PROBLEMS OF POWER QUALITY WITH THE MITIGATION BY USING HYBRID ACTIVE POWER FILTER FOR THREE PHASE SYSTEM

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ABSTRACT

Power Quality has become the buzzword in today's environment of power electronics, digital communication and automation industry based on digital circuitry. Greater sensitivity of devices and equipment to power quality variations, interconnection of sensitive loads in extensive networks and automated processes, and an increase in the loads that use power electronics in many of the power conversion processes have made power quality imperative for industries and the market. The perception of PQ is quite different among different stakeholders namely, the regulator, the consumer, the network operator and the device manufacturer. Consequently, there are increasing number of disputes on PQ issues and individual responsibility of the stakeholders on PQ all over the world. The practical solution to all these problems, however, is to be based on overall impacts of the PQ related issues.

The Paper gives an overview of the problems related to the power quality & this paper also presents an implementation of hybrid active power filter for decreasing the distortions in currents in a three phase systems.

Keywords: Power Quality Problems, Hybrid Active Power Filter For 3-Ph System, Simulink Model with Result

I. INTRODUCTION

"The concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment" & "as the ability of a system or an equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to process operation in the industrial process or system" these are the definitions of Power quality according to the IEEE Standards. PQ covers two broad issues namely: 1.Interruption free power supply which means Reliability of Power supply 2. The constant voltage and frequency of power implying Power Quality. PQ presumes 100% reliability. Power quality, or more specifically, a power quality disturbance, is generally defined as any change in power (voltage, current, or frequency) that interferes with the normal operation of electrical equipment. The standard (IEEE Standard 1159-1995, "IEEE Recommended Practice for Monitoring Electrical Power Quality") describes many power quality problems, of which this paper will discuss the most common.

The application of power electronic in power conversion shows drawbacks that lead to power quality problems which could relate to harmonics affecting communication interference, heating, solid-state devices malfunction, resonance. Solutions involve several techniques that include the use of passive and active power filter (APF). A more advance approach is the use of hybrid filters amongst other involves the use of both the passive filter and shunt APF in combination. They are being used to eliminate both the lower order and higher order harmonics. The passive filter is normally designed to eliminate the bulk of load-current harmonic leaving the more complex problems to be solved by the APF. Shunt APF normally operates using pulse width modulation (PWM) inverter techniques to inject the required non-sinusoidal current requirements of nonlinear loads but is complex with the number of switches in use. Another approach is the use of series active power filter that uses basic bridge-diode circuit, boost circuit and an inductor. Single phase converter produces a relatively high proportion of ac ripple voltage at its dc terminal, it is undesirable because of its heat producing effect. A smoothing needed to get continuous operation. It can be minimized by increasing number of pulses. Three phase ac supply with a suitable transformer connection permits an increasing the pulse number. When the number of pulses increased out-put voltage gets smoothen. So here we are implementing an extension of single phase hybrid active power filter with three phases HAPF. The time-domain approach is used to control the power switch of proposed PAPF during compensation process. This approach is based on the principle of holding the instantaneous current within some reasonable tolerance of a sine wave. The error is computed from the difference of instantaneous actual current signal with its reference signal, normally pure sine wave. This error is then conditioned and processed to obtain the required switching pattern known as the pulse wave modulation (PWM) wave. A simple proportional integral control method is implemented to aid response from the control which uses a supply current detection to accomplish shunt APF tasks. A simple LC filter is used in conjunction to study its effects.

II. PROBLEMS RELATED TO POWER QUALITY

IEEE Standard 1159-1995 also addresses these problem with the goal of providing consistent terminology for power quality reporting from the professional community. Some of these ambiguous terms are described in this paper as follows:

2.1 Blackouts

Description: It is short or long term loss of electric power to an area.

Causes: Faults at power stations, Damage to electric transmission lines, substations or other parts of the distribution system, Short circuit, or the overloading of electricity mains.

