A Literature Survey on Power Factor Correction using Boost Converter Rectifier-Cascaded with DC to DC Converter with Multiple Loads

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Abstract: This paper presents the study of power factor correction using boost converter: Comparing with ac to dc PFC the proposed PFC has lower requirements of power device ratings, which leads to lower cost, higher efficiency, and lower electromagnetic interference. New recommendations and future standards have increased the interest in power factor correction circuits; a review of the most interesting solutions for single phase and low power applications is carried out. They are classified attending to the line current waveform, energy processing, number of switches, control loops, etc. The major advantages and disadvantages are highlighted and the field of application is found.

Index-Terms -Power factor correction (PFC), single-phase boosts converter AC/DC converter, forward converter, DC motor Drive, Total Harmonic Distortion (THD), reactive power, sinusoidal line Current

I. INTRODUCTION

Power supplies connected to ac mains introduce harmonic currents in the utility. It is very well known that these harmonic currents cause several problems such as voltage distortion,

Heating, noise and reduce the capability of the line to provide energy. This fact and the need to comply with "standards" or "recommendations" have forced to use power factor correction In power supplies. Unity power factor and tight output voltage regulation are achieved with the very well-known two stage approach; however, this is probably the best option for ac-dc

Converters due to the following reasons-

- Sinusoidal line current guarantees the compliance of any regulation.
- It gives good performance under universal line voltage.
- It offers many possibilities to implement both the isolation between line and load, and the hold-up time.
- The penalty on the efficiency due to the double energy processing is partially compensated by the fact that the voltage on the storage capacitor is controlled. The fact of having a constant input voltage allows a good design of the second stage.

Generally to convert AC to DC a diode bridge rectifier is used. Due to the non-sinusoidal nature of the input current, THD will be very high and input power factor also will be low. Two factors that give a measure of the power quality in an electrical system are power factor (PF) and total harmonic distortion. The amount of useful power being consumed by an electrical system is decided by the PF of the system. The amount of harmonics injected by equipment is determined by the THD of the current drawn by the system. The input current of diode rectifier contains odd harmonics making THD high and distortion power factor is less than resulting in poor power factor. Hence looking into the serious effects generated by conventional converters, the diode bridge rectifiers should not be used. There is a need to achieve rectification at close to unity power factor and low input current distortion. In addition to achieve a regulated DC output, the main criteria in the design of such AC/DC power supply are in achieving high power factor and low THD. This is possible by replacing bridge diode with some additional converter in such a way to achieve a sinusoidal input current and low THD. Switches mode power factor correction AC-DC converters with high efficiency and power density are being used as front end converters. These rectifiers are either buck or boost type topologies. In this paper rectifier converter with boost and forward converter have been proposed. Its input power factor and THD analyses has been made. Power factor and total harmonic distortions of the single phase conventional diode bridge rectifier and diode bridge rectifier with boost and forward converter. The analysis has been made using Simulink MATLAB. The detailed power factor and THD has been done. Further proposed converter with multiple loads is analyzed.

II. CONVENTIONAL RECTIFIER BASED AC TO DC CONVERTER

Rectifiers have many uses, but are often found serving as components of DC power supplies and high voltage direct current power transmission system. Rectification may serve in roles other than to generate direct current for use as source of power. Single phase diode rectifiers are needed in relatively low power instrument that need some kind of power conditioning .Harmonic in rectifier is approx. 153% which is very high power factor will degrade.

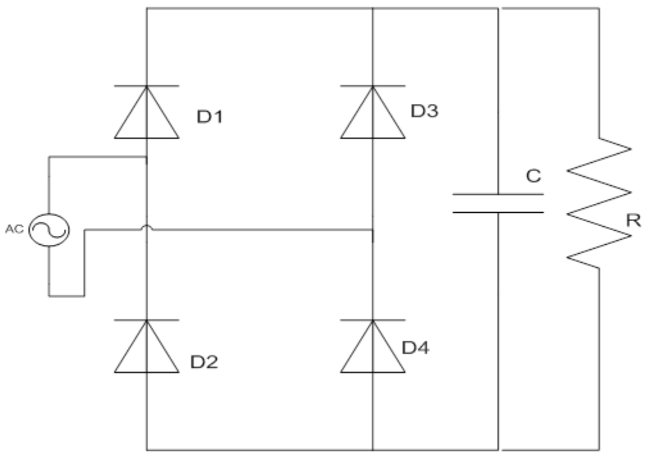

FIG-1 AC to DC Converter

A single phase rectifier consists of four diodes connected in a closed loop bridge configuration so as to produce the rectified output voltage.

