Reduction In Total - Harmonic- Distortion for AC To DC Converter With Improved Power Factor Using Boost Converter With PID Controller

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Abstract

The present scenario is trending towards quality power supply. There are different parameters which decides the power quality like continuity, wave shape, wave distortion, ripples, flickering, harmonics etc. In this paper the method of reduction of total harmonic distortion for AC – to- DC converter with improved power factor by implementing a boost converter along with the PID controller. To prolong the life time of electronic circuits the electrolytic capacitor is excluded as the electrolytic capacitors weakens with time. The power-factor-correction (PFC) circuit for ac-to-dc converters is based on boost conversion with power decoupling. The controlled conventional machine is hired to reallocate the excessive electricity to the inefficient side of the ac side through decoupling the input power into a dc aspect . Instead of using a large electrolytic capacitor with the boost converter , the conventional energy law follows the track of minimum errors in Vref and Pref which is configured by PI controller gate pulse input to power switches. A MATLAB/SIMULINK circuit is designed with an ac voltage source of 90 V , 110 V and 130 V at 60 Hz. In the design case, a surprisingly small inductor is needed. In addition, small losses are delivered by means of the additional power switches. These benefits are increased by using high switching speed power switches. Simulation results on a SIMULINK circuit version have established the effectiveness of the proposed technique.

Keyword: *electrolytic capacitor, power-factor-correction, SIMULINK, decoupling.*

1. Introduction

A perfect 1-φ supply for domestic appliances is given by using 230 V, 50 Hz. However the power system has an impedance within the circuit which always limits the drift of line cutting-edge within the circuit of the energy device. This impedance is not completely prevented or nullify its impact to a much lower degree. This outcomes the voltage difference between substation power deliver and the consumer facet. Voltage is less in the consumer side. These devices have mains rectification circuits that is the primary reason of fundamental harmonic distortion. There had been lot of such devices & they will be drawing reactive electricity from the identical source resulting in large amount of reactive component of power flow and producing harmonics. Both of the above affects the PF of the transmission line. The former affects the displacement PF even as the latter one influences the distortion PF of the device. PF particularly cognizance on the amount of usable and wastage of the power inside the power system. The higher the PF the better is the factor of power usage and lesser the waste. Hence it is therefore required to improve the PF by means of a few way or other methods [1].

In most of the electronic gadgets which requiring AC-DC converters need the DC output voltage to be regulated with exact performance. Typically most of the circuit used earlier aren't of this type so they may be affecting the utility of the gadget and affecting the masses linked to the systems and causing different destructive consequences on the power systems. From the earlier days electronics engineers are concentrating at the developing new standards and techniques for the great application to satisfy these standards. The circuits designed for this cause are called the power factor correction circuits. Increase in pattern of electronics, the power requirement is decreasing and the reactive component of electricity drawn from the supply system is increasing. This is due to use of rectification of AC input and using a bulk capacitor after the diode bridge rectifier [1]. Number of techniques for the power factor correction and harmonic reduction have been developed however few of them were frequently used for the best performance of the system [1].

AC/DC power conversion is required for the aid of many industrial applications, domestic equipment and consumer electronics to take the pulsating power from ac device, e.g. Grid, and to supply steady DC power to the load. An AC/DC converter, additionally referred as a rectifier, is the electrical tool to perform AC/DC conversion or rectification, shown as Figure 1. Since the total amount of energy is processed by means of the rectifier, the performance and reliability of the rectifier is of great significance

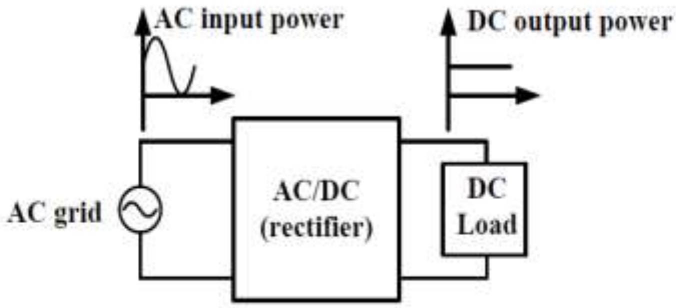

Figure 1: Block diagram of a rectifier

One of the critical programs of rectifier is providing power conversion for lights. In 2012, energy used for lights bills for 17% of the entire U.S. Power intake [1]. Among the various lighting technologies, the strong-nation lights, i.e. LED, is demonstrated to have superior performance and reliability as well as environmental pleasant [2]. With the improvement of semiconductor generation in consecutive years, the quantity of LED mounted in well known lighting fixtures packages has been rapidly improved [4, 5].

