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Project Title: DESIGN AND SIMULATION OF HIGH POWER FACTOR RECTIFIER BASED ON LUO CONVERTER TOPOLOGY

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ABSTRACT

This paper presents a new control scheme that deals with an active input power factor correction with single phase bridge rectifier fed LUO Converter Topology using Hysteresis current control Technique to compensate the harmonic current generated by the Diode Rectifier so as to achieve a power factor nearer to unity and to regulate the DC bus voltage. The comparison of an inductor current and ramp carrier waveform gives the Duty cycle which is associated with Hysteresis Controller in each switching period. The Hysteresis current controller is used to track the line current command. Benefits of this proposed Converter are high power density, Simple control strategy, less harmonic control content, nearly unity power factor and unidirectional power flow. As a result, the input current waveform is sinusoidal and in-phase with supply voltage having high power factor.

Keywords - Hysteresis current control, Voltage Gain, Power factor.

INTRODUCTION

Principally, Harmonic pollution and low Power Factor (PF) in power systems are usually caused by inductive loads such as transformers, electric motors and high intensity discharge lighting and this low Power Factor has been corrected by implementing different types of available schemes. However, currently the trend is shifting to electronic equipments are more and more being used in everyday life. A fixed ac into variable dc converter is a innermost part of any power supply unit used in the all electronic equipments. In this converter, input current on a.c side is wealthy in low order harmonics due to filter capacitor, inductor and switching device. Due to the occurrence of these harmonics, the Total Harmonic Distortion (THD) is high. Hence the input power factor is poor. Harmonic voltages and currents in an electric power system are a outcome of non-linear electric loads. The harmonics is measured by the factor THD. Due to the presence of harmonics the current increases which will decrease the input Power Factor. In order to improve the input Power Factor in case of the non-linear load, the Power Factor Correction circuit is necessary. The harmonic and power factor characteristics of switched-mode power supply have attracted more attentions in the power electronics community in the last decade or so.

LITERATURE SURVEY

EXISTING SYSTEM

There are various researches on the topology and control method of the active PFC applications. Among them, the PFC of LUO converter has the combined advantages of the switched capacitor, voltage lift technique and the impedance network[5]. The LUO converter is a series d DC-DC coverters which are used to reduce the effects parastic eleements and also reduces the vltage and current ripple[10]. In Pulse Width Modulation (PWM) dc–dc converters with current- mode control, the relationship between duty cycle and inductor current is an essential characteristic in closed-current loop behavior [6]. In recent years, the power factor correction (PFC) technique has gained wide attention in low-power offline power supply development due to the requirements imposed by the European standard IEC 1000-3-2. The boost front-end is used to achieve a close-to-unity power factor and low total harmonic distortion (THD) [7]. The PFC of LUO converter has been dsigned to act as an inherent power factor pre-regulator in various applications such as DICM, speed control of BLDC motor and battery charging[4]. The values of inductor and capacitor are designed using equations in [2] and [3]. Even though all the earlier works made a great contribution to improve the power factor of AC to DC converters, the proposed system developed in this paper will be effective for improving the power factor and insist on harmonic standards and guiding principle which will limit the current twist permitted into the utility i.e. a.c side.

PROPOSED SYSTEM

The proposed converter consists of a single phase supply, Diode bridge Rectifier, LUO converter connected to the load. The open loop is performed to active unity power factor, reduced Harmonics, increased efficiency. The closed loop circuit employs Hysteresis current control and active power factor correction method. In open loop control strategy, the variation in output DC voltage is common problem if the load is variable, but we can obtain constant output if closed loop is used. In closed loop control, output current signal is compared with reference current signal which decreases the error in the output and gives the desired output. Advantage of using Hysteresis technique involves excellent dynamic performance, ability to control peak-to-peak value of ripple current in simple implementation.

The proposed PFC technique consists of one full-bridge diode rectifier and one LUO PFC Converter. Here the full bridge diode rectifier is considered as the non-linear load which is the source of harmonics. A hysteresis current control is adopted to track the required line current command. In this arrangement PFC LUO converter can be used to eliminate the harmonic current generated by the diode rectifier. The PFC LUO converter supplies the required harmonic current produced by the non-linear load, hence the total arrangement draws a nearly sinusoidal current with improved power factor.

TOOLS

SOFTWARE TOOL

Initially, simulations were completed to learn about how the converters worked and what the effects were of changing the component values on the output signal. When it comes to literature survey, there are many types of modeling followed by simulation literatures which are there for LUO converter such as PSim, MATLAB, PSpice, PSCAD and so on are available in the market for power converter modeling and simulation.. In comparison of all models, MATLAB software has a total control over the model and there is reduced limitation about the model. In this paper MATLAB/Simulink is used to perform modeling and simulation. The boost converter is made with two energy storage elements, one n-channel MOSFET, one diode and diode rectifier as a harmonic generator. The mathematical modeling begins with the diode rectifier in the LUO converter followed by energy storage elements, Switching devices and Active power factor correction circuit.

