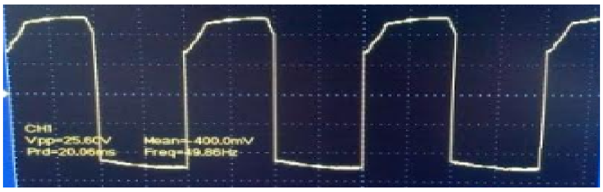


Fig. 14 output voltage of inverter

In fig 14 it is observed that the output of the MOSFET inverter. The output peak to peak voltage is 25.5V.

V. CONCLUSION

Power quality means to have harmonics free transfer of power in the system as harmonics causes fluctuations in voltage and current which are not good for the equipment's at home. So in order to maintain constant voltage profile we need a good power quality. Shunt active power filters compensates load by injecting equal but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic component generated by the load but phase-shifted by 1800. Here we use controllers called pq theory and dq theory. This shows that without shunt active power filter the thb is 26.14% and with shunt active power filter thd is 2.65%. The hardware model of shunt active power filter is designed.

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