2. Non-Linear Load & Effect On Distribution System

The tool related to a power device requires a few form of rectification, as this system produces non sinusoidal line currents because of the nonlinear traits of the load linked to the device. Diode rectifiers that are linked to the input side of the power gadget can convert the AC input to DC output. 1-φ diode rectifiers are used for the low power packages and for the high power applications 3- φ rectifier circuits are used. In both of those 1- φ and 3-φ bridge rectifiers a big capacitor is used in the output port of the rectifier for acquiring the DC output voltage with a lower ripple [2]. Because of this the line current is non-sinusoidal. In all case basically peculiar harmonics amplitude are considered with recognize to the essential aspect. While the effect on the machine with the 1- φ low power nonlinear load characteristics may be taken into consideration as negligible, but the general effect at the system is considered if more wide variety of such loads are related to the machine. Line current harmonics have very damaging outcomes at the distribution and client community structures [2].
These effects include [3]:

- There will be more losses and overheating of core of the transformer.
- Excess current can flow in neutral conductor of three phase four wire system with neutral.
- Power factor will reduce.
- Electrical resonances in the power system
- Premature aging and failure of capacitors and insulation.
- The distorted line voltage may affect other consumers connected to the network.
- Telephonic interference will takes place.
- Errors can occur in metering instrument.
- Increase in the audio noise.
- Distortion of line voltage via impedance of the line.

3. Passive PFC AC to DC converter:

In this kind of PFC AC to DC converter circuits, best the passive filters are getting used in conjunction with diode bridge rectifier, in order to improve of the input power component and shape of the line current in the system. Using this PFC AC to DC converter , input power factor of the device may be increased from the value

0.7 to 0.8 nearly. With the increment of the input voltage of the supply system, the dimensions of circuit used for power factor correction with extra additives will be elevated and the value will also increase. The important objective of the PFC AC to DC converter is, filtering input current harmonics in line current. These currents harmonics is filtered by using LPF and it permit the fundamental wave and stopping all of the other harmonics to improve the power factor. Using the passive PFC AC to DC converter, higher order harmonics can be reduced to a set limits and the power factor cannot reach to a value close to 1.0. The output voltage cannot be controlled on this PFC AC to DC converter circuit [4].

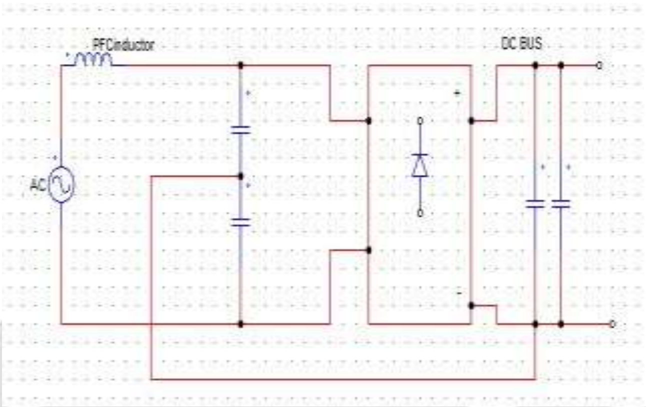

Fig: 2. Passive PFC AC to DC converter Circuit [3]

4. Active PFC AC to DC converter:

An active power factor correction circuit is designed to control the power drawn by the load in the electrical system and it obtains a power factor close to unity. Any active PFC AC to DC converter designed for power factor correction can works as by controlling the current drawn by the load from the supply setup and making it to comply with the source voltage waveform. The components used in this method are to correct the shape of the input current waveform and to get the output voltage that is controllable [5].According to the frequency of switching of the active PFC AC to DC converter solution may be divided into two sets [5].