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A single phase rectifier consists of four diodes connected in a closed loop bridge configuration so as to produce the rectified output voltage is shown in Fig.1.

The four diodes are connected in series pairs with only one diode pair conduct during each half cycle. The rectifier with filter capacitor is called a conventional AC-DC utility interface which is given in Fig.2 (a). The filter capacitor reduces the ripples present in the output voltage. Although a filter capacitor significantly suppresses the ripple from the output voltage, it introduces distortions in the input current and draws current from the supply discontinuously, in short pulses as shown in Fig.2 (b).

THD of such waveform will be very high and power factor also will be very low. This introduces several problems including reduction of available power and increased loss.

III. TRADEOFF QUALITY-COST

When the input current is sinusoidal (at 50 /60 Hz), the input power is pulsating (at 100 /120 Hz) and, since the power demanded by the load is constant, it is necessary to include an element to store the energy.This element is usually a capacitor, but it should be dimensioned for twice the line frequency (100 or 120 Hz). Therefore it is a large component. Finally, a second dc–dc converter is required to regulate the output voltage.

Therefore, the penalty for the highest quality waveform (sinusoidal) and tight output voltage regulation is-

1) Two control loops in the pre-regulator;
2) A big storage capacitor;
3) An additional dc–dc converter with its own control circuit;

IV. TYPES OF PFC

Passive PFC-

Harmonic current can be controlled in the simplest way by using a filter that passes current only at line frequency (50 or 60 Hz).Harmonic currents are suppressed and the non-linear device looks like a linear load. Power factor can be improved by using capacitors and inductors i.e. passive devices. Such filters with passive devices are called passive filters.

Disadvantage: They require large value high current inductors which are expensive and bulky. A passive PFC circuit requires only a few components to increase efficiency, but they are large due to operating at the line power frequency

Active PFC-

Active PFC circuits are based on switch mode converter techniques and are designed to compensate for distortion as well as displacement on the input current waveform. They tend to be significantly more complex than passive approaches, but this complexity is becoming more manageable with the availability of specialized control ICs for implementing active PFC. Active PFC operates at frequencies higher than the line frequency so that compensation of both distortion and displacement can occur within the timeframe of each line frequency cycle, resulting in corrected power factors of up to 0.99. Active approaches can be divided into two classes-

A. Slow switching topologies.
B. High frequency topologies

A. Slow Switching Topologies-

The slow switching approach can be thought of as a mix of passive and active techniques, both in complexity and performance. The most common implementation is shown in Figure and includes the line frequency inductor L The inductor is switched during the operating cycle, so this is considered an active approach, even though it operates at are actively low frequency typically twice the line frequency. This is a boost circuit in the sense that the AC zero crossing is sensed and used to close the switch that places the inductor across the AC input.

B. High Frequency Topologies-

Conceptually, any of the popular basic converter topologies, including the fly back and buck, could be used as a PFC stage. We will focus, however, on the boost topology since it is the most popular implementation. There are several possible control techniques that can be used to implement a boost PFC converter, but the version.

Power Factor Correction Circuits-

The classification of single-phase PFC topologies is shown in Fig. 2 The diode bridge rectifier has no sinusoidal line current. This is because most loads require a supply voltage V2 with low ripple, which is obtained by using a correspondingly large capacitance of the output capacitor Cf. Consequently, the conduction intervals of the rectifier diodes are short and the line current consists of narrow pulses with an important harmonic contents. There are several methods to reduce the harmonic contents of the line current in single-phase system.

