Evaluating Power Factor and Thd of Power Supply using Various Correction Circuits and Filters

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Abstract: **Due to the growing use of non-linear load equipment and new technologies in buildings, harmonic currents generated in distribution systems creates a new problem for electrical engineers. In this modern power system the power quality issue is important issue. The problem is due to some non-linear loads showing different current waveforms when supplied by a distorted voltage. in electrical power system through careful planning and design can minimize the risk of power quality problems and related losses in electrical system. Through power factor corrector circuit, filters and some facts devices it can be minimize up to a range. this paper aims to calculate the load, power supply, power factor and THD of an college building .and after calculative analysis use remedial action to improve power quality .develop some circuit for PFC which are based on an optimized power sharing to improve the waveform quality and reduces the switching losses.**

Key words: - Power Quality, Non-Linear Load, Total Harmonic Distortion (THD), Power Factor, Power Factor Correction.

INTRODUCTION

Electrical supply should be a perfect sinusoidal waveform without any kind of distortion. If the current or voltage waveforms are distorted from its ideal form it will be termed as harmonic distortion or voltage distortion. in the past because the designs of power systems were very simple and conservative so voltage distortion or harmonic distortion was very less. But, nowadays with the use of complex designs and more no of non linear loads in the domestic commercial and industries harmonic distortion has increased as well. In present day waveform distortion in voltage current and frequency are associated in power system called power quality problem [1]. In power system network waveform distortion, reactive power burden load balancing and high neutral current are common power quality problems mostly such problems occur due to operation of lagging power factor loads, nonlinear loads and unbalanced loads.[2]

It is then convenient to take some precautions, reducing the levels of generated disturbances and to immunize the sensible equipment, in order to assure the reliability of the electric installations. To accomplish these objectives, it is very important to measure and analyze the harmonics distortion, study its impacts and propose corrective action there are various corrective action will be taken for mitigation of power quality problem some command methods are power factor correction of the system, using filters for reduction of waveform distortion and facts (flexible alternating current transmission system) devices etc. [3] [4] [5]

This paper summaries total power supply, connected load, continue demand, power factor of an college building. After calculation we have involves simulation for power factor correction and THD reduction. It starts with simple Passive power factor corrector circuit and switches to advanced circuits by implementing a advanced techniques such as active PFC, active filters and their subsequent effect on the current and voltage waveforms expecting better results, mainly focusing on the objective of improving the input current waveform i.e. making it sinusoidal by tuning the circuits and power factor correction . All the simulation work is carried out in MATlab – Simulink.

Power System Quantities under Non-sinusoidal (Non-Linear) Conditions

Traditional power system quantities such as rms, power (reactive, active, apparent), power factor, and phase sequences are defined for the fundamental frequency context in a pure sinusoidal condition. In the presence of harmonic distortion the power system no longer operates in a sinusoidal condition, and unfortunately many of the simplifications power engineers use for the fundamental frequency analysis do not apply.[6][7]

Active power

The active power P [KW], which is responsible of the useful work, is associated with the portion of the current which is in phase with the voltage.

Reactive power

The reactive power Q [KVAr], which sustains the electromagnetic field used to make e.g. a motor operate is an energy exchange (per unit of time) between reactive components of the electrical system (capacitors and reactors). It is associated with the portion of the current which is phase shifted by 90° with the voltage.

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Apparent power

The apparent power S [KVA], which gives a geometrical combination of the active and of the reactive powers, can be seen as the total power drawn from the network.