Effects: Total loss of power to an area, tripping of substations, under certain conditions, a network component shutting down can cause current fluctuations in neighboring segments of the network leading to a cascading failure of a larger section of the network. This may range from a building, to a block, to an entire city, to an entire electrical grid.

2.2 Brownouts

Description: A brownout is an intentional or unintentional drop in voltage in an electrical power supply system.

Causes: Use of excessive loads causes reduction in voltage which in turn causes brownouts.

Effects: Unexpected behavior in systems with digital control circuits & The system can experience glitches, data loss and equipment failure.

2.3 Voltage Sag (or Dip)

Description: A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0.5 cycle to 1 minute.

Causes: Faults on the transmission or distribution network (most of the times on parallel feeders). Faults in consumer's installation. Connection of heavy loads and start-up of large motors.

Consequences: Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.

2.4 Very Short Interruptions

Description: Total interruption of electrical supply for duration from few milliseconds to one or two seconds.

Causes: Mainly due to the opening and automatic enclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover.

Consequences: Tripping of protection devices, loss of information and malfunction of data processing equipment. Stoppage of sensitive equipment, such as ASDs, PCs, PLCs, if they're not prepared to deal with this situation.

2.5 Long interruptions

Description: Total interruption of electrical supply for duration greater than 1 to 2 seconds

Causes: Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices.

Consequences: Stoppage of all equipment.

2.6 Voltage Spikes

Description: In electrical engineering, spikes are fast, short duration electrical transients in voltage.

Causes: Lightning strikes, Power outages, Tripped circuit breakers, Short circuits

Effects: Voltage spikes may be created by a rapid buildup or decay of a magnetic field, which may induce energy into the associated circuit.

2.7 Voltage Swell

Description: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.

Causes: Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

Consequences: Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

2.8 Harmonic distortion

Description: Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency.

Causes: *Classic sources: electric machines working above the knee of the magnetization curve (magnetic* saturation), arc furnaces, welding machines, rectifiers, and DC brush motors.

Modern sources: all non-linear loads, such as power electronics equipment including ASDs, switched mode power supplies, data processing equipment, high efficiency lighting.

Consequences: Increased probability in occurrence of resonance, neutral overload in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, errors in measures when using average reading meters, nuisance tripping of thermal protections.

2.9 Voltages Surges

Description: It is a voltage rise that endangers the insulation of electric equipment.

Types :

1. Lightning surges.
2. System-generated surges.

Causes: Shutdown of heavily loaded circuits. Necessary commutation of a high-powered network (e.g. Pf correction) & Switching events such as the connection or disconnection of a current and short-circuiting to ground.

Effects: Computers and other sensitive electronic equipment can seriously be damaged by such an over-voltage surge & Temporal fluctuations produce parity errors and interrupts protection systems.

2.10 Flicklings

Description: It is a visible change in brightness of a lamp due to rapid fluctuations in the voltage of the power supply.

Causes: It increase as the size of the changing load becomes larger with respect to the prospective short circuit current available at the point of common connection.

Effects: Filament of lamp can be damaged & Reduction in life of electrical equipment

2.11 Voltage Fluctuation

Description: Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz.

Causes: Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads.

Consequences: Most consequences are common to undervoltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.

2.12 Voltage Unbalance

Description: A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences between them are not equal.

Causes: Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault).

Consequences: Unbalanced systems imply the existence of a negative sequence that is harmful to all three phase loads. The most affected loads are three-phase induction machines.