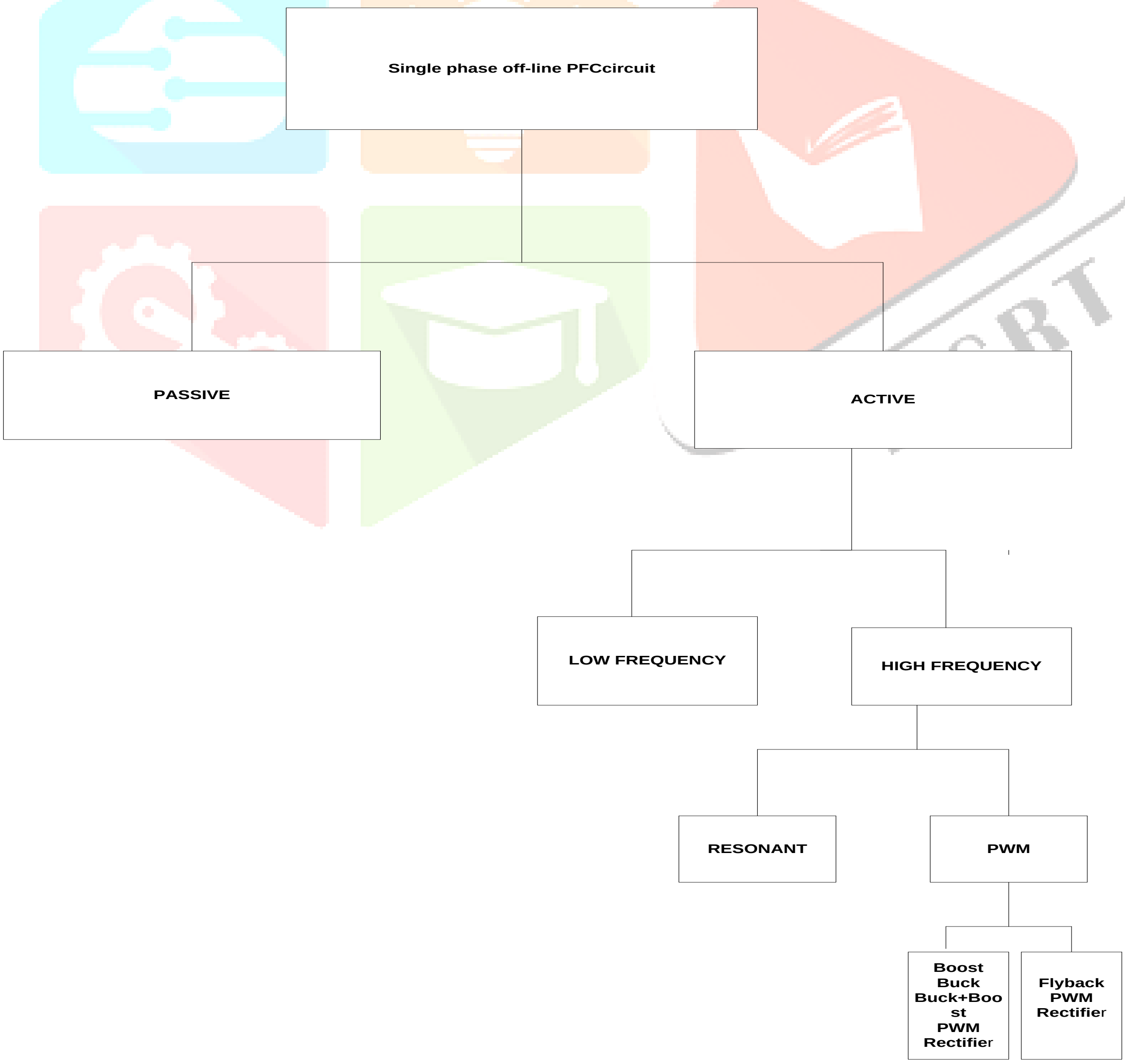

FIG-2 Classification of single-phase PFC topologies

V. LITERATURE SURVEY

Use of series active filter is a low-cost approach to power factor correction (PFC). Comparing with the traditional PFC, the proposed PFC has lower requirements of power device ratings, which leads to lower cost, higher efficiency, and lower electromagnetic interference. It also can eliminate the bulky inductor needed in the traditional PFC (Zhiguo Pan et al 2007).

