International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 02 | Feb 2020 www.irjet.net p-ISSN: 2395-0072

Analysis and Implementation of Active Power Filters

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ABSTRACT - Active power filters (**APF**) are filters, which can perform the job of harmonic elimination. Harmonic, where passive power filters use combinations of resistors (R), inductors (L) and capacitors (C) and does not require an external power source or active components such as transistors. The filter can compensate for harmonic currents, power factor and load unbalance. Together simulation and experimental results are presented, showing that better dynamic and steady-state response can be achieved with this approach. To generate desired APF output voltage by Pulse Width Modulation based on generated reference voltage.

Key Words: Active Power Filters (APF), Pulse Width Modulation (PWM), Current Source Inverter (CSI), Voltage Source Inverter (VSI).

1. INTRODUCTION

The uses of loads which are not linear in nature and which also vary with time have been continuously increasing in the present time. As a result it causes distortion in current/voltage waveforms and introduces harmonics in it. Ultimately causes poor power factor of power supply. These problems can be eliminated with the help of APF which provides power conditioning. It helps in compensating the reactive power, regulating the voltage and eliminating the harmonics. APF is primarily used for eliminating harmonics on consumer load. The other function is to compensate for voltage imbalance. To distribution system it provides harmonic damping factor.

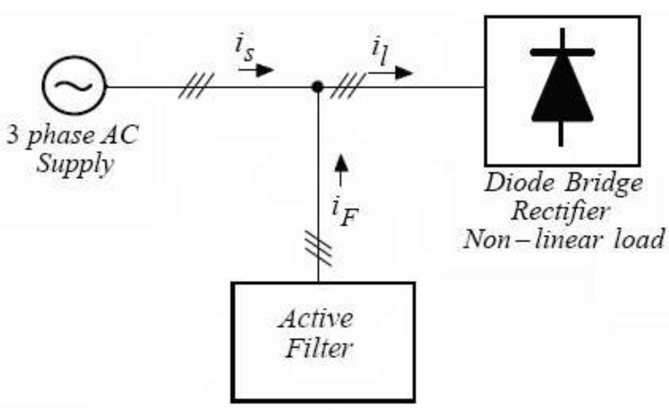


Fig.1. APF

The stability of transmission system along with the quality of power i.e. its PF is enhanced by continuous development of APF(VSI and DC capacitor in the circuit). This device can utilize the PWM to the maintain and adjust the inverter's output(Voltage/current). It can also utilize the method of controlling DC link voltage where it can draw leading/lagging reactive power from supply. APF can be a series/shunt device with the function of providing compensation for harmonics/reactive power. With switching control unit it has inverter (for generating compensating harmonics of interest which are based on the controller's switching gates). To remove the particular harmonics from the line it injects equal and opposite harmonic. APF basic principle of compensation is shown in fig. 1

APF uses a closed loop type of control so as to reduce current harmonics. The line to be compensated for harmonics is injected with compensating current (i_f) by APF. The injection depends upon the changes in the load connected to the system. The line current is,

$$i_s = i_f + i_l$$

i_f = compensating current, i_l =distorted load current The above equation depicts the sinusoidal nature of line current by adding compensating current.

The technique used by APF is mostly PWM. Hence first of all its design has to be decided and later the controller is developed.

2. CLASSIFICATION OF APF BASED ON SYSTEM TOPOLOGY

A. Shunt (fig.2) configurations, Compensate the AC side of rectifier. It can also be used for compensating reactive power. These are now available for commercial use.

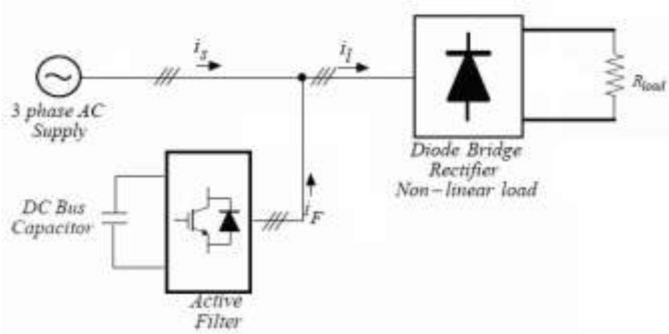


Fig.2. Shunt APF

B. Series (fig.3) configurations, It is used in general for the diode rectifier with a dc link capacitor which is the voltage harmonic source. It can be used in regulating voltage. Its use is limited to the laboratory.