1. The active PFC AC to DC converter because of low frequency: In this class switching of circuit takes place at low order harmonics [5].

2. The active PFC AC to DC converter due to high frequency: In this case, circuit switching frequency is greater than the line-frequency [5].

The power factor gained in this circuit is more than 0.9. And similarly the level of power factor may be elevated to a better range to reach stability and it may be acquired via including a few filtering setup to the circuit [3]. With the active PFC AC to DC converter circuit you may determine the input voltage continuously. And the size of the circuit is smaller than in case of passive PFC AC to DC converter circuit [5]. Harmonics in this case are decreased to the lower values

The advantages are that the system weight is low as compared to the passive PFC AC to DC converter circuit .Size of the system is small and power factor value can be reached to unity approximately. Decreases the harmonics to lower values. Its advantages are that It will automatically correct the AC input voltage. It can be possible for it to operate on full rated voltage .but the disadvantages are that design of this system is a bit complex as more number of elements are present. Highly expensive due to its need to provide extra elements present in the circuit[1]

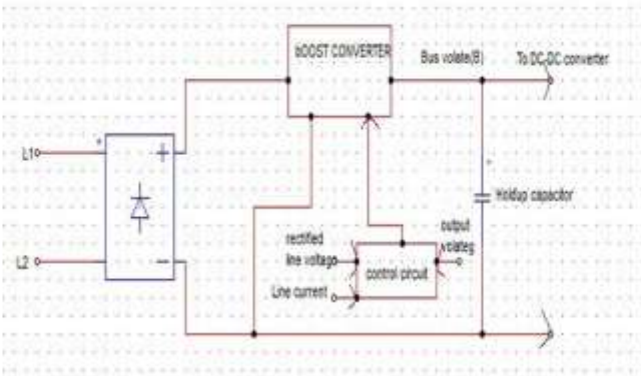

Fig: 3 Control circuit for adjusting a boost voltage to maintain a sinusoidal input current [3]

5. High power factor control circuit:

The Schematic diagram of a high power factor control is given underneath in Fig .4. This circuit diagram is much like boost converter. The diode bridge used here for the purpose of rectifying the input voltage which is AC and it converts the input voltage wave shape from AC to DC. The capacitor used for this conversion is connected at the output port of the converter .The value of capacitor is used is small and it main purpose is to control if any noise present within the circuit. Constant voltage can acquired at the output side of the converter, however input voltage is controlled by external means. Output power obtained on the capacitor output side is in the shape of a sine wave.. This sine wave has a frequency is equal to two times that of the line frequency [4].

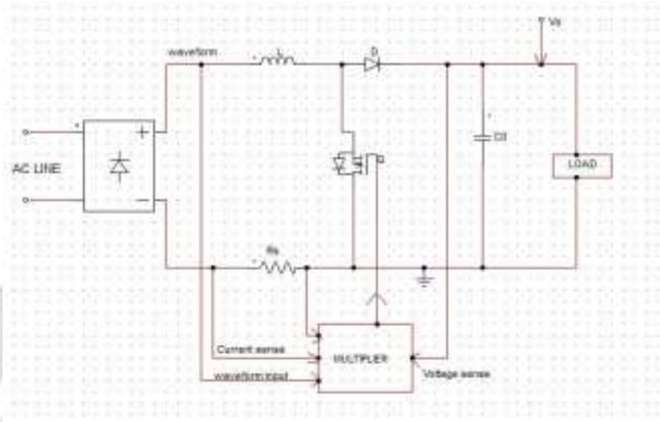

Fig: 4. High power factor control circuit [4]

6.Methodology

Over past few decades, increasingly more power electronic converters were used due to the advancement on electronic components and semiconductor generation. These power converters draw distorted currents from the ac source, causing the deterioration of power quality of the ac grid [1 , 2]. To mitigate this problem, a power factor corrector (PFC) is inquired in many electronics products to comply with the rules [3-9]. Conventionally, a diode bridge accompanied by a boost converter is used as the PFC to shape the waveform of the ac input current. An electrolytic capacitor with huge capacitance must be connected to the PFC to reduce the low-frequency ripple on the dc output [10]. The electrolytic capacitor isn't always only of massive size but might also shorten the overall lifespan of the power electronics converter [11-14].