The need to keep EMI emissions by electronic power supplies below the limit specified by international standards have dictated that any new power supply design must include active power factor correction at the front end. The modern trend in power supply designs is towards digital control. The power factor correction circuit employs zero voltage transition arrangement to minimize switching losses. Interface requirements between the power converter stage and the digital control processor are tackled. Average current mode control method is employed in the controller. The complete design has been tested by means of Power Sim power electronics simulation software. The resulting input voltage and current waveforms show that the design is successful. (Paul Nosike Ekemezie et al 2014)

The work initially involves simulation of basic power electronic circuits and the analysis of the current and voltage waveforms. It starts with simple circuits with a gradual increase in complexity by inclusion of new components and their subsequent effect on the current and voltage waveforms. We focus on the objective of improving the input current waveform i.e. making it sinusoidal by tuning the circuits. The new analytical method simplifies the design of S2PFCs by making it possible to compare a large number of different designs from the same viewpoint in order to identify the best topology. Finally, research has enabled us to reduce the total size of the additional inductors that are used by a factor of two to three with respect to previous implementations. For rectifier circuits with power Jactor correction, boost converters are generally used, and as a result the output voltage becomes limited. To expand the controlled voltage range, buck-boost or Cuk converter types should be utilized. This paper presents a circuit configuration with power factor correction by a third type of' buck boost converter, termed as 'canonical switching cell'. Single-phase power factor correction using a buck boost converter can control the output voltage over a wide range, because it has the ability to step-up and step-down the output voltage. Firstly, this paper compares the mechanisms of the power transmission and the characteristics based on the switching ripple of various converters. Secondly, the canonical switching cell is applied to the single-phase power factor correction. It is proposed that this converter is suitable for power factor correction.(Ms. Kurma Sai Mallika et al 2007)

Power factor control is a major role in the improvement of power system stability. Many of the existing systems are expensive and difficult to manufacturer. Nowadays many of the converters have no input power factor correction circuits. The effect of power factor correction circuit is used to eliminate the harmonics present in the system. This type of power factor correction circuit is mostly used in the Switched Reluctance Motor controller drive. Fixed capacitor systems are always leading power factor under at any load conditions. This is unhealthy for installations of power system. The proposed embedded system drive is used to reduce the cost of the equipment and increase the efficiency of the system. Experimental results of the proposed systems are included. It is better choice for effective cost process and energy savings (Kurma Sai Mallika et al 2007).

When the input current waveform is chosen properly, power factor reduction leads to a reduction in filter capacitor size (and therefore to reduced system cost) while still meeting power quality requirements. Notice that the choice of waveform is independent of the particular power conversion topology to be used. It applies equally to boost, flyback, buck, and other topologies that have been used in PFC applications. (O. Garcia et al 2001)

VI. PROBLEM FORMULATION

Often used in dc-dc converter modules for power levels below 100w, single transistor resonant reset forward converter are also useful for dc-dc converts with adjustable output voltages. Derived from the buck topology, the signals transistor forward converter employs a transformer and thus a means of galvanic isolation as well as voltage step-up or step-down, which makes it a good choice for offline application requiring both. Its duty cycle can exceed 50%, making its suitable for low-cost dc-dc converters that operate from a wide range of input voltage and deliver widely varying outputs. The forward converter (which based on a transformer with same-polarity winding, higher magnetizing inductance, no air gap) does not store energy during the conduction time of the switching elements. A linearly increasing current flows through the choke and the load.

A.Boost converter-

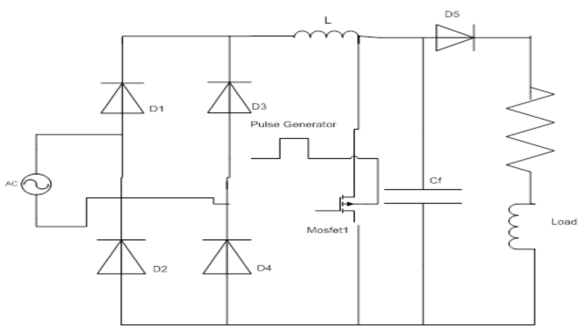

FIG-3 Boost Converter

The simple equation for calculate the input current of boost regulator which is use power balance equation-

$$P_{in}=P_{out}/\eta \qquad (1)$$

In DC to DC converter, input and output powers are products of the respective currents & voltages. Then adding the triangular ripple current, so equation-

$$I_{IN}=I_{OUT}\times (V_{out}/V_{in}) \times 1/\eta+\Delta 1/2 \qquad (2)$$

When boost converter is working, the input current will be always large, then the load current (Iout). Since the output voltage of a boost is always greater than the input voltage, the input current must be greater than the load current. The conversion of energy- the input power will be equal to the output power plus the losses.