College Buildings Electricity Supply and Load Detail

we have measure details about electricity load ,demand ,power factor and several other electrical quintities in Dr.C.V.Raman University with the help of techometer ,clampmeter and harmonic analyzer. details about load in college university building is shown in table 1. (in summer) and table 2. (phase wise mesurement in winter)

Cont. demand -120.00KVA, supply voltage- 11KV, Purpose : education inst1

Table 1-Total supply power consumptions and demand record in summer

Total supply power in college	315 kva
Loads connected in college building	Unit (kw) loads are varying
Hostel	20-25 kw
Guest house +tanning and placement+ distance education building	15-17kw
Old administration building	15-17kw
Canteen +Information technology building +library	22-24kw
Raman radio(radio station)	20-25kw
Arts +science building	5-8kw
Workshop +block E (management Education +B Ed. Education +low)department	35-40kw
Block A+ Block B (engineering department)	30-35kw
Block c (engineering department)	14-16kw
Block d (engineering department)	10-12kw
New administration block	50-55kw
Metal length	1-2kw
Street lights	3-5kw
Substation	5kw
Total electricity loads in college building	Around 220 kw to 250 kw

Total power consumption record in winter - 5/11 /2014 at 2.25 pm (phase wise measurement)

Phase	Voltage	Load
R phase	259 V	46.8KW
Y phase	260 V	35.02 KW
B phase	270 V	30.852KW

Power Factor

Power Factor can be defined as the cosine of the angle between the current and the voltage. This power factor is also known as the Displacement power factor. The conventional measurement of the power factor is relevant only for loads that are linear and the waveforms are purely sinusoidal. With the increase in non-linear loads such as inverters, constant speed and constant torque drives, CFL etc this definition of the power factor is not adequate. This is because the harmonics have an impact on the power factor. Thus the total harmonic distortion should also be considered while calculating power factor. After calculation that power factor is named as true power factor. The true power factor refers to the measured power factor at the system frequency which is adjusted for the Harmonic distortion. [8][9]

Displacement Power factor = $\frac{kw}{\sqrt{(kw^2+kvar^2}}$ Distortion factor = $\frac{1}{\sqrt{(1+THD^2}}$,

Where THD refers to the total harmonic distortion

True Power Factor = Displacement Power Factor ×Distortion Power Factor.

Thus for loads which have high harmonic content, the true power factor needs to be calculated

Calculative Analysis of Reactive Power Source Requirement for PF Improvement in College Building

Total Power Consumption In College Building = 250kw (around value)

Power factor =$\frac{kw\ (system\ total\ load)}{kva\ (system\ suppyly\ voltage)}$

True Power factor = 0.796 lagging (calculative value)

Displacement Power factor = 0.84 to 0.88 lagging (according to electricity bill from CSPDCL)

Reactive power supply by source ($kvar_1$) =191.6376 KVAr

Required rating of power factor for best result it will be 0.95 to 1 for practical purpose if we want to increase PF .95 lagging than the required rating of KVA supply = $\frac{kw}{pf}$ =$\frac{250}{0.95}$ = 263.157

Reactive power supply by the source for this pf value ($kvar_2$) = $\sqrt{kva^2 - kw^2}$

$$=\sqrt{263.157^2 - 250^2}$$

= 82.20466 KVAr

Since rating of reactive source required for power factor correction purpose

= $kvar_1$ - $kvar_2$
= 191.6376- 82.20466
= 109.4329 kvar

From the above calculation we have conclude that an 109.4329 kvar reactive power source can helpful for the improvement of pf and also reduces the losses in college building. For power factor improvement active power factor corrector circuit ,passive power factor corrector circuit facts devices ,various filters are used. All this devices compensate the reactive power and reduces the losses of the system and also reduces the total harmonic distortion.

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Power Factor Improvement through Passive Power Factor Corrector Circuit (Using Capacitor Bank)

The most practical and economical power factor improvement device is the capacitor. As stated previously, all inductive loads produce inductive reactive power (lagging by a phase angle of 90°). Capacitors on the other hand produce capacitive reactive power, which is the exact opposite of inductive reactive power. In this instance, the current peak occurs before the voltage peak, leading by a phase angle of 90°. By careful selection of capacitance required, it is possible totally cancel out the inductive reactive power when placed in circuit together. [10]

The simulation model fig(1) is a supply system of college building without any reactive power compensation source fig(2) presents the active and reactive power graph and fig (3) is FFT analysis for that simulation model. After simulation we find the result as power factor 0 .79 THD 110.96% .after a calculative analysis we have found that a 109.4392KVAr reactive power source can help to improve power factor compensate reactive power and reduce THD fig(4)shows the simulation diagram with capacitor bank fig (5)shows the active and reactive power and fig (6) is FFT analysis for that simulation diagram after simulation we find the result as power factor .9511 and THD 103.18.