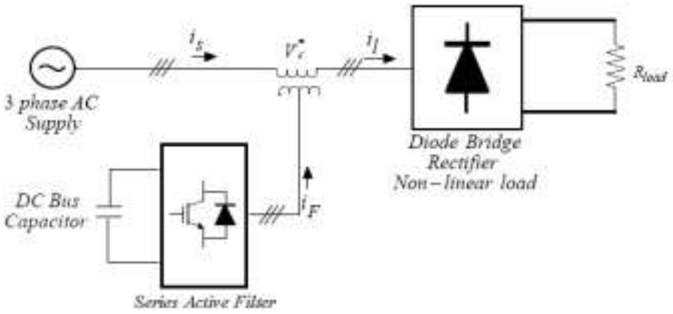


Fig.3. Series APF

C. Hybrid active-passive power filter (HAPF, fig.4). To perform better it is the combination of passive and active filter. The use of LC tuned filter eliminates the additional use of switching-ripple filter because it does the function of filter for harmonics as well as switching-ripple.

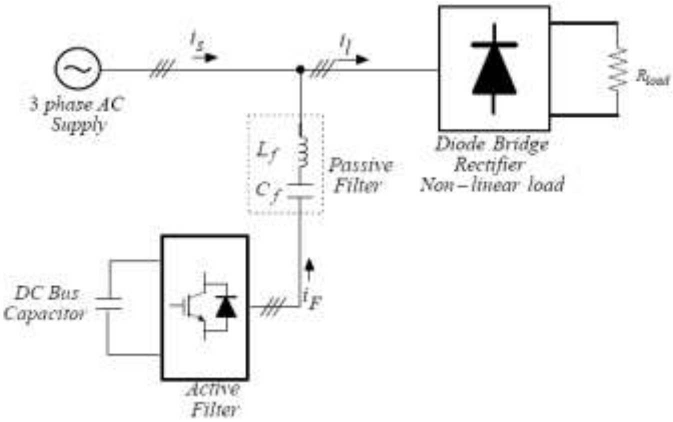


Fig.4. Hybrid active power filter

III. CLASSIFICATION BASED ON CONVERTER

There are basically two types of it based on the mentioned criterion,

A. Voltage source inverter (VSI)

B. Current source inverter (CSI)

A. VOLTAGE SOURCE INVERTER (VSI)

In it the DC side voltage has only one polarity (unipolar) and by reversing the polarity of Direct current power is reversed in it.

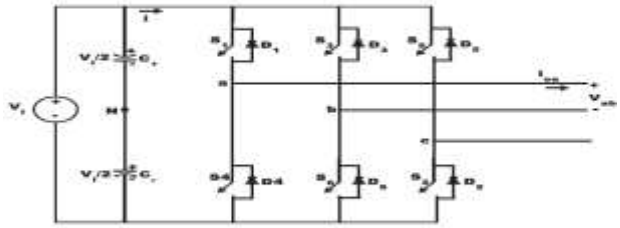


Fig .5 Basic topology of a voltage source inverter

B. CURRENT SOURCE INVERTER (CSI)

The DC current always flow in one direction in it. The power is reversed by reversing the DC side voltage.

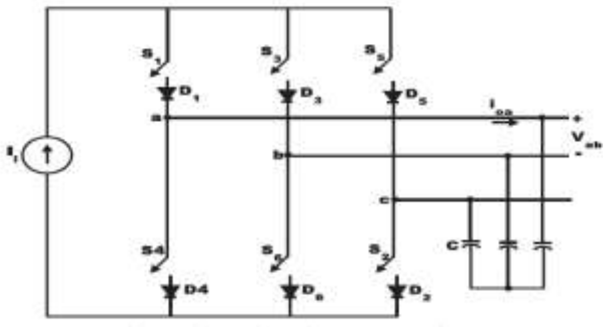


Fig. 6 Basic topology of current source inverter

IV. MODELLING OF PWM TECHNIQUE WITH APF

In the recent times the development in the field of solid state devices has grown rapidly. Hence the use of devices like microprocessors in the industrial application is becoming more common. To be specific these are utilized in the power converters for the purpose of switching which supplies the load or motor. The switching power received by the motor/load is controlled with the use of PWM. Power transistors used in converters are switched by receiving PWM pulses at their gate. The frequency and amplitude of these pulses are fixed. These are in the form of train but with variable width. For every period of PWM there is one pulse which has fixed magnitude. On application of these pulses on gates of power transistor, the power transistors turns on which changes the PWM period based on the same signal for modulation As compared to linear power amplifier its merits are,