Maximum output voltage; limitation on the maximum output voltage for the boost is the maximum rated voltage of the MOSFET and or diode.
The duty ratio defined as the on-time of the MOSFET divided by the total switching period. So, the boost converter duty ratio can be found within this equation-

$$D=1-V_{in} \times \eta/V_{out} \qquad (3)$$

B. Forward Converter –

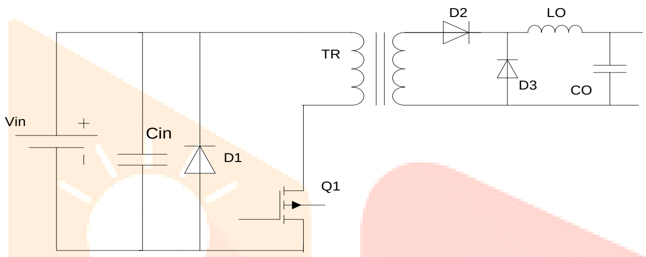

Fig-Forward converter

Forward converter like dc-dc converter, behave like the fly-back and half bridge converter can supply either high or low input voltage and provide electrical isolation via a transformer. Forward converter design can high output.
power along with high energy efficiency. Forward converter behaves like step down converter with pre switched voltage transformation. The following relationship is therefore given b/w the turn's ratio and duty cycle: -

$$DC=N1/N2\times V_o/V_i \qquad (4)$$

According to the transformer the effective currents are given by-

$$I_{eff,\,sec}=I_o\times\sqrt{DC} \qquad (5)$$

$$I_{eff,\,prim}=I_o\times N2/N1\times\sqrt{DC} \qquad (6)$$

The system cost must be minimized while considering the following magnitudes as specifications for the design: output power (Po), input voltage range (Vin-max), line frequency, maximum value of the output voltage (v), ambient temperature, and maximum temperature of the heat sink. The design must also meet the corresponding PFC and EMI standards.
The term -power factor‖ or PF in the field of power supplies is slightly deviate from the traditional usage of the term, which applied to reactive AC loads, such as motors powered from the AC power line. Here, the current drawn by the motor would be displaced in phase with respect to the voltage. The resulting power being drawn would have a very large reactive component and little power is actually used for producing work. However, in power electronics field, some of that equipment generates pulsating currents to the utility grids with poor power quality at high harmonics contents that adversely affect other users (Mohan et al. 2005). The situation has drawn the attention of regulatory bodies around the world. Governments are tightening the regulations and setting new specifications for low harmonic current.
Since the number of electronic appliances is growing, an increasing amount of non-sinusoidal current is drawn from the distribution network (Mohan, et al. 2005). Consequently, due to the increasing amount of harmonic currents drawn, the distribution network becomes more and more polluted. As a direct consequence, available power from the grid becomes less. This is because unnecessary current components, which contribute to the root mean square (RMS) value of the line current is drawn from the grid which produces unnecessary power. On the other hand, the harmonic currents distort the line voltage waveform, and may cause malfunction in sensitive electrical equipment connected to the grid.

VII. OBJECTIVES

The Active Power Factor Correction (APFC) is a method to improve the power factor near to unity, reduces harmonics distortion noticeably and automatically corrects the distorted line current of an SMPS. It will replace the Passive Power Factor Correction (PPFC) which has become a conventional method for the past 20 years. This research aims to implement the Unity Power Factor

(UPF) for single-phase rectifier which is used in designing the high-end SMPS by using APFC approach. For this purpose, a power electronic circuit is inserted between the bridge rectifier, the output filter capacitor and the load. This approach requires additional semiconductor switches and control electronics, but permits cheaper and smaller passive components.

The goals of this research are:
• To simulate and analyze the typical power supplies.
• To investigate the effects of harmonics and low power factor to the power system.
• To simulate and analyze the methodology chosen for UPF.
• To determine the best control mode for UPF.
• To implement a single-phase UPF rectifier in designing the better SMPS.

In this paper, three types of converters are considered and they were designed in two stages converter. The first stage deals with a rectification process that is AC to DC conversion together with PFC Boost topology while the second stage deals with DC to DC conversion as Flyback topology was used. The preferable type of PFC is Active Power Factor Correction (APFC) since it provides more efficient power frequency. An active PFC uses a circuit to correct power factor and able to generate a theoretical power factor near to unity. Active Power Factor Correction also markedly diminishes total harmonics, automatically corrects AC input voltage, and capable for a wide range of input voltage.