DESIGN AND ANALYSIS OF UNCONTROLLED-RECTIFIER WITH CAPACITIVE FILTER

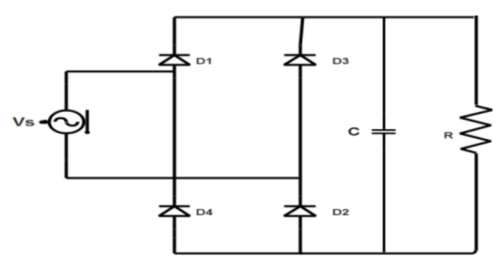


Fig 1. A Single-phase full wave diode bridge rectifier with capacitive filter

The process of conversion of AC input voltage into DC output voltage is called rectification. Since the output voltage of the diode based rectifier is uncontrolled, the diode based rectifier is also referred as uncontrolled rectifier. The circuit of uncontrolled rectifier is shown in the fig. The capacitor C is connected across the load to smoothen the DC output voltage. The capacitor filter connected across the load is to bypass the ripple through the capacitor and is grounded which means the output is a pure DC signal. The ripple in the input current waveform is because of the reactance in the capacitance. This capacitance reactance is inversely proportional to the frequency, So when frequency changes it will affect the reactance. The capacitor connected across the load charges up when the voltage from the rectifier rises above that of the capacitor and then as the rectifier falls, the capacitor provides the required current from its storage energy.

Design of capacitor filter

Ripple current is given by,

$$RF = \frac{average\ output\ voltage}{ripple\ voltage}$$

$$C = \left(\frac{1}{4fR}\right)\left[1 + \left(\frac{1}{2RF}\right)\right]$$

Table 1: Design values

Ripple Factor(RF)	5%
Load resistance	100 ohm
Supply frequency	50Hz
Supply voltage	230V

By substituting the above values in the C we get the filter capacitance as,

C=757µF.

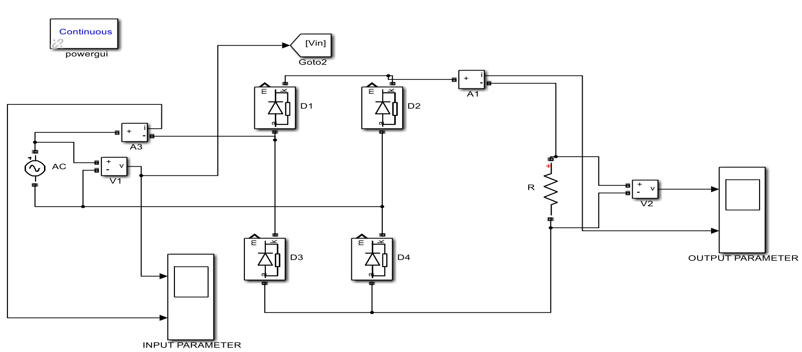


Fig.2. Simulation of Full bridge diode rectifier

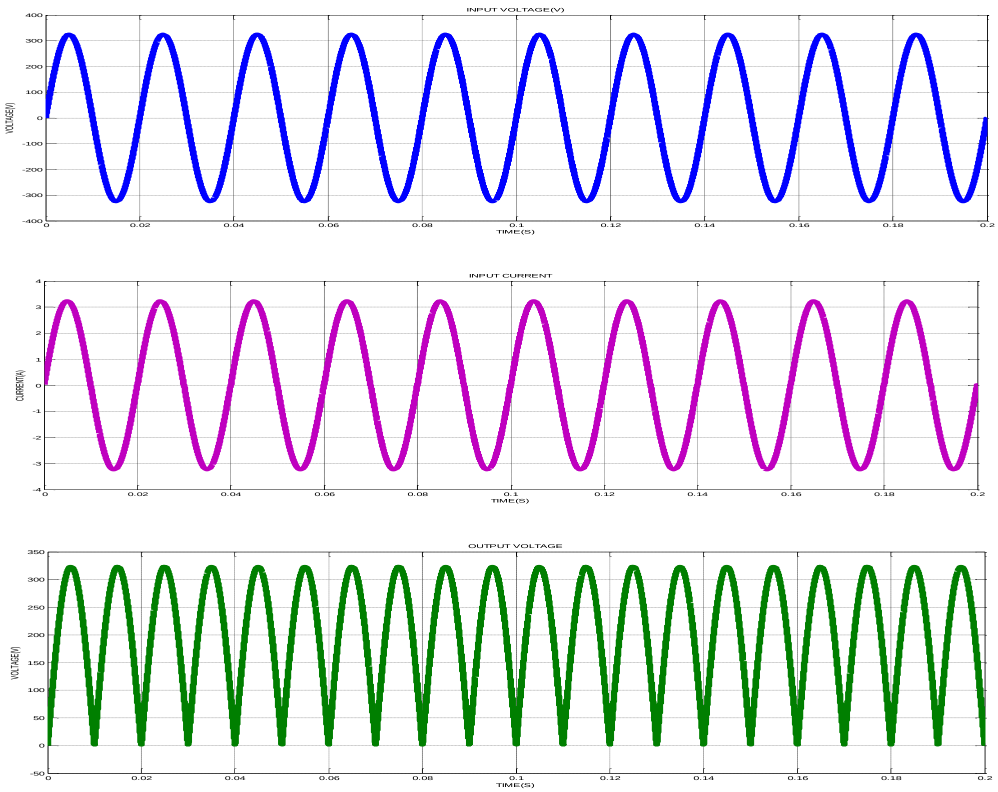
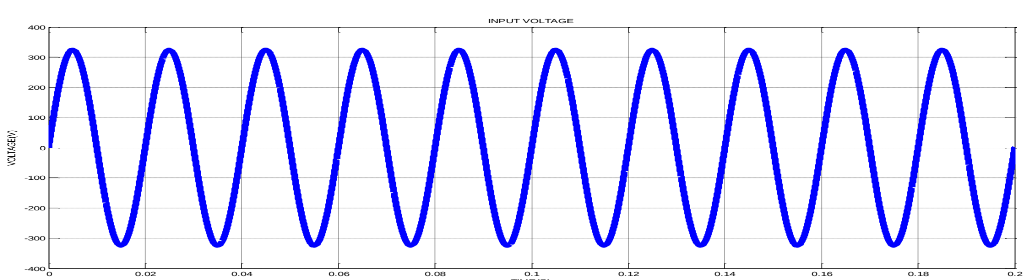