To exclude the usage of the big electrolytic capacitor, this paper attempts to reconfigure the PFC circuit by introducing a pumped-storage energy tank. An additional inductor with associated power switches is implanted in a boost converter as an energy tank for regulating the instant power from the ac source based totally on decoupling principle. A high power factor can be realized by properly adjusting the operating-ratios of the active power switches of the energy regulation tank. In this case, only a fraction of the supplied energy has to be processed with the aid of the output capacitor for decreasing the ripple at the output voltage within a suitable range. With this sort of configuration, the converter can gain a high power factor and a low overall harmonic distortion (THD) at the ac input [15-17]. Moreover, the lifespan of the ac-to-dc converter may be prolonged via replacing the electrolytic capacitor with a metalized film capacitor. To preserve a steady output electricity, a power controller using PID scheme can be delivered to calculate error in excessive electricity at some stage in those two durations and controls the voltage as a current changes sign from the load for the relaxation time of a cycle. Ideally, with this kind of tactic, the output strength of the energy conversion circuit can be stored at a constant. In best practice, a small ripple is present on the output voltage. As a result, the output filter out capacitor can be efficiently reduced.

6.1 Power decoupling

Fig.5 illustrates the concept of power decoupling. The ac-to-dc converter is supplied from the ac mains. The rectified input voltage is expressed as

$$v_{rec} = V_p |\sin 2\pi f_i t| \quad (1)$$

where f and V_p are the line frequency and the peak of the ac voltage, respectively.

For a single-phase ac circuit with unit power factor, the input current is sinusoidal and in phase with the voltage of the ac source. The instantaneous input power, p_i, can be represented as

$$p_i = P_o - P_o \cos 4\pi f_i t \quad (2)$$

where P_o is the average output power.

This equation shows that the input power may be decoupled right into a dc component and an alternating power with a frequency twice the line frequency. As shown in Fig.3.1, the instantaneous power is higher than the average power within the duration from 1/8 to 3/8 and from 5/8 to 7/8 of T_i in an ac line cycle. To preserve a steady output power, a power controller using PID scheme can be introduced to calculate error in excessive power at some stage in those two durations and controls the voltage as a current flows through the load for the relaxation time of a cycle. Ideally, with this kind of tactic, the output power of the energy conversion circuit can be maintained at a constant. In practice, a small ripple is presents on the output voltage. As a result, the output filter out capacitor can be efficiently reduced.

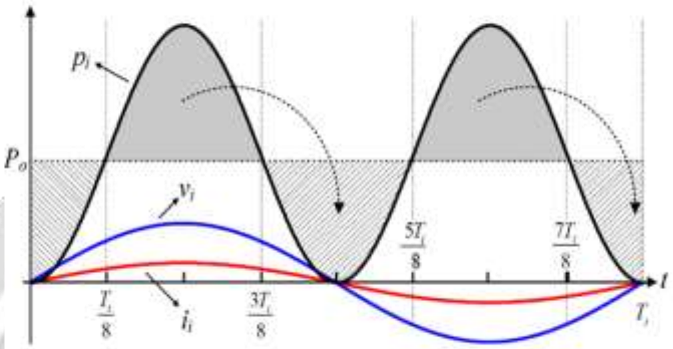

Fig. 5. Concept of power decoupling with feedback mechanism.

