Power Factor Correction using Boost Converter Technique

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***Abstract*— This paper describes a single phase rectifier with improved power factor by using the boost converter technique. Low power factor is caused by non-linearity of the input current. Boost converter is one method of re-shaping the input waveform to be same pattern with the sinusoidal input voltage. The boost converter acts as a Power Factor Correction (PFC) of the input circuit. The complete design has developed and tested by using PSIM simulation software. The results were compared without PFC and passive PFC and active PFC. Finally the simulation results are shown to verify the performance of this modified PFC. Significant percentage of reduction for the THD and percentage of improvement for power factor is achieved by active PFC.**

Keywords: rectifier, boost converter, active PFC, passive PFC, power factor correction (PFC), power factor

I. INTRODUCTION

In most electrical and electronic power supplies, the AC input is rectified and connected directly after the diode rectifier bridge. The AC mains are common and extended source of energy. DC power supply is needed for operation of electronic equipments such as in computers, televisions, monitors and others. A simple circuit consisting of diode rectifiers and bulk capacitor are possible to obtain DC voltage. There are some problems in the input circuit which excessive peak current that produced contribute high level harmonic distortion and gave poor performance of Total Harmonic Distortion (THD) and power factor. [1] In order to improve these problems, many power factor corrections of ac dc converters are presented to achieve high power factor and low harmonics distortion by modified the input stage of the diode rectifier and the filter capacitor of the circuit. [2]

Power factor is defined as the ratio of the real power (P) to the apparent power (S) or cosine for pure sine wave for both current and voltage that represents the phase angle between the current and voltage waveform. Figure 1 shows the power factor triangle. [3] Power factor is a **measure how efficiently electrical power is consumed. The** power factor can vary between 0 to 1. It can be either lagging when the circuit in inductive where are the current lags behind the voltage or the power factor is leading in capacitive circuit when the current leads the voltage [4]. The poor power factor results in reduced efficiency which increases cost electricity. [3] Many utility companies call upon penalties for the low power factor. The converter will absorb apparent power higher that the active power is consumes when the converter has less than unity power factor.

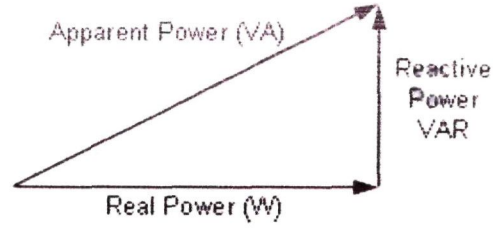


Figure 1: Power factor triangle

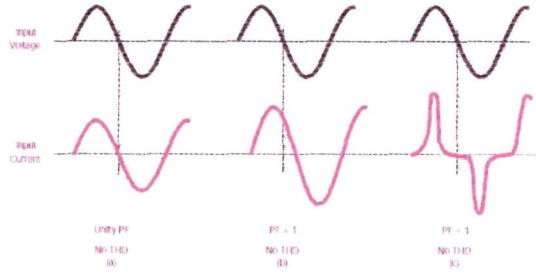


Figure 2: Relationship of AC input voltage and current

Figure 2 show the relationship of AC input voltage and current. Firstly, the basic situation which is in purely

resistive loads. In this case, the current is sinusoidal and is the same phase with the voltage. As we can see, the power factor is unity and the Total Harmonic Distortion (THD) is zero. The next case shows the situation with the linear reactive load. The current still in sinusoidal but there have a phase-shifted to the voltage waveform. The phase-shifted will result the power factor is less than unity. The THD still in zero because the input current is still in sinusoidal. Lastly, the case shows the situation with a non linear load. In this case the current is not in sinusoidal and the resulting in power factor is less than unity and non-zero THD.

II. SYSTEM DESRIPTION

A single phase rectifier with boost converter is shown in Figure 3. Boost converter is used for reshaping input current. [2] [6]. The bulk energy storage capacitor sits on the output side of the boost converter rather than just after the diode bridge. The input current (Is) would be highly non-linear for rectifier without PFC. It happened when the capacitor C1 is having large value. [6]