Fig.3. Simulation results of Full bridge diode rectifier without capacitor filter

The simulation of uncontrolled rectifier and its results are shown above.Without filter capacitor the input current is not distorted as shown.The output voltage is a rectified DC voltage.It is not a pure DC.Inorder to get the pure DC waveform the filter capacitor is required across the load.



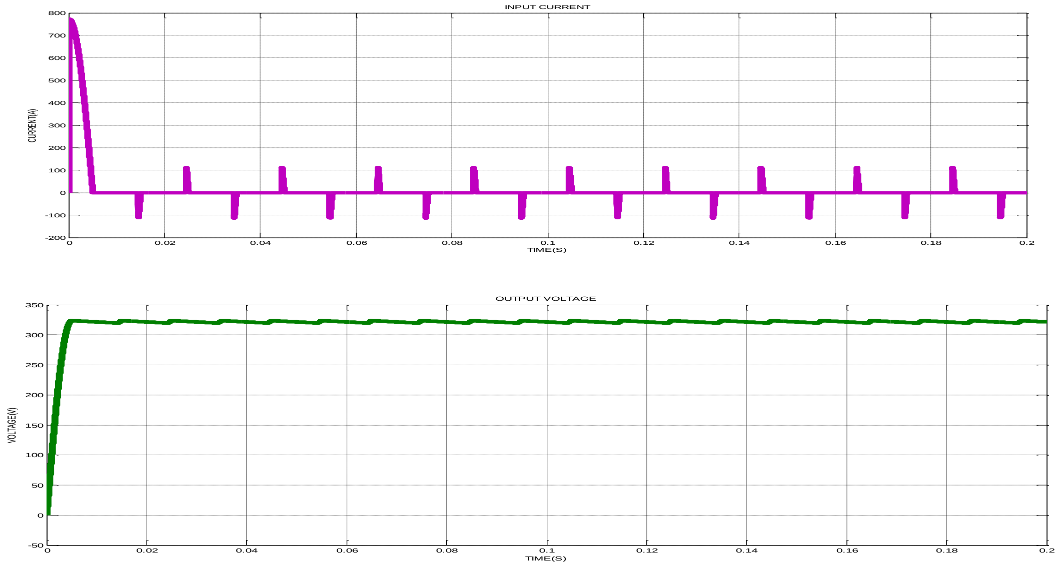


Fig.4. Simulation results of full bridge Diode rectifier with Capacitor

With filter capacitor the input current is distorted as shown. The input voltage remains the same. The output voltage is a DC voltage. When the capacitor has low value, it has little effect on DC output waveform. But if the smoothening capacitor is large enough and the load current isn't too large, the output voltage will be almost as smooth as pure DC. The FFT analysis is shown in the figure.