6.2. Circuit Configuration and Operation

The proposed ac-to-dc converter with the proposed power factor correction circuit including a boost converter with a feedback voltage and power PID controller. In the base paper the boost converter is formed by means of an inductor for boost conversion, L_1, with an associated active power switch, S_1, with a freewheeling diode, D_1. In the proposed model the feedback PID controller is composed of active controllers for voltage and power , to adjust the amount of the pumped-stored energy in the inductor L. The power decoupling for power factor correction is finished by properly controlling the duty- ratios of active power switches .The circuit operation of the proposed model is better explained in which the mechanism is illustrated with the aid of different mode for power flows into or out from the inductor. The proposed simulink model is shown below

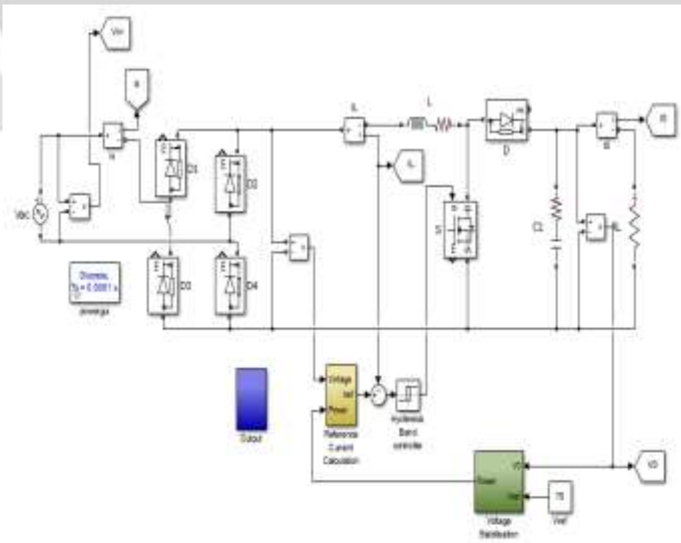

Fig.6. The ac-to-dc converter with the proposed PFC circuit.

The energy storing mode happens when the input power p_i is higher than the output power P_o. While in the proposed work the reference voltage is compared with actual measured output voltage , the difference voltage occurred is given as feedback to the PID controller. Using the difference/error in required voltage the PID controller processes the required power that is to be pumped in feedback. In the energy pumping mode of proposed model the energy stored in boost converter series inductor is pumped to the load side by controlled switching operation of active power switch whose switching speed and timing is controlled by the circuitry which includes PID controller and hysteresis band current controller Using this power calculation and reference power the desired firing angle is decided by the operation of hysteresis band current controller and this hysteresis pulse generator which forwards the controlled gate pulse to the switch of boost converter.

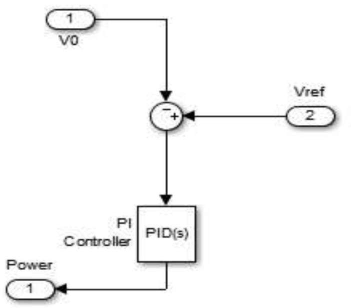

Fig 7 :Voltage control Using PID

The feedback PID controller is embedded with the voltage stabilization section which is fed by the reference voltage V_{ref} and output voltage V_o and the controller's output controls the voltage through the power control mechanism**.**

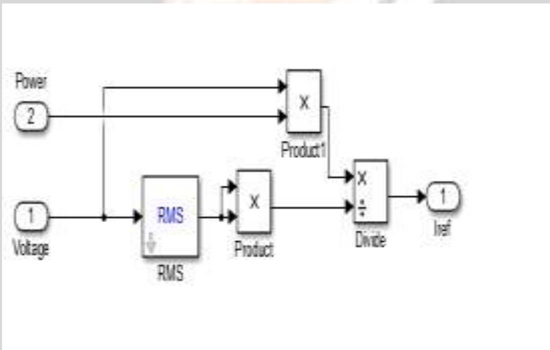

Fig 8: Power control mechanism

This mechanism is processed through hysteresis current controller .The difference of the load current I_L and reference current I_{ref} is used to control the switching of the mosfet through the hysteresis current controller.