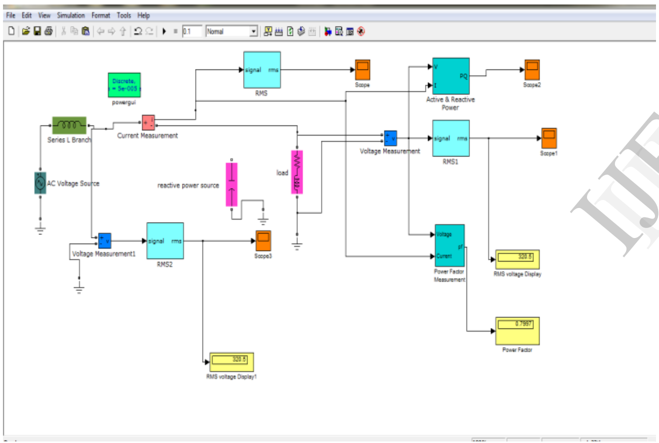

Fig 1 :- PPFC circuit without capacitor bank

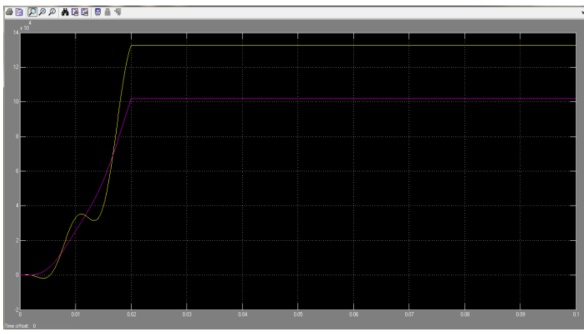

Fig 2:- active and reactive power graph without capacitor

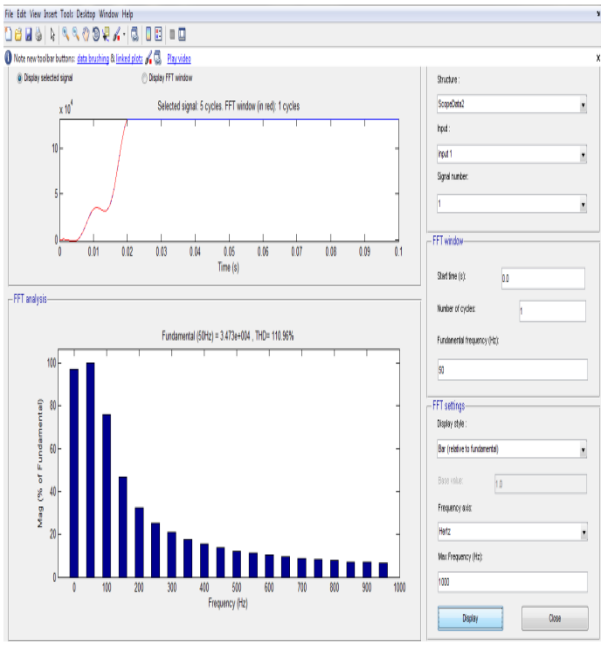

Fig 3 :- FFT analysis for THD(total harmonic distortion) without capacitor

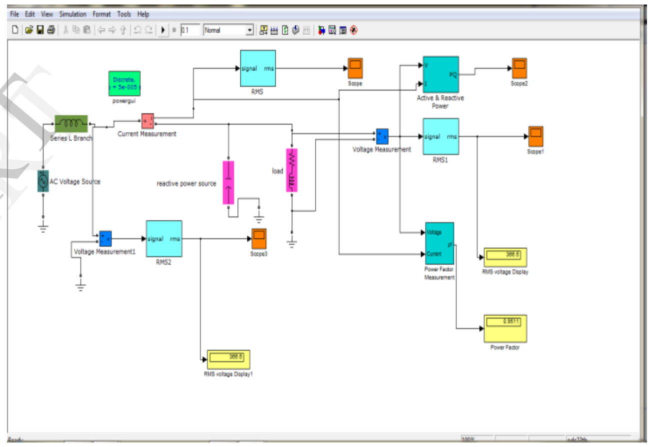

Fig 4:- PPFC circuit with capacitor

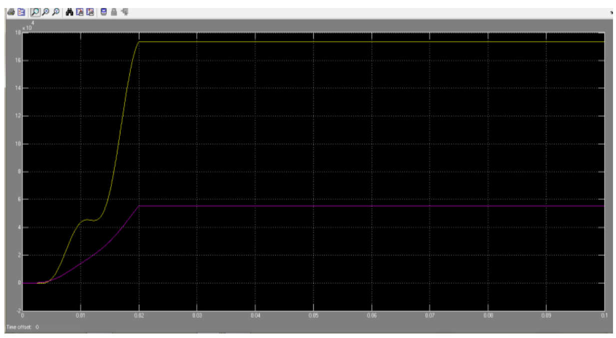

Fig 5:- active and reactive power graph with capacitor

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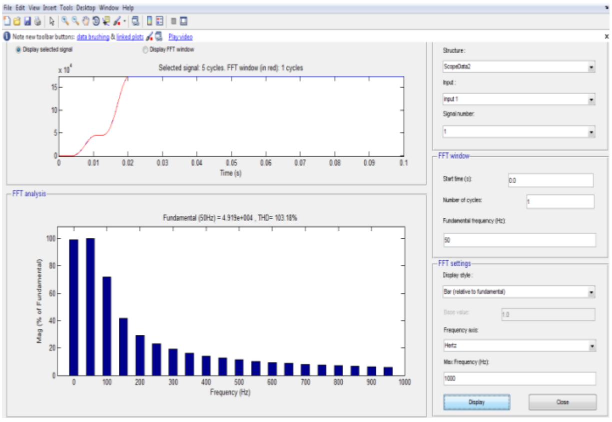

Fig 6 :- FFT analysis for THD(total harmonic distortion) with capacitor

Power factor improvement using active power factor corrector circuit

Passive power factor correction for high power applications requires large inductors and capacitors. Which create it so bulky and costly therefore in place of PPFC, Active power factor correction is used in high power applications. In active power factor corrector circuit the input current is forced to follow the input voltage, so the ratio between voltage and current will be maintained constant and the power factor will be unity, whole circuit emulates as a simple resistor by the power supply.[11]

Control Principle of APFC

An active power factor corrector circuit basically an AC/DC converter, as its core is a standard SMPS (switch mode power supply) structure, which control the current supplied to the consumer through "pulse width modulation"(PWM).the PWM triggers the power switch, which separates the intermediate DC voltage in constant pulse sequences. This pulse sequence will then be smoothened by the intermediate DC capacitor, which generates DC output voltage. [12]

Power Factor Improvement Through An Boost Converter

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor); when being discharged it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages. in boost converter having advantage that the output is always slightly higher than the input and also the advantage of cost ,size and power losses.[13][14]

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A simulation diagram of APFC using boost converter is shown in fig. (7) fig. (8) and fig. (9) shows the reactive and active power graph and FFT analysis for that simulation model. After simulation we have find the result as power factor .9662 and THD 19.69%.