Table2: Power factor with various R load

S. No	R load values (ohm)	Power factor
1	75	0.8766
2	80	0.8798
3	100	0.8693
4	115	0.8667
5	125	0.8782

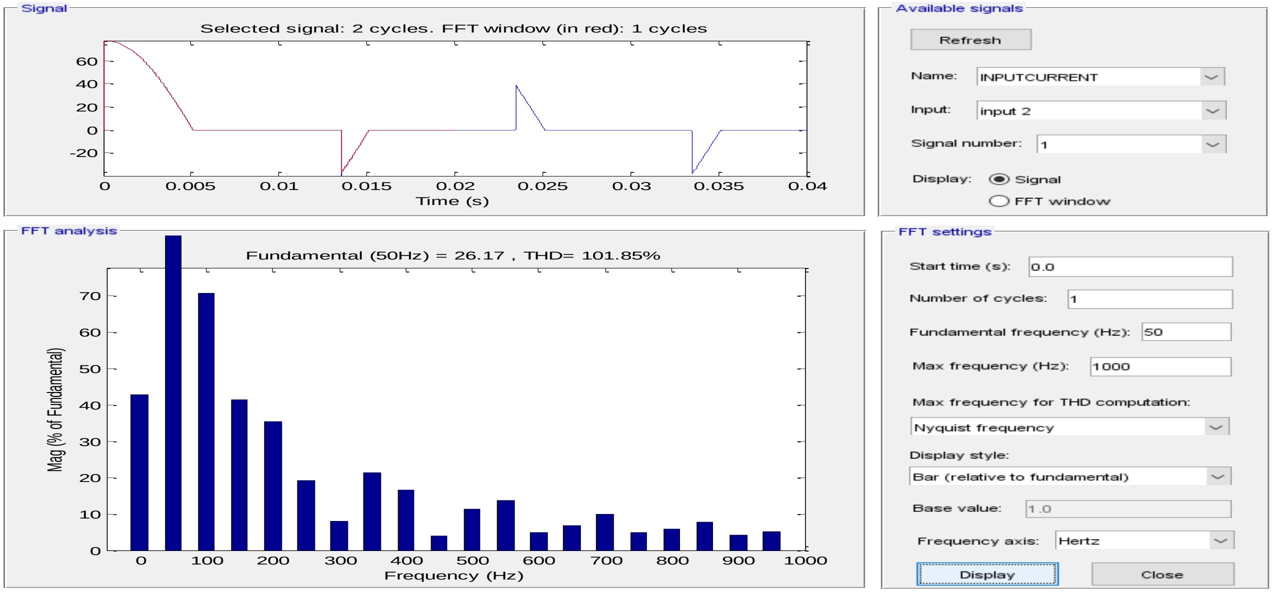


Fig.5. FFT and THD analysis of diode rectifier with filter capacitor

From the simulation results, by using the smoothening capacitor across the load the input current gets distorted and reduced the power factor. Thus harmonics and power quality issues will arise.

METHODOLOGY

The proposed converter consists of a single phase supply, Diode bridge Rectifier, LUO converter connected to the load, Active power factor correction circuit and hysteresis controller in order to improve the Power Quality on input side.

5.1. DESIGN AND ANALYSIS OF LUO CONVERTER

DC-DC conversion has been developing rapidly and widely employed in many industrial applications like DC motor drives, computer systems, medical equipments. The LUO converter is a newly developed DC-DC converter. The LUO converter can increase the voltage stage by stage along a geometric progression compared with conventional DC-DC converters the voltage lift technique is widely employed method in electronic circuits. The technique which makes the DC-DC converter within a simple controlled loop is termed voltage lift technique. After a long term research this method has been successfully applied for DC-DC converters. This technique effectively overcomes the effect of parasitic elements and produces high output voltages. Due to time variations and switching nature of the power converters, the static and dynamic behavior varies. Also the voltage lift technique opens a good way to improve circuit characteristics.

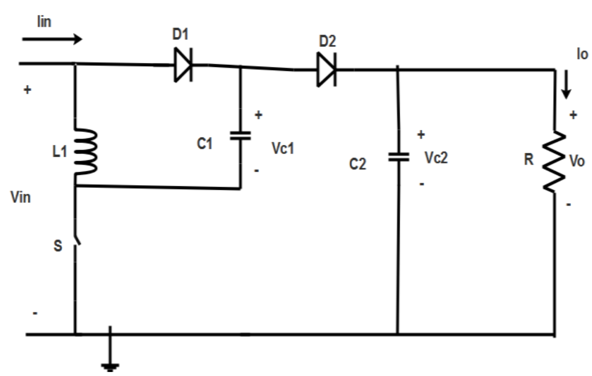


Fig.6.Circuit diagram of Super-lift LUO Converter

Four series LUO converter are the examples of the voltage lift techniques. However the output voltage increases in stage by stage along the geometric progression. This paper presents the novel approach of voltage lift technique which increases the voltage along the geometric progression. There are two subseries namely, main series and sub series. Each circuit of the main series has one switch S, n inductor, 2n capacitors, (3n-1) diodes. Similarly the additional series has one switch, n inductors, (2n+1) capacitors, (3n+1) diodes. The conducting duty ratio is K, switching frequency F and the load is resistive load R.

Case1: When switch is ON,

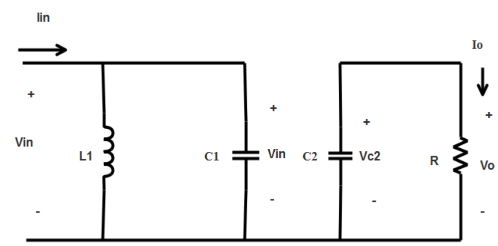


Fig.7. Equivalent circuit of Super-lift LUO Converter during switching-on

The voltage across the capacitor charges to Vin during the switching ON period KT and the current iL1 flowing through the inductor L1 increases with the voltage Vin .