Lower power dissipation

1. Easy implementation and controlling
2. Temperature variation is nil and aging-cause
3. Compatible with micro-processors

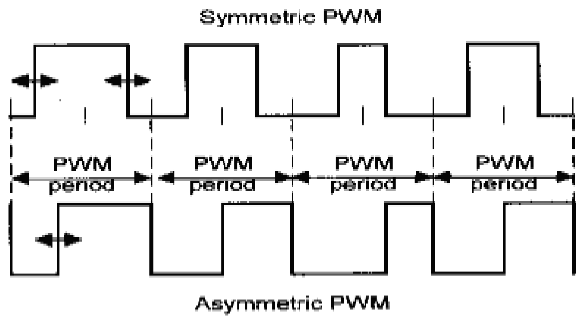


Fig.4.1 Symmetric and asymmetric PWM signals

V. SIMULATION RESULT AND ANALYSIS

The fig 7.1 along with fig. 7.19 displays the APF model with different loads. The simulation models shown uses the 230V as input supply which is the RMS value of voltage and 5kHz as switching frequency before and after balancing of power.

CASE 1: LINEAR LOAD

Case 1.1: Balance RL load with no APF

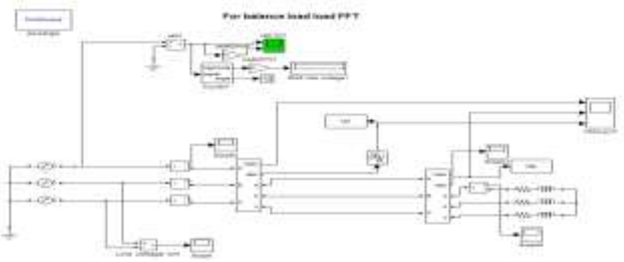
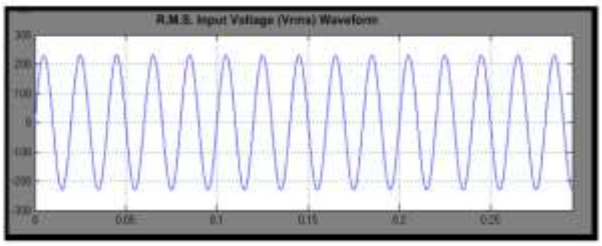
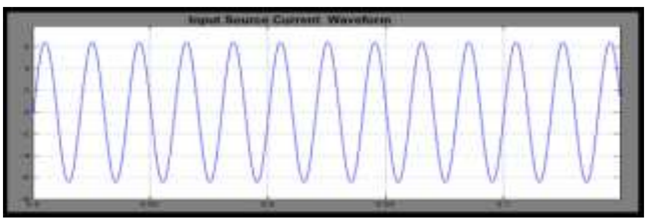


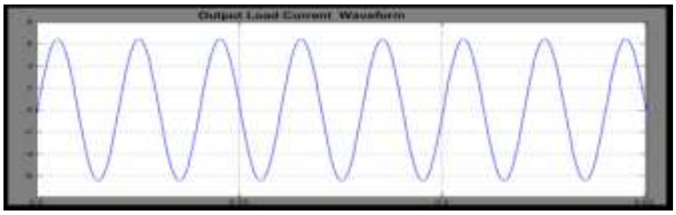
Fig.7.1 3Φ balance RL-load with no APF



(a) Input RMS source voltage waveform



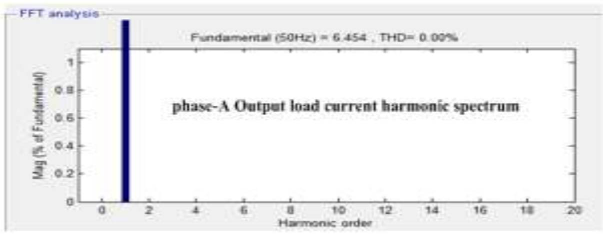
(b)Input source current waveform



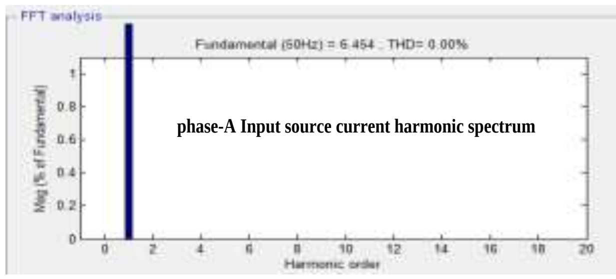
(c) Output load current waveform

Fig. 7.2. Waveform of 3Φ balance RL-load with no APF.