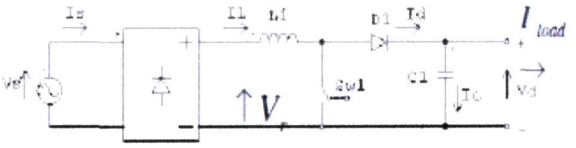


Figure 3: Boost PFC converter

The boost converter involves a switch, a diode, an inductor and a capacitor. The switch and diode depend on the voltage and current stress that they must handle for all the possible operating conditions. The boost converter is also called step up converter where the output voltage always is greater than the input voltage. [6]

III. POWER FACTOR CORRECTION

Power factor correction (PFC) is one of the methods to improve the low power factor of a system by using suitable devices. There are two type of the PFC namely the passive and active power factor correction. The aim of the power factor correction circuits is to make the input of the power supply behave like purely resistive or a resistor. [5, 7] By using the passive PFC, it can achieve the objective of the low power factor applications. The addition of a filter inductor which is connected to the series with the input circuit, the passive elements is introduced to improve the line current. The power factor in the passive PFC will increase to a value of 0.7 approximately. The achievement is degraded with the smaller values of inductance. The passive PFC is more suitable at lower power levels.

The active power factor correction results are more suitable option for achieving the nearest unity power factor and the sinusoidal input current waveform. The active PFC design functions by controlling the input current in order to make the current waveform behave like the supply voltage. A converter and switching frequencies higher than the AC line frequency is added between the output of the diode bridge rectifier and the bulk capacitor in the active power factor correction. Figure 4 shows the single phase power factor correction (PFC) topologies. [10]

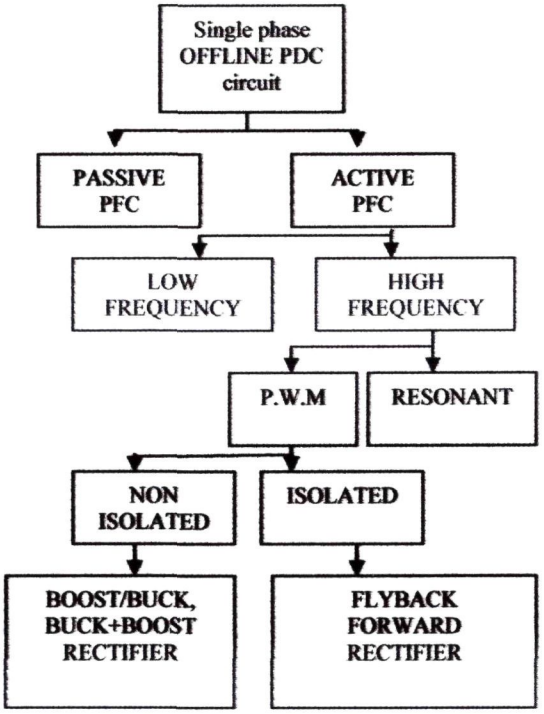


Figure 4: Single phase offline PFC topologies

i. Passive Power Factor Correction

The AC-DC converter comprises of a full bridge rectifier followed by a large filter capacitor for the input stage. The input current for the rectifier circuit comprises of the largest discontinuous peak current pulses. The high distortion of the input current occurs due to the diode rectifier conduct for the short period. [8]

By using this passive power factor correction, the value of the power factor can be increased of the 0.7 approximately. Increasing power factor due to the idea of passive PFC which is to filter out the harmonic currents by using low pass filter.

Thus, this passive power factor correction has the following main advantages and disadvantages:

Advantages – it has a simple structure, it is rugged and reliable. The cost was very low and the high frequency switching losses are not sensitive to noises.

Disadvantages – it creates harmonic, it has poor power factor, it produces high losses and it reduces power maximum power capability from the load. In the passive

PFC, the use of the inductor in the input circuit is incorporated in the circuit. [8]

ii. Active Power Factor Correction

An active PFC is a power electronic device designed to control the amount of power drawn by a load and achieve a power factor as close as possible to unity. In an active PFC, the function was by controlling the input current and make the current behaves like supply voltage. [9]

There are two classes of the active PFC solutions which are the low frequency and the high frequency active power factor correction. The low frequency active PFC is when the switching takes place at low-order harmonics of the line frequency and it is synchronized with the line voltage. For the higher frequency PFC, the line frequency is much lower than the switching frequency. [9]

IV. METHODOLOGY

The simulation process is carried out by using PSIM software. The PSIM simulation models for nonlinear load without PFC, with passive PFC and with active PFC are shown in Figure 5, 6 and 7. The simulation circuit can be divided to three sections which are the main source (input), the PFC (rectifier) and the load (output).