III. MITIGATION BY USING HYBRID ACTIVE POWER FILTER WITH THE HELP OF REMOVING HARMONICS

The indiscriminate use of non-linear loads has given rise to investigation into new compensation equipment based on power electronics. The aim of this equipment is the elimination of harmonics in the system and reduction in reactive power flow. Depending on application type, series or parallel configurations or combination of active and passive filters are used. Active power filters can be used in conjunction with passive filters improving compensation characteristics of the passive filter and to avoid the possible occurrence of the generation of series or parallel resonance. If the passive filters are not connected, the active power filter could compensate only voltage regulation and voltage unbalance. The best method is to combine the compensation characteristics of passive and active power filters, as shown in Fig. 1 which is Hybrid Filter. In this way, the compensation characteristics of the passive filter is significantly improved since the active scheme generated voltage harmonic components across the terminal of the primary windings of the series transformer, forcing current harmonics generated by the load to circulate through the passive filter instead of the power distribution system. By controlling the amplitude of the voltage fundamental component across the coupling transformer, the power factor of the power distribution system can be adjusted. However, the control of the load power factor imposes a higher voltage across the filter capacitor. This effect has to be considered when the filter capacitors are specified. This type of configuration is very convenient for compensation of high power medium voltage non-linear loads, such as large power ac drives with cycloconverters or high power medium voltage rectifiers for application in arc furnaces.

The new proposed hybrid APF consists of two types of filter,

Active Power Filter

Passive Power Filter

IV. ACTIVE POWER FILTER

4.1 Shunt Active Power Filter

The more usual APLC configuration is the shunt or parallel connection. Figure 1 shows the basic scheme of the connection, where an IGBT switching device represents the APLC power block. The loads with current harmonics can be compensated by this APLC configuration. A typical example of a current- source load is a rectifier with resistive branch in dc side. Figure 1 shows the basic performance of a shunt APLC. The general aim is that the shunt APLC will inject into the system a compensation current, i_C, to cancel the harmonic component of the load current, i_L. The source current i_S becomes sinusoidal after the compensation.

The current waveform of a nonlinear load, a three-phase diode rectifier with a highly inductive DC branch, is shown in Figure 2. After the shunt APLC connection, this injects a compensation current, Figure 2c, in parallel with the load. Figure 2d shows the source current of the system. Before the compensation is equal to the current load, and after it is sinusoidal. In this example, the source voltage is sinusoidal,Figure2a.

4.2 Series Active Power Filter

Figure 3 shows the connection scheme of a series APLC. It is connected to the system through a coupling transformer. The compensation voltage, v_C, is used to cancel the voltage harmonics of the load, *e.g.* diode rectifiers with high capacitance in the DC side.

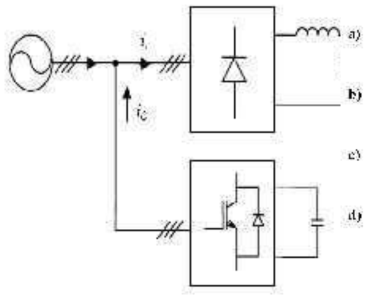

Fig.1 Shunt Active Filter

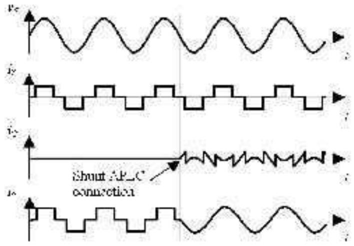

Fig. 2 Shunt Filter Wave Forms

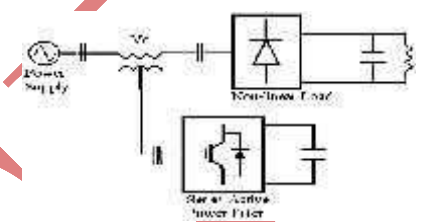

Fig3 . Series Active Filter

V. PASSIVE FILTERS

Passive harmonic filters consisting of capacitors, inductors, and resistors can be classified into

- Tuned filters
- High pass filters.

5.1 Tuned Filters

Tuned filters are used to filter out particular harmonic frequency. Fig. 3.1 shows a Single tuned filter having series connection of a capacitor, an inductor, a resistor and separate out a single frequency harmonic. [5]

Double Tuned filters: A double tuned filter has characteristics of providing low impedance path to 2 harmonic frequencies. It has advantage of low loss at the lower frequencies. A double tuned filter is shown in fig.4

Fig.3.1. A Single Tuned Filter.