Case2: When switch is OFF,

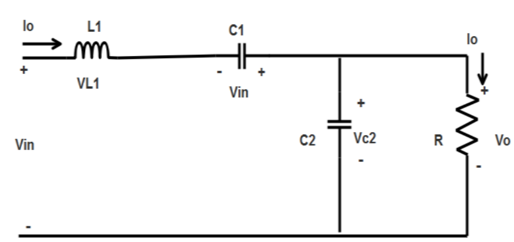


Fig.8. Equivalent circuit of Super-lift LUO Converter during switching-off

The current across the capacitor decreases with the voltage of (Vo-2Vin) during the switching OFF period (1-K)t.

Hence the ripple of inductor current iL1 is,

$$\Delta IL = \frac{VinKT}{L1}$$

$$\Delta IL = \frac{Vo-2Vin(1-K)T}{L1}$$

The voltage transfer gain is,

$$Vo = \frac{(2-K)Vin}{(1-K)}$$

Thus the input current is equal to (iL1+ iC1) during switching ON and only equal to iL1 during switching OFF. capacitor current iC1 is equal to the iL1 during switching OFF.In steady state the average charge across the capacitor C1 should not change. The values of the inductor and the capacitor are designed using the below equations respectively.

Design of inductor

$$L = \frac{VsK}{f\Delta IL}$$

$$= \frac{230*0.5}{50000*2.07}$$

L =1.1*10^-3

Design of capacitor

$$C = \frac{(1-k)Vo}{fRo\Delta Vo}$$

$$= \frac{(1-0.5)*20}{50000*100}$$

*C = 2*10^-6F*

CURRENT SHAPING TECHNIQUE ON AC SOURCE INPUT CURRENT SIDE

In general, the current waveform is load dependant and it can be forced by either active or passive methods. Both active and passive methods can be effectively used for harmonic mitigation. The different solution has been recently introduced as a result of advances in power semiconductor devices to make possible for the switch nearly ideal performance and reliability. The basic principle of an active power filter (APF) is to utilize power electronic technologies to produce specified current components that cancels harmonic current component caused by harmonics. Active power filter can perform one or more function required to compensate power systems and to improve power quality. The performance depends upon power Rating and speed of the response. In comparison to passive filters, active power filters offers very fast control response and more flexibility in defining the required control task for economical are the major advantages of using active power filters for harmonic mitigation. The selection of active power filters depends upon the source of the problem.

Active device provides a variety of ways to shape the input current. Each of the basic ideas has several variations leading to a large number of topologies and control schemes. The basic difference between boost and buck topologies is the form of energy storage. The boost topologies store energy in a source of constant voltage, such as a large capacitor. Also the boost topologies have output voltages greater than the peak of line voltages and the switching transistors monitor the voltage. Buck converters provides voltage lower than the line. The hysteresis technique is most widely employed for active input current wave shaping due to its simple implementation. This strength of this method lies in the fact that it provides the instantaneous current regulation using a simple control circuit.

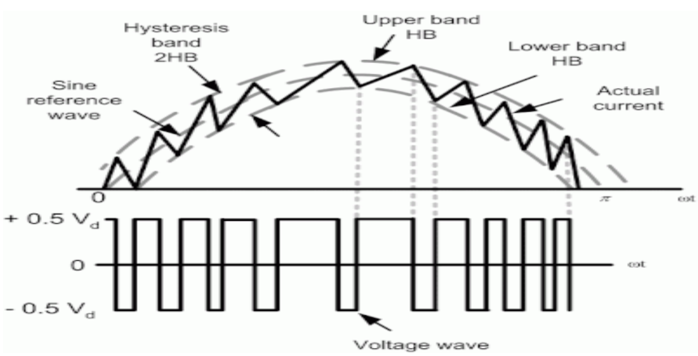


Fig 9: A Single-phase front-end diode –rectifier input-current wave shaping circuit controlled by hysteresis technique.

ACTIVE POWER FACTOR CORRECTION TECHNIQUE

The simulation is done in a step by step manner.The active power factor correction is used to shape the input current in phase with the input voltage.This will improve the power factor at the input side nearly to unity.The aim is to control the rectifier input current, by controlling the gate pulse applied.

Let us assume the current reference Iref. The inductor current Ifb is sensed and it is compared with Iref to produce error signal. Iref should be sinusoidal and Ifb is also sinusoidal irrespective of load i.e it should keep in reference with the wave shape of voltage. Whatever be the reference the Ifb should follow the reference such that the error is zero. The error signal is fed into the PWM through PI Controller which is fed to the driver circuit and that provides the switching signal to the MOSFET. The PI Controller will adjust the PWM such that the error becomes zero i.e Ifb is same as Iref.

$$Irms = \frac{Po}{(Vm/\sqrt{2})} = \frac{\sqrt{2}Po}{Vm}$$

$$Iref = Im\ sinwt = (\frac{2Po}{Vm})(\frac{Vin}{Vm})$$

The actual inductor current appear with the switching ripple which in keeping the waveform of Iref. The outer voltage loop involves the comparrison of V0ref with the actual V0 and fed into PI controller whose output is then multiplied with Iref. The outer voltage loop should be slow whereas the inner current loop should be fast to get an effective unity power factor(UPF) action. The MATLAB simulation of LUO converter with Active power factor correction circuit is shown in figure 10.