The HCC is basically robust on load parameters deviations, reveals very fast transient effect and is appropriate for easy applications. In HCC method as shown in Figure 9, I_L (load/line current) is compared with I_{ref} (reference current). The preferred shape and magnitude of I_{ref} are derived from the voltage controller output. I_{error} is output of the hysteresis controller. It is difference of I_L actual and I_{ref} . The pulse generated by the HCC in the form of Ierror functions as switching pulse for the active power switches by triggering its gate

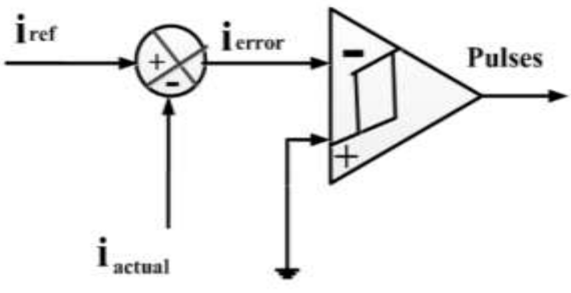

Fig:9. Switching pulse generation through HCC

The main idea of hysteresis current controller is that the real-time current I_L (actual current) signal is compared with I_{ref} (command current) signal. In the method of process: if I_L is greater than the maximum hysteresis values $I_{ref} + h$, then the switch is turned ON to decrease I_L ; if I_L is less than lower limit $I_{ref} - h$, then the switch is turned OFF to increase I_L where the hysteresis width is defined by h. Through the control technique within a fixed range, the actual current I_L could be control. In the method of hysteresis comparison, the reference current has been tracked by the real-time actual current I_L.

When the switch is in on state the decoupling inductor of the converter is charged and when the switched is off the it releases the energy stored to the load the energy storage is done when Po is more than Pin. When the Po is less than Pin the energy is released. This Vref and Iref matching with the live parameters causes the power factor to approach towards unity. The use of HCC and PID controller reduces the THD.

7. Results and Discussion

An AC to DC converter with current control of boost converter circuit model is built in Simulink to verify the harmonic analysis of the proposed model. The ac-to-dc converter is energized from an AC input voltage at a frequency of 60 Hz to power to a DC load rated at an output voltage. The AC voltage may also vary in a given range. The power and voltage range characteristic is realized by way of adjusting the duty ratio of the converter switches from 0 to 0.85 at a switching frequency of 60 kHz. The current and voltage controlling is done by PID controlled mechanism. The hysteresis band current controller compels the output DC current to track the set reference current ,which on limit violation creates a pulse which regulates the switching of the boost converter active power switches Since the output voltage ripples can be successfully decreased, by using output capacitor

Fig. 10 (a) suggests the simulated waveforms at the rated ac 110 voltage. Fig. 10 (b) shows the input current and Fig. 10 (c) displays output dc voltage. The Fig. 10 (d) represent the inductor current while Fig.10 (e) shows the %THD. With an AC input voltage of 90v. A high power factor is obtained as 0.99 is executed with a THD of 6.1 %. With an AC input voltage of 110 V A power factor is high 0.99 is achieved with a THD of 6.0 %.With an AC input voltage. of 130 V A power factor is high 0.99 is achieved with a THD of 5.9%.

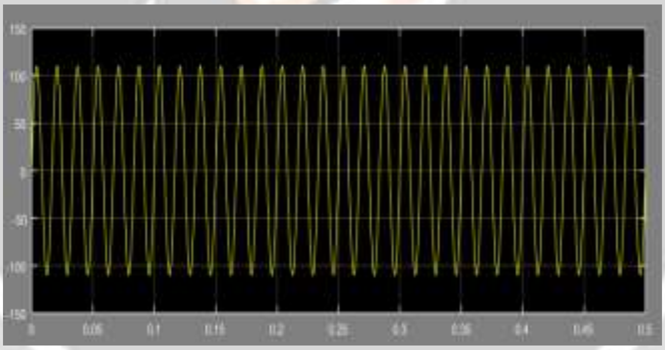

Figure 10 a : Vin Input voltage (110V amplitude)