The above waveforms are of Phase A before compensation.



(a) Load current harmonic spectrum



(b) Source current harmonic spectrum

Fig. 7.3 linear balance load's Harmonic spectrum with no APF for Phase-A

The spectrum shown above of harmonics is for Phase A before

Case 1.2: PWM Technique for Linear balance RL load with APF

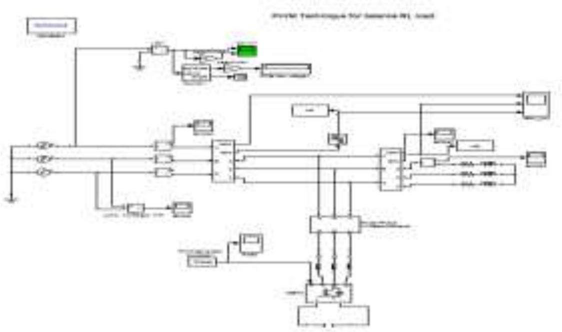
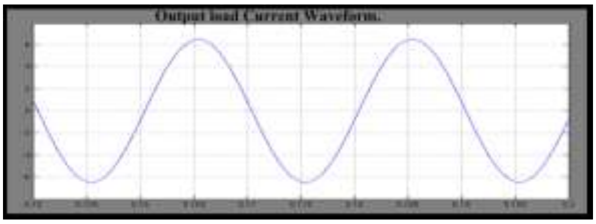
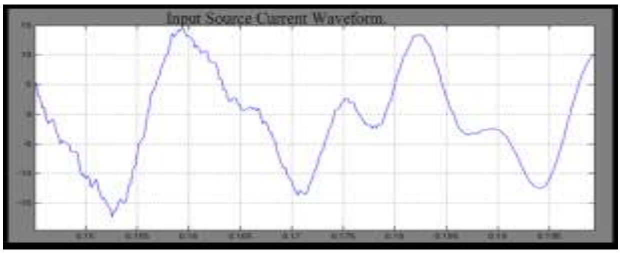