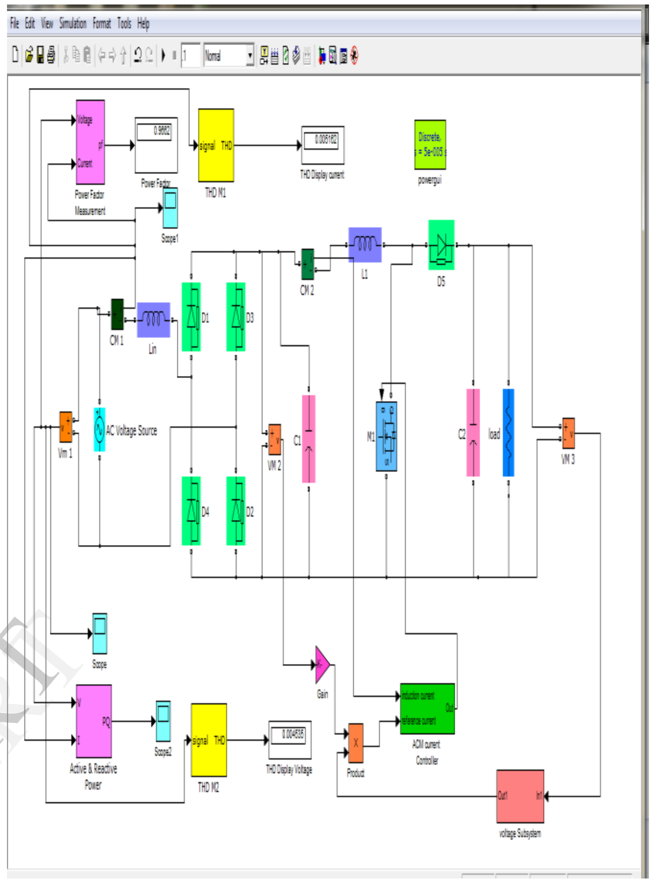

Fig 7 :- Boost Converter

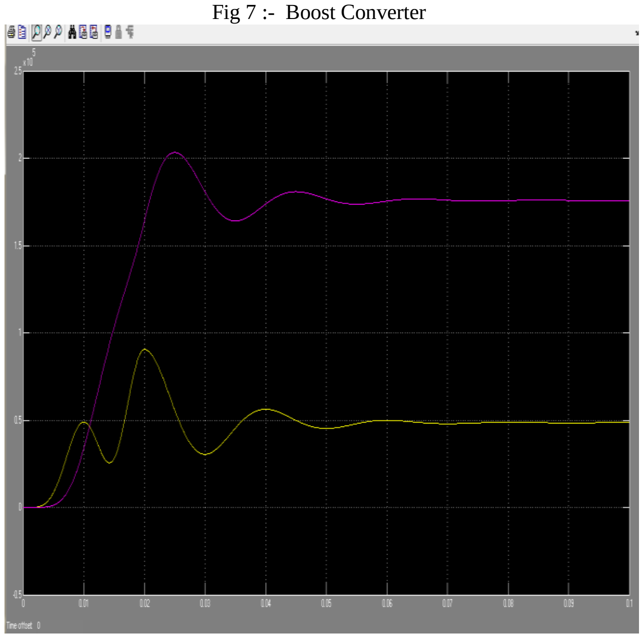

Fig 8 :- Active and reative power with boost converter

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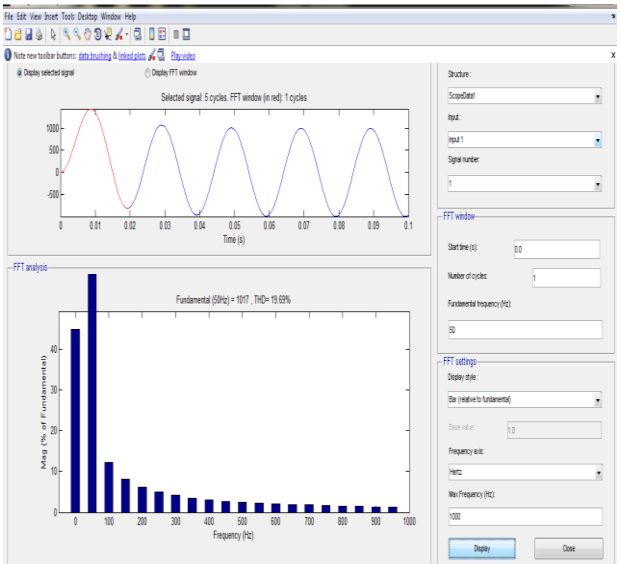