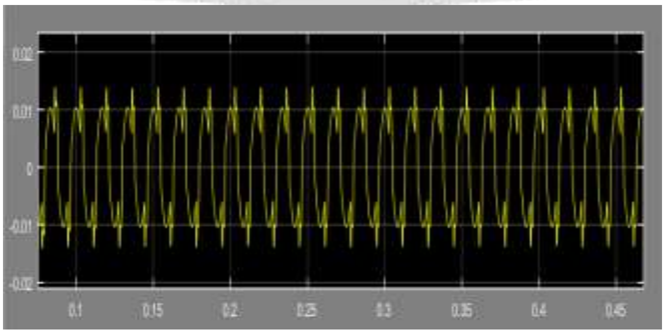

Figure 10 b : Iin Input current

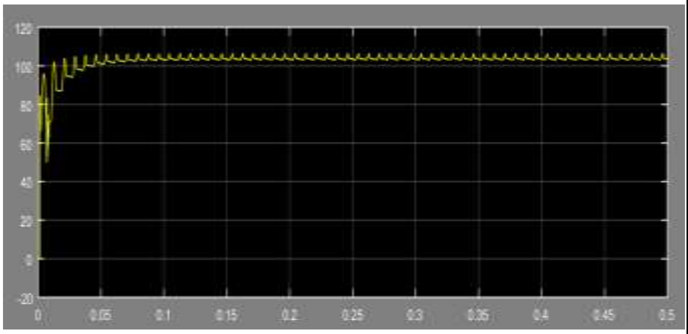

Figure 10 c : O/P Voltage

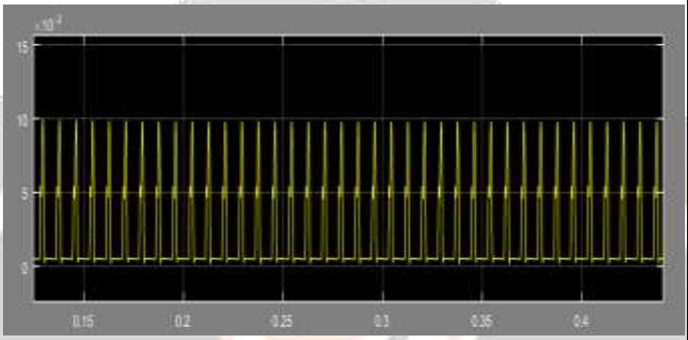

Figure 10 d : Inductor Current

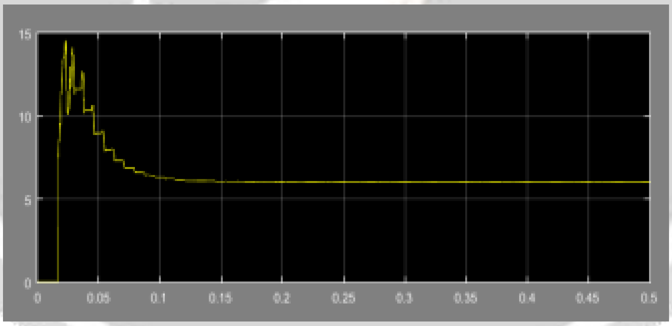

Figure 10 e : Total harmonic distortion (%THD)

8. Conclusion

This design cognizance on AC to DC converter to lessen the total harmonic distortion and enhancing the power factor and subsequently to exclude the use of bulky electrolytic capacitor, a PI controller is employed in the feedback controlled path of the boost converter to increase the controlled operation of converter circuit for the ac-to-dc converter. The current controlling device i.e hysteresis current controller and power control mechanism is employed to reallocate the excessive energy to the inefficient side the ac power through decoupling the input power into an ac aspect of a dc portion. Instead of using a large electrolytic capacitor inside the traditional boost converter, the current follows the law of minimum errors in V_{ref} and P_{ref} i.e I_{ref} which is configured by PID controller gate pulse input to power switches. A MATLAB/SIMULINK circuit is designed for an output energy of 157 W with an ac voltage source of 90V,110V and 130 V at 60 Hz. In the design case, a surprisingly small inductor is needed. In addition, small losses are delivered . These benefits are alleviated by using higher rating active power switches and tuned filter circuit with higher permeability. Simulation results on a SIMULINK circuit version have established the effectiveness of the proposed technique. For a delegated output power, a higher overall performance is done at a better input voltage.

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