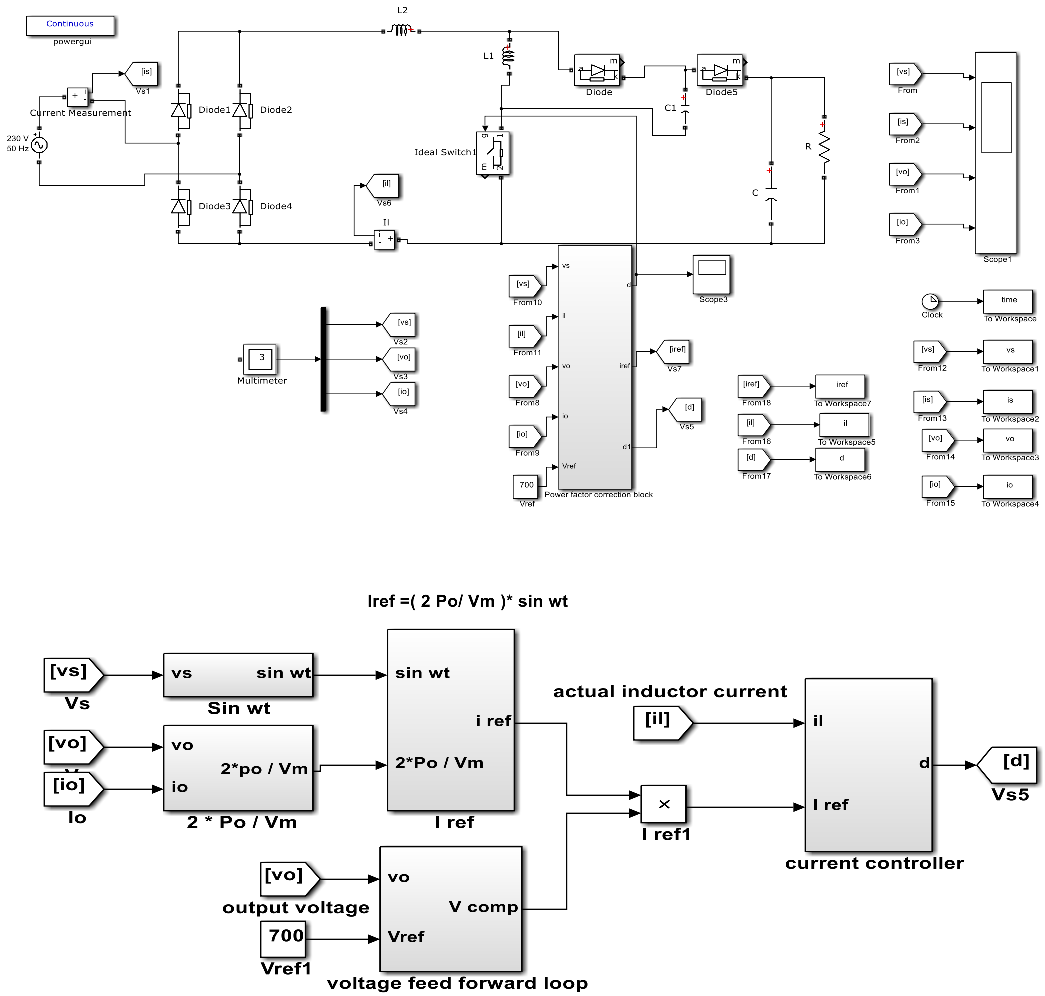


Fig.10. Diode rectifier with active power factor correction circuit

RESULTS OF PROPOSED SYSTEM

The simulation results of uncontrolled rectifier with active power factor correction circuit is shown in the figure 11. The LUO topology is used in this simulation.