Fig 9:- FFT analysis with boost converter

Power factor improvement through an dual boost converter

conventionally ,boost converters are utilize as a power factor corrector circuit .however a recent approach for power factor correction dual boost converter is to use connected in parallel .where first choke and switch are use as main PFC while second choke and switch are for filtering .the filtering circuit serves two purpose first to improves the quality of the line current and second one is to reduce total switching loss of the PFC .the reduction in switching losses occurs due to different values of switching frequency and current amplitude for the two switches. [15]

Fig (10) shows the simulation model for a dual boost converter circuit .after simulated the model we have find 0.9896 power factor and 15.31% THD. fig (11) and fig (12) shows the active and reactive power graph and FFT analysis for that model.

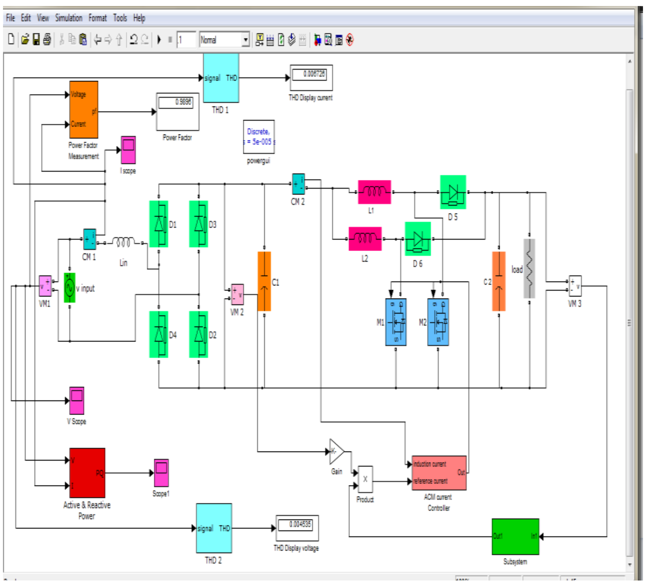

Fig 10 :- dual boost converter

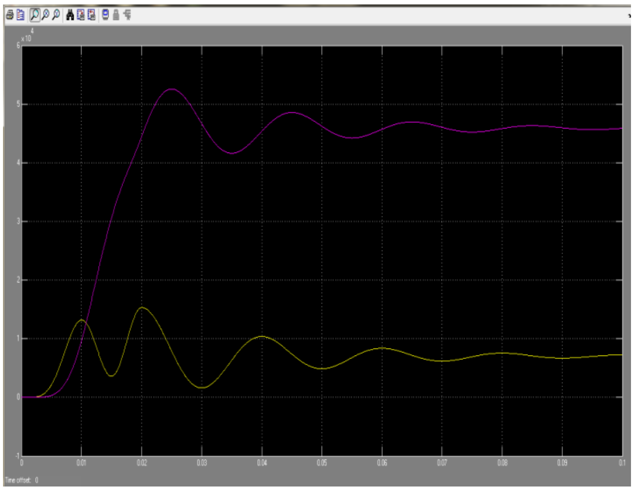

Fig 11:- active and reactive power graph with dual boost converter

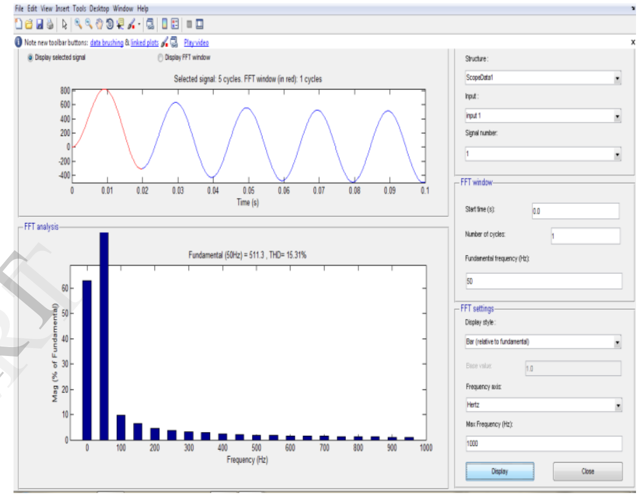

Fig 12 :- FFT analysis for dual boost converter

Three phase Active harmonic filter :- Shunt active power filter compensate 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 180o. This principle is applicable to any type of load considered a harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the Load power factor. [16]