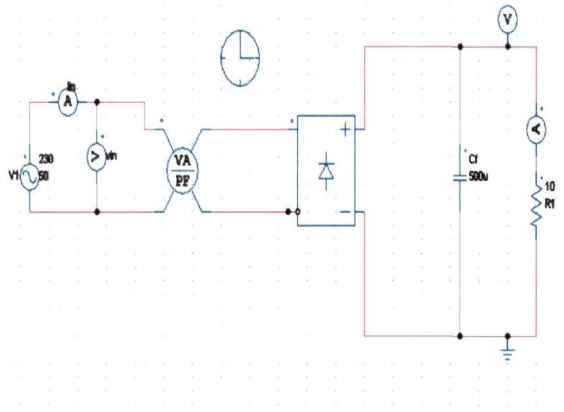


Figure 5: Simulation for non linear load without PFC

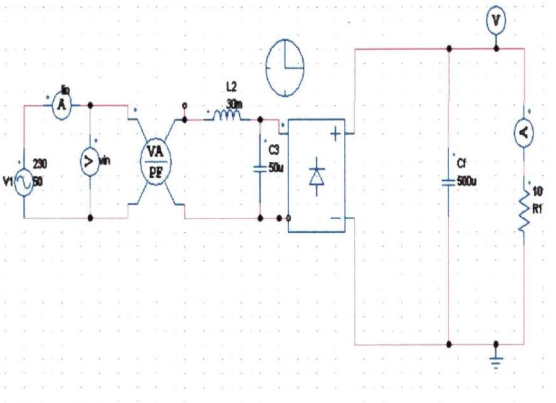


Figure 6: Simulation for Passive PFC

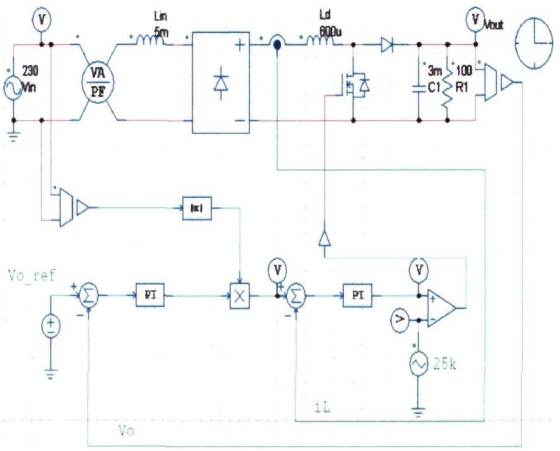


Figure 7: Simulation for active PFC (boost converter)

The software simulation process is divided into three steps which are non linear load, passive PFC and active PFC (boost converter). The Figure 8 shows the flowcharts for the simulation.

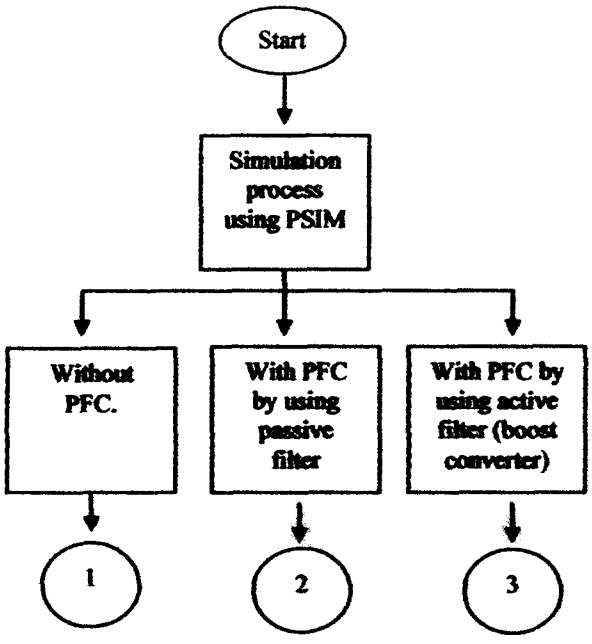


Figure 8: The flowchart of the simulation process

Firstly, a non-linear load without PFC is simulated for proof of concept using PFC. In the next step, passive PFC is added in the circuit. The passive PFC which is additional to the diode bridge rectifier. The inductor and capacitor are added before rectifier. The passive elements are introduced to get better the nature of line current. As the voltage increases, the sizes of PFC components increase too. In the third step, an active PFC replaced the passive PFC. The boost converter is added in this circuit. Then the control circuit also added into the boost converter. MOSFET is used in the boost converter circuit which functions as the switching. The flowchart of the steps in simulation is shown in Figure 9.