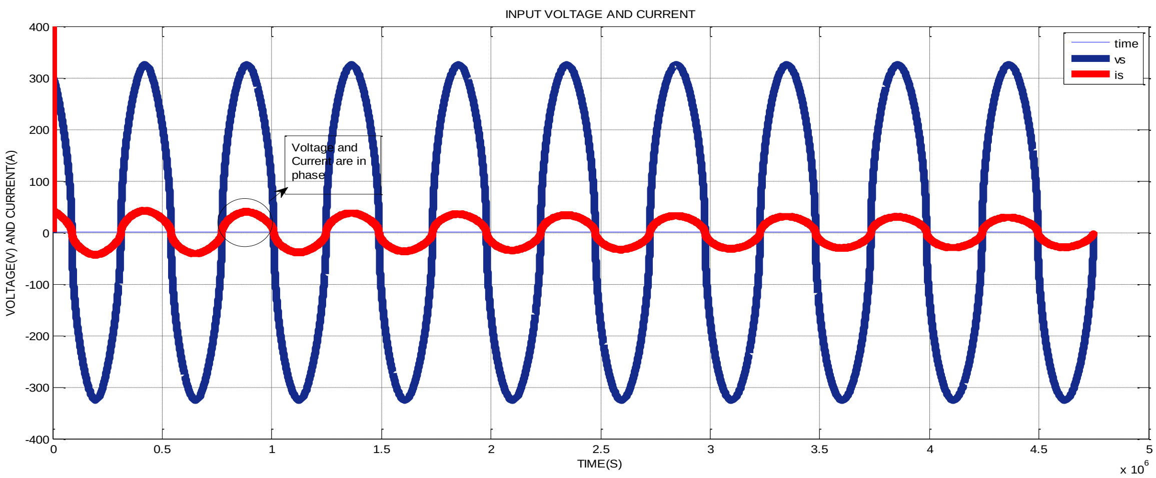
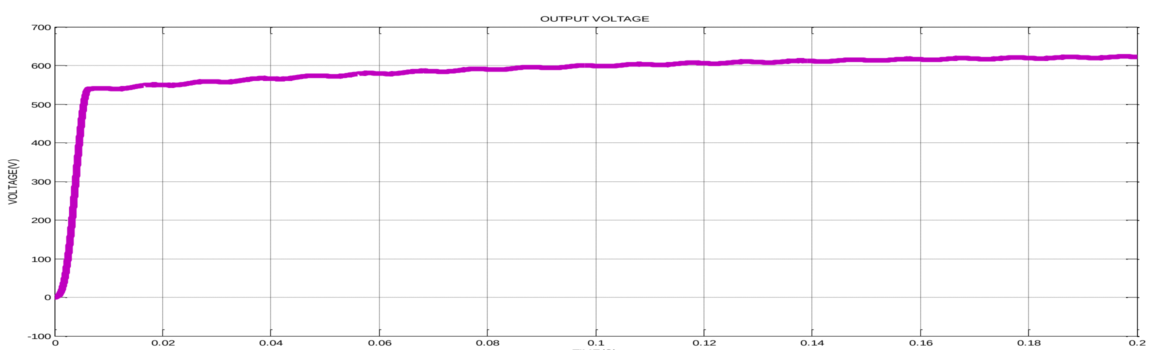


Fig.11. Simulation results of Input voltage and input current in which the current is in phase with voltage



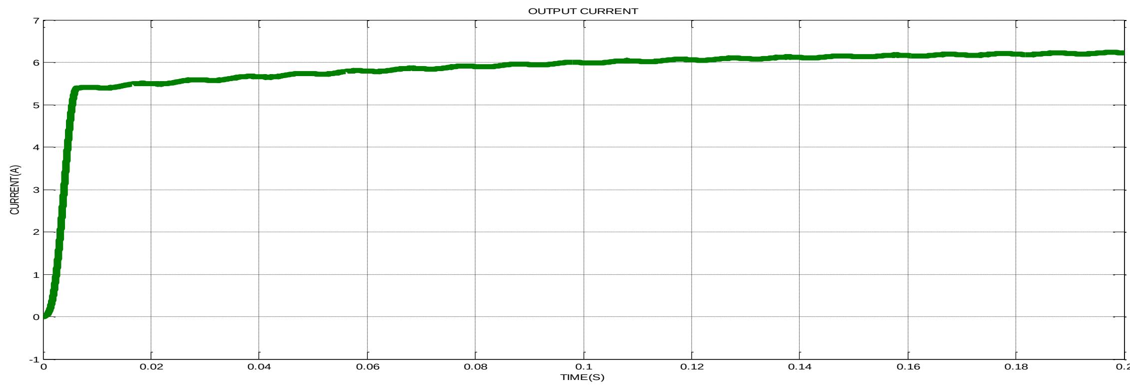


Fig.12. Simulation results of output voltage and output current

The simulation for the converter mentioned earlier in the design procedure produced good results. From the simulation results it is clear that by using the active power factor correction circuit the input current is shaped to be sinusoidal and the current is in-phase with the input voltage. This again illustrated that the losses in the converter were reduced as the circuit was under less stress.