Fig. 7.4 PWM Technique for Linear balance RL load with APF



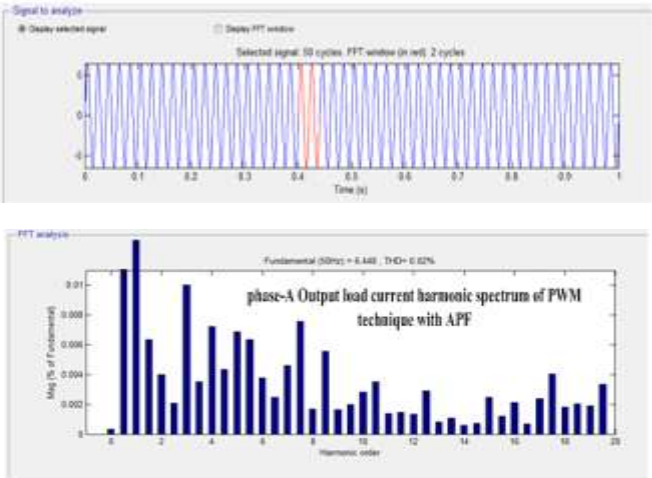
(a) Load current



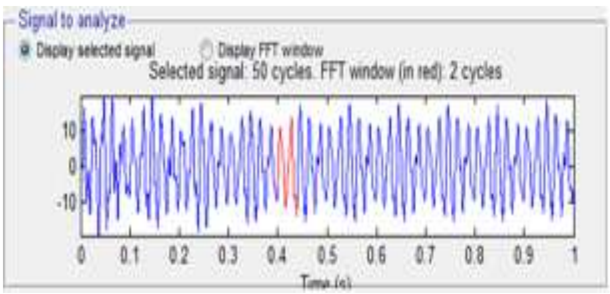
(b) Input source current

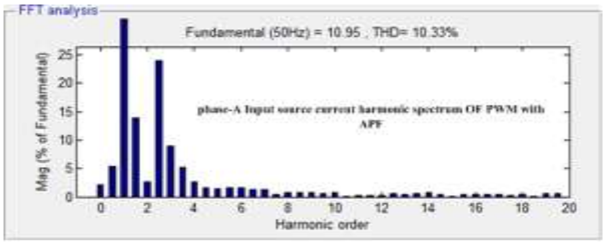
Fig.7.5 waveform of PWM Technique for Linear balance RL load with APF

The waveform shown above for the current is after applying the compensation by APF with PWM.



(a) Output load current





(b) Input source current

Fig.7.6 PWM technique for linear balance RL load with APF's harmonic spectrum

The harmonic spectrum shown above is after applying the compensation by APF with PWM.

Case 1.4: Linear unbalance RL load with no APF

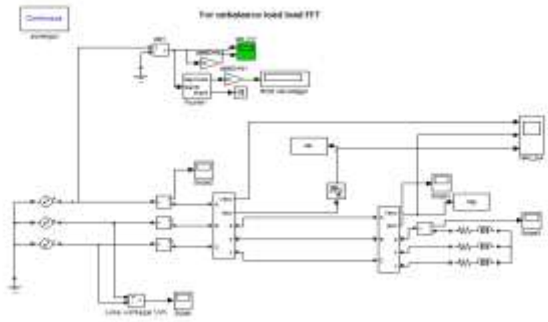
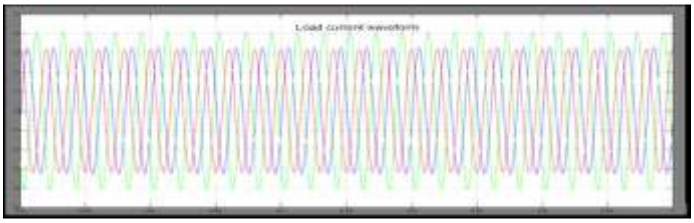
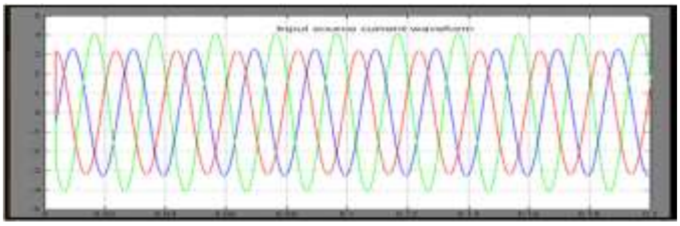


Fig. 7.10 3Φ unbalances RL-load condition without APF



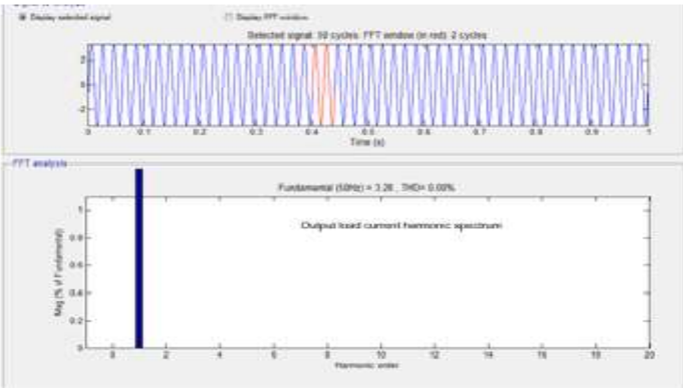
(a) Output load current



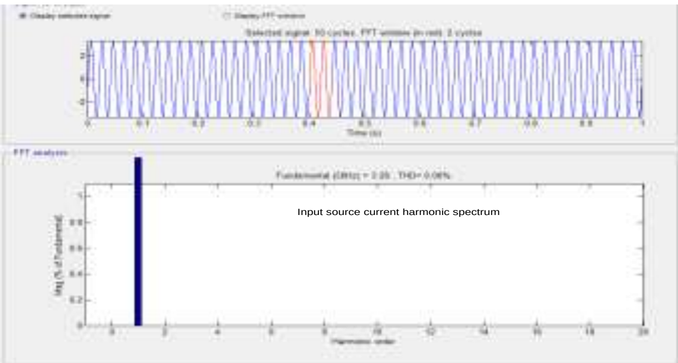
(b) Input source Current

Fig. 7.11 3Φ unbalances RL-load with no APF's waveform

The above waveforms are before compensation.