VII. Proposed Model with multiple loads

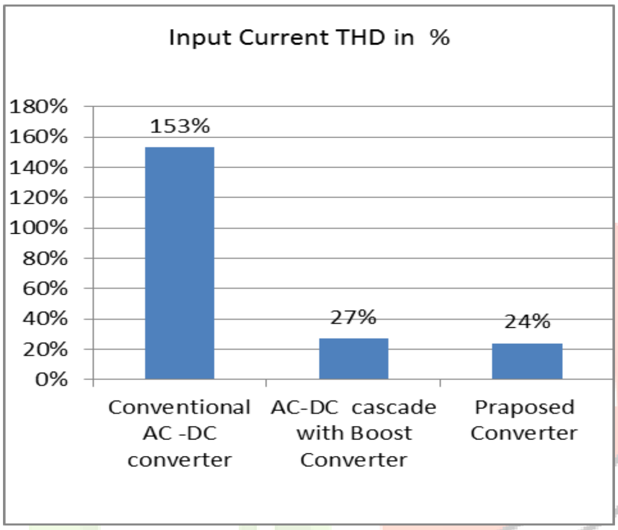

Fig 5- Input current THD

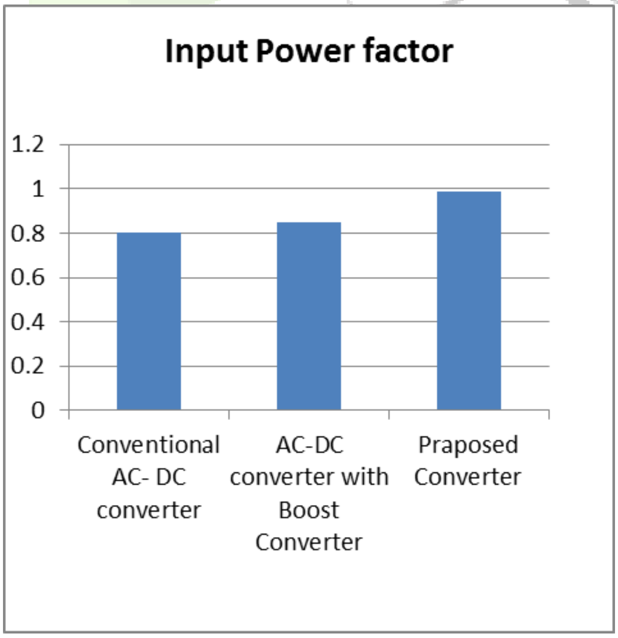

FIG 6-Input power factor of converters

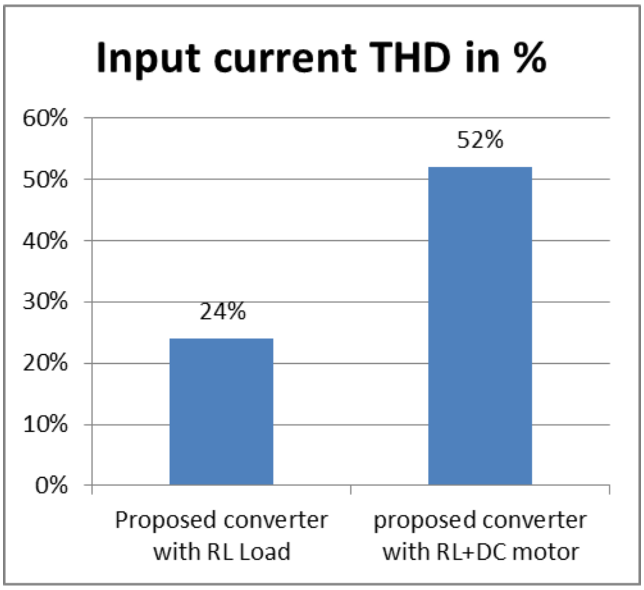

FIG 7- Input current THD

Its show the how to increase input current THD, when used load and DC motor.

Total power factor (TPF) =Displacement power factor ×Distortion power factor

Displacement power factor = W/VA = cos ø
DPF= 1/√1+THD (I)2.

VIII. CONCLUSION

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The single phase PFC boost converter gives a better solution to gadget low priced good power factor AC to DC converters with rapid output regulation.
The purpose of power factor correction is to minimize the input current distortion and make the current in phase with the voltage. When the power factor is too low, the current waveform does not follow the voltage waveform. This result not only in power losses, but may also cause harmonic that travel down the neutral line and disrupt other device connected to the line.

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