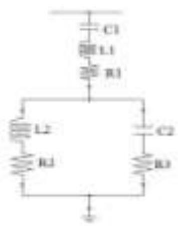

Fig.4. Double Tuned Filter

5.2 High Pass Filter:

The characteristic of high pass filters is to offer low impedance path to all the high frequencies. Fig.5 shows HPF

C-Type High pass filter:

Fig. 6 shows a C-type high pass filter having a capacitor in series with the inductor which provides low impedance path to low frequencies. This helps in reducing the loss at low frequencies. Fig.6 shows C-type HPF

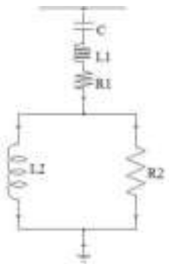

Fig.5. High Pass Filter.

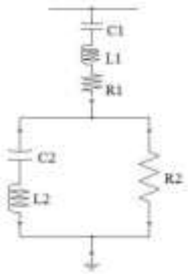

Fig.6. C-Type High Pass Filter.

Passive filters are connected in parallel with nonlinear loads such as diode/thyristor rectifiers, ac electric arc furnaces, and so on. Among them, the combination of four single-tuned filters to the fifth, seventh, 11th and 13th-harmonic frequencies and a second-order high-pass filter tuned around the 17th-harmonic frequency has been used in a high-power three-phase thyristor rectifier. The drawback of passive filters is that they create resonance condition at particular frequencies they are intended to work for. This raises the magnitude of harmonic voltages at that particular frequency.[8]

VI. HYBRID FILTER

Figure 7 shows some of the hybrid passive and active filters. The basic aim of these combinations is to reduce the cost of the static compensation. The passive filters are used to cancel the most relevant harmonics of the load, and the active filter is dedicated to improving the performance of passive filters or to cancel other harmonics components. As result, the power of the active filter is reduced, and the passive filter problems (*e.g.* resonances with the source impedance) are mitigated. In summary, the total cost decreases without reductionof the efficiency.

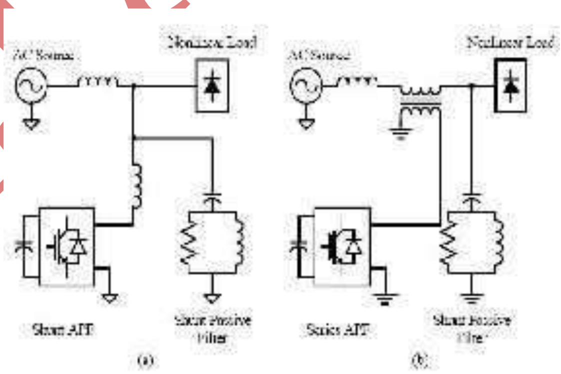

Fig7. Hybrid filter

VII. SIMULATION MODEL

In this work, MATLAB/Simulink was used to analyze the behaviour of the proposed system. Fig. 8

shows the proposed system that consists Hybrid Filter with HAPF shunt-connected with the non-linear load and main supply. A gate drive circuit was used to boost the small PWM signal into an appropriate level for turning ON of the IGBT and to provide physical isolation between the power and electronics section.