(a) Output load current



(b) Input source current

Fig.7.12 3Φ unbalances RL-load with no APF's Harmonic spectrum

The above Harmonic spectrums are before compensation

Case 1.5: PWM technique for Linear unbalances RL load with APF

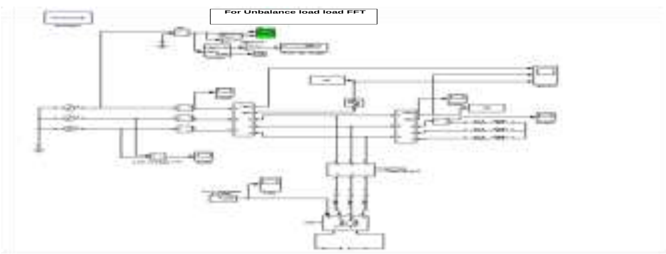
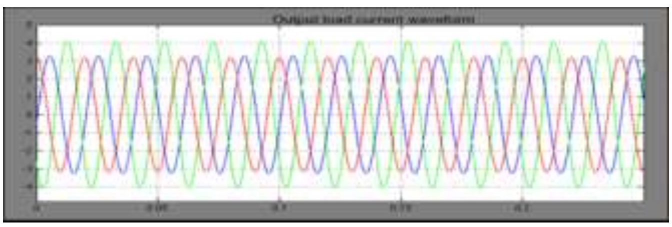
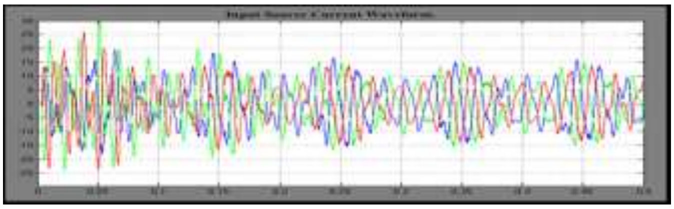


Fig. 7.13 PWM technique for linear unbalance RL load with APF



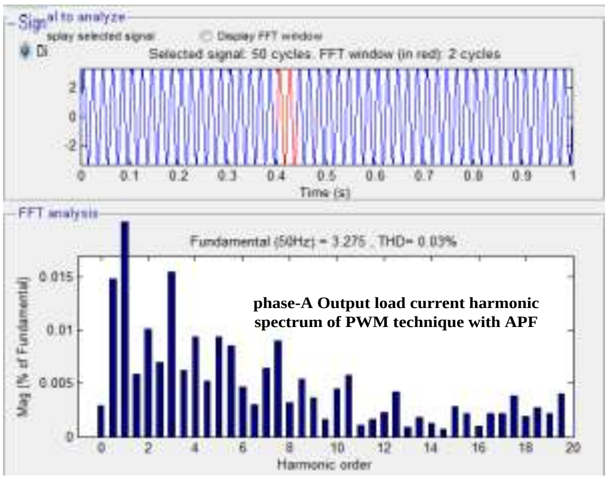
(a) Output load current



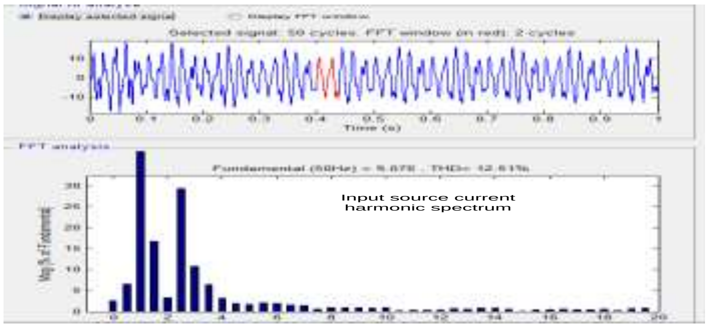
(b) input source load Current

Fig.7.14 PWM technique for Linear unbalance RL load with APF's waveforms

The above waveforms shown are obtained after applying compensation by the APF with PWM



(a) Output load current



(b). Input source current

Fig.7.15 PWM technique for linear unbalance RL load with APF's Harmonic spectrums

The above Harmonic spectrums shown are obtained after applying compensation by the APF with PWM.