Three-phase active harmonic filter simulation model is presented in fig (13) ,filter eliminates the current distorted waveform and after compensated fig of current is find quit sinusoidal then the privious stage which are shown in fig

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14) and fig (15).

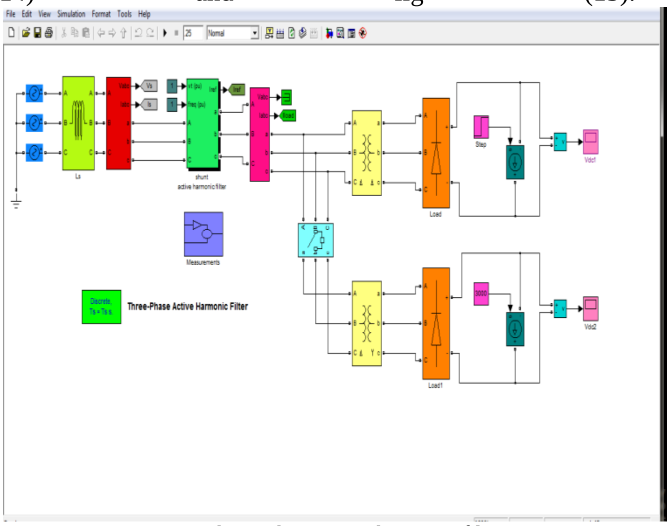

Fig 13 :- three- phase active harmonic filter

Fig 14 :- waveforms for current harmonic compensation

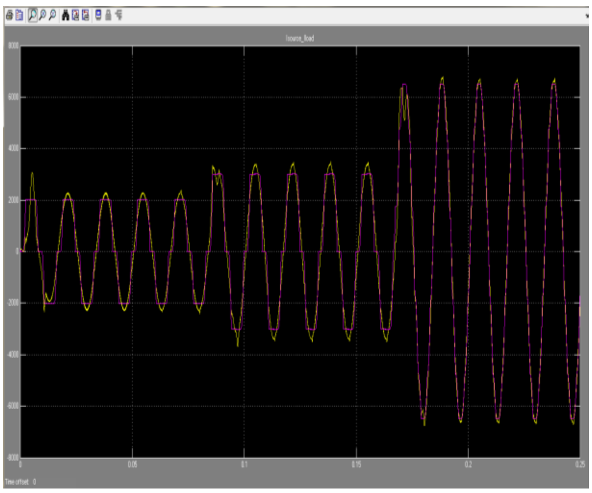

Fig 15:- I_{ref} and I_{source} waveforms

CONCLUSION

In this paper we will discussed about power factor correction and THD reduction using various remedial action . for power factor correction and THD reduction capacitor bank ,boost converter ,dual boost converter and active harmonic filter are simulated with MATLAB simulink. it is noticed that the power factor is better in dual boost converter and also THD is less in dual boost converter. For the current harmonic reduction active harmonic filter is very effective method .this all technique can be further improved by using PI and FUZZY controllers.

Circuit	Power factor	THD
Capacitor bank	0.9511	103.18%
Boost converter	0.9662	19.69%
Dual boost converter	0.9896	15.31%

Table :-analysis of PF and THD

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