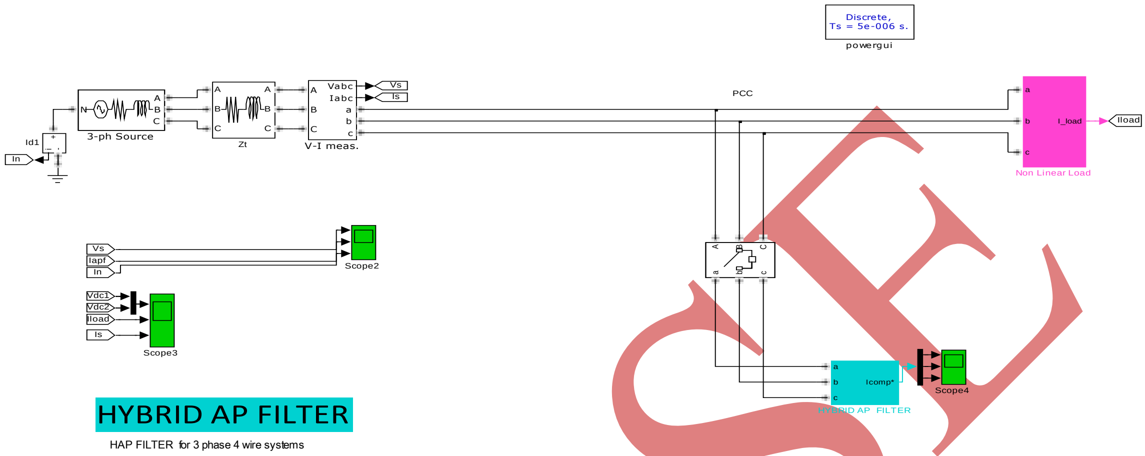

Fig.8 HAPF Simulink Model

VIII. SIMULATION RESULTS

Selected simulations results on the operation of the proposed hybrid active power filter arrangements are presented. The behaviour of the supply subject to non-linear load is investigated in four modes of operation; without filter, b) with passive filter c) with APF and d) with hybrid. Fig. 8 show results obtained from simulation. In this project without using any rectifiers. The output voltage and currents gets distorted in phase shifts or out of phase. So, the total harmonic distortion values is on the range of 38% to 42%.by connecting simple passive filter half of its means 20% to 24% to reduced. by adding active power filter thd value reduced to 10% to 12%.finally by implementing hybrid active power filter means combination of both active and passive filters the thd value reduced to below 4.36% which is to be economical.