Case 2.2: PWM Technique for Nonlinear R load with APF

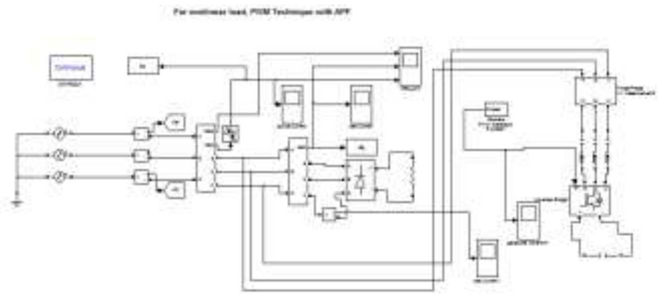
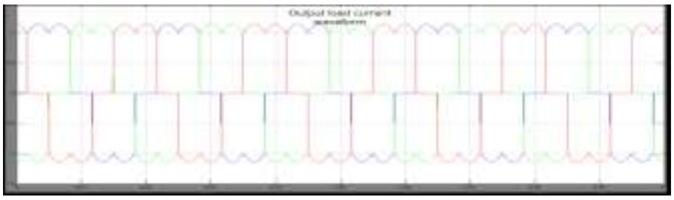
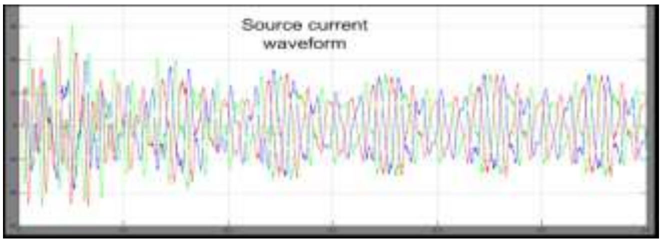


Fig. 7.22 PWM technique for nonlinear R load with APF



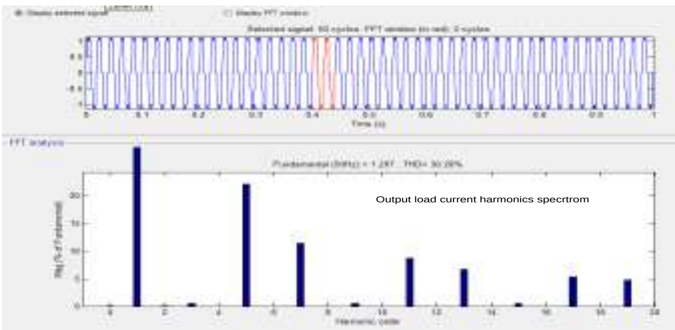
(a) Output load current



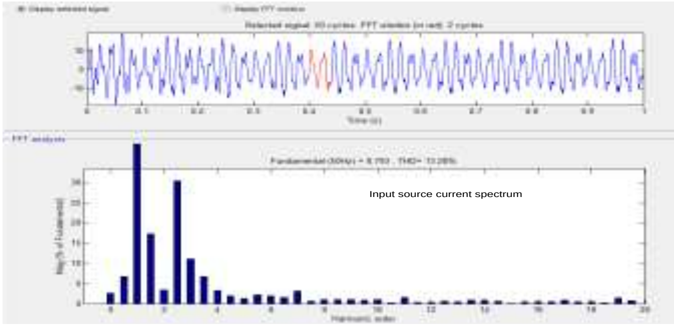
(b) Input source current

Fig.7.23 PWM Technique for Nonlinear R load with APF's waveform

The waveforms shown above have been obtained after applying the compensation by APF with PWM.



(a) Output load current



(b) Input source current

Fig.7.24 PWM technique for nonlinear R load with APF's harmonic spectrum

The harmonic spectrums shown above have been obtained after applying the compensation by APF with PWM.

VI. CONCLUSION

The problem of current harmonics in distribution system can be reduced effectively by the use of APF. On the platform of MATLAB/Simulink a balanced non linear load is provided with 3 phase APF. The power system's power factor is improved by using PWM with the reduction of current harmonics by hybrid APF.

The current ripple reduction is achieved by PWM.

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