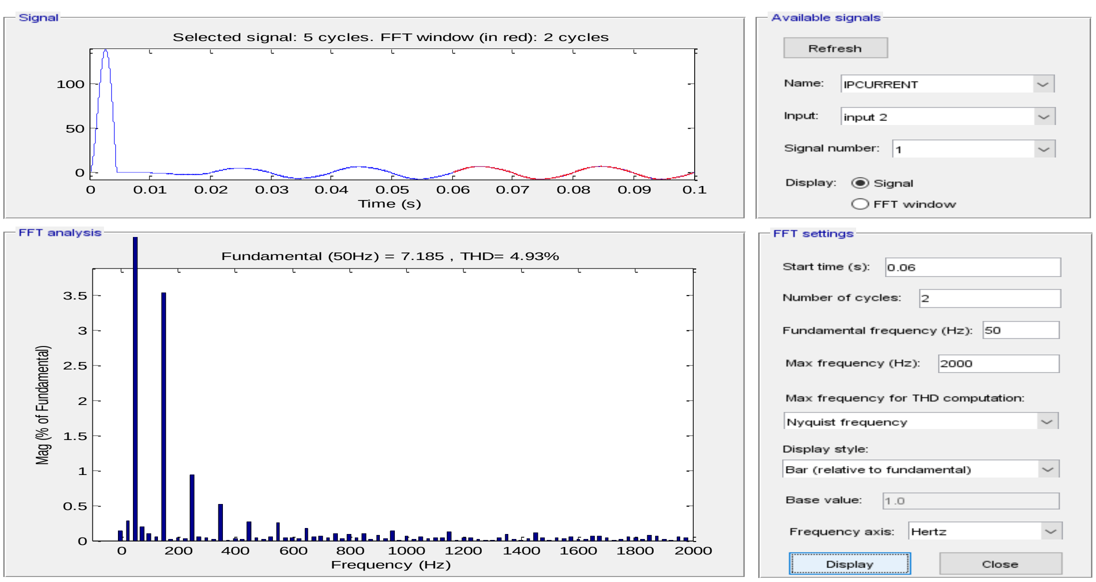


Fig.13. FFT and THD analysis of diode bridge rectifier with APF

Table 3. PF of various R load using APFC

S. No	Rload (ohm)	Power factor
1	100	0.9976
2	75	0.9975
3	50	0.9975
4	25	0.9975

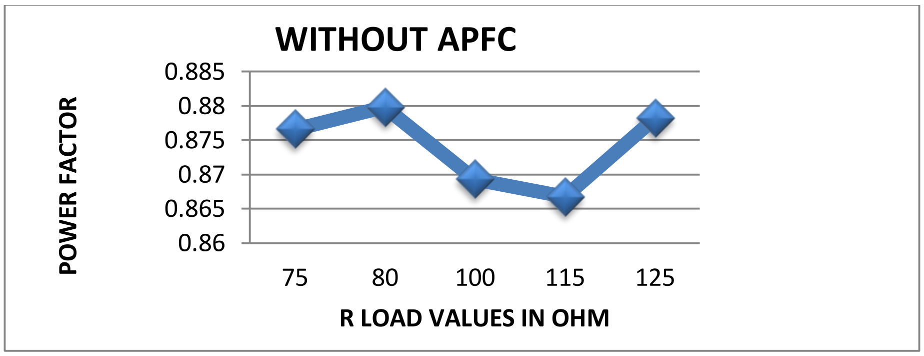


Fig.14. Plot of Power factor for various R load values in LUO Converter without APFC

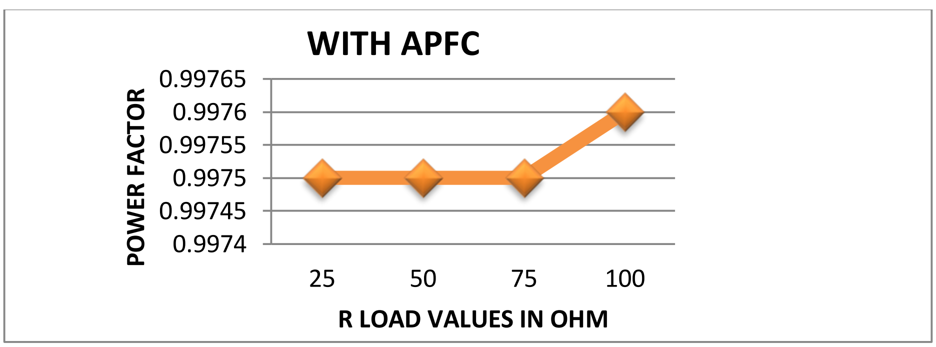


Fig.15. Plot of Power factor for various R load values in LUO Converter with APFC

CONCLUSION

From the results obtained in the simulation of proposed system, it is clear that both input voltage and current are in-phase eventhough in the load variations. Power factor varies from 0.9975 to 0.9976 thus reducing the reactive power into greater extent. The proposed AC to DC converter has resulted in THD of less than 5% with nearly unity power factor. Thus the input power factor is greatly improved and Harmonic content is reasonably reduced. Thus it satisfies the IEEE standards for THD. Using ideal components, simulations of the Luo converter elementary circuit backed up the claims of the concept and design procedure produced by F.L. Luo. The output showed negligible voltage ripple, the o utput gain, reduced Harmonic content, High efficiency and time response all proved to be within the specified values.

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UNCONTROLLED RECTIFIER THD IN %	WITHOUT APF THD IN %	WITH APF THD IN %
101.85	80.40	4.93