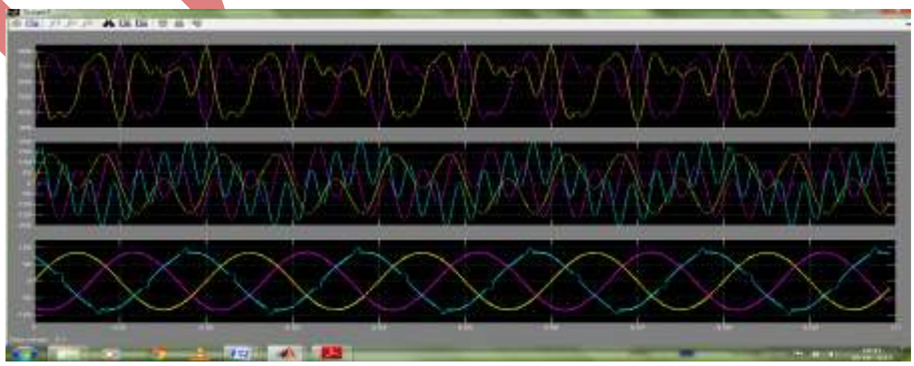

Fig.9.Dc Component Current, Load Current & Source Current without Filtration

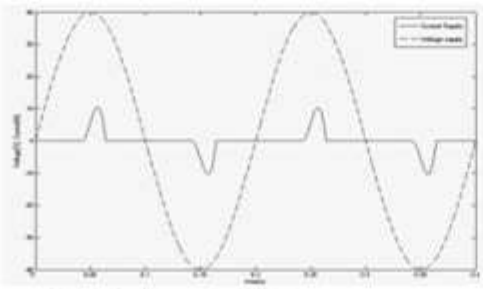

Fig.10. with passive filter

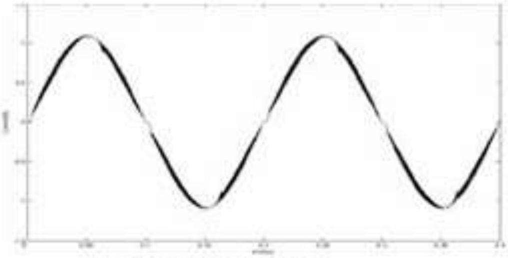

Fig.12. with active filter

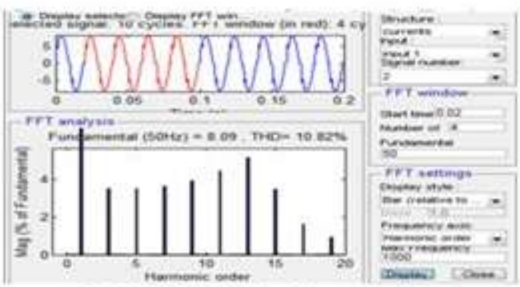

Fig.11.THD analysis with passive filter

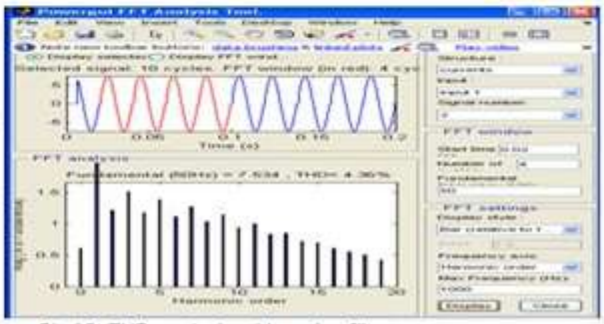

Fig.13. THD analysis with active filter

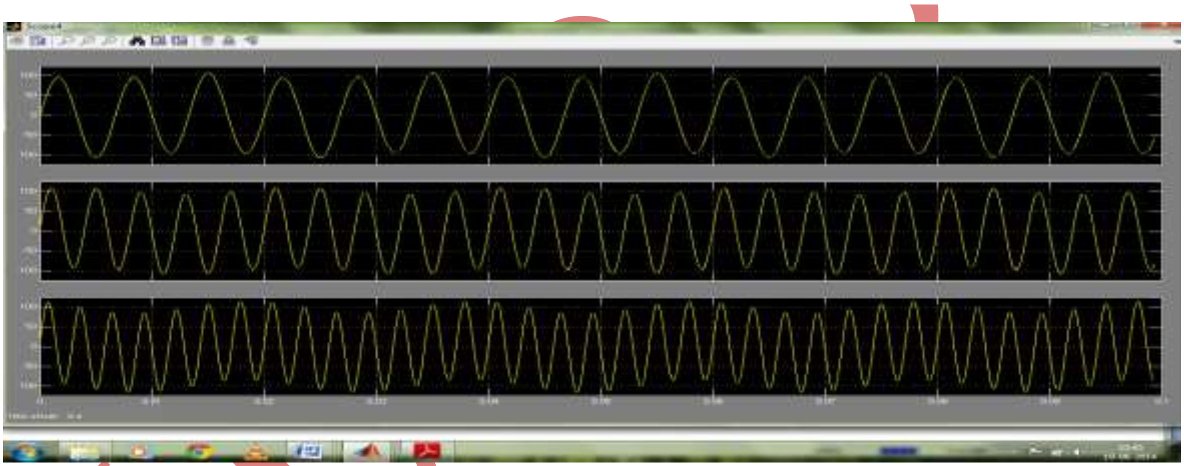

Fig.14 Output Current Without Harmonics Distortion

Comparision

Type of Filter	THD Value
Without Filter	38%
Passive Filter	10.82%
Active Filter	7.83%
Hybrid Active Filter	4.36%

IX. CONCLUSION

This work has illustrated that the single-switch could be used to effective to improve the performance of a passive filter using hybrid APF arrangements that is equally capable of reducing harmonic components in the current supply and achieved unity power factor operation in a three phase system feeding a non-linear load. Expected sinusoidal supply current that in phase and time with the supply voltage can be obtained by injecting equal but opposite current to shape the pulsating supply current into a sinusoidal form and in time and phase with the supply voltage. The system employs only one control loop to generate appropriate active PWM switching signal, thus minimized the control requirement and reduce switching stress and losses.

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