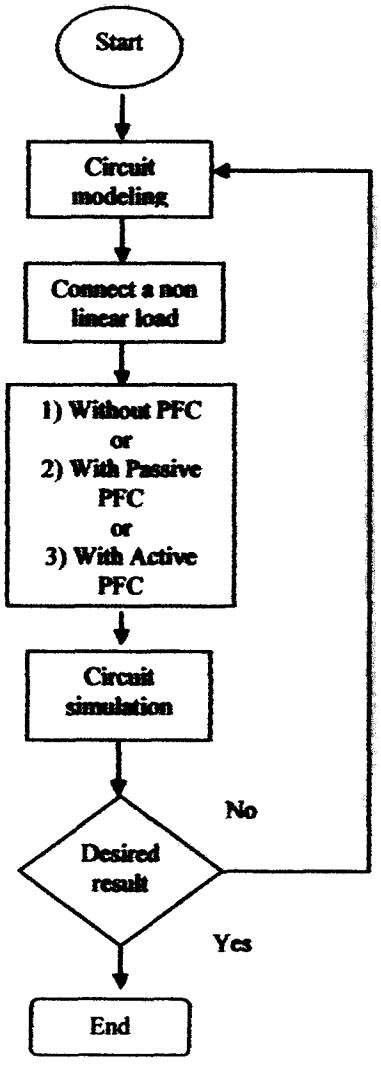
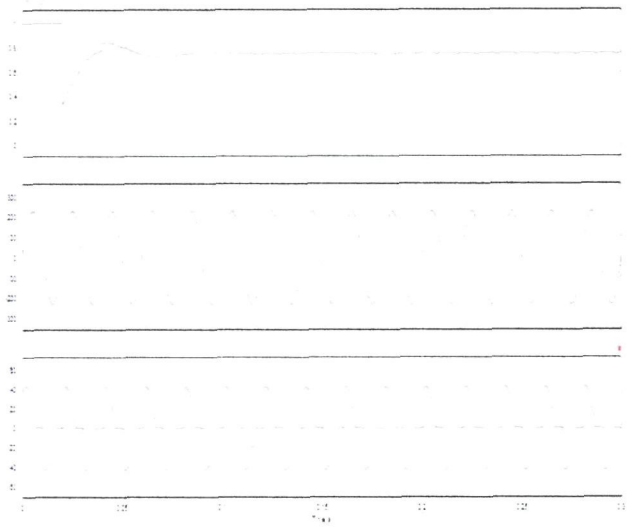


Figure 9: The flowchart of the steps in simulation

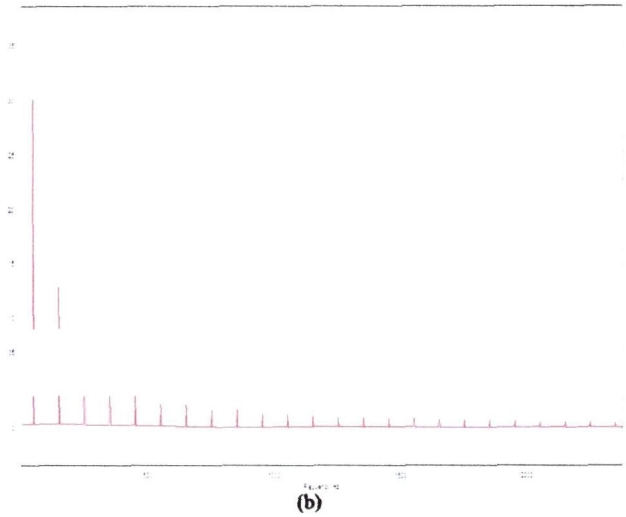
V. RESULT AND DISCUSSION

i. Without Power Factor Correction

For the non linear load which is the circuit without the PFC, the power factor is low compared to the using of power factor correction. From the waveforms, we can see the power factor is 0.74 from 0.10 seconds onwards. The shape of input current is not likely the shape of input voltage such is shown in Figure 10(a). Figure 10(b) show that the THD current waveform. The THD current for this circuit is 53.69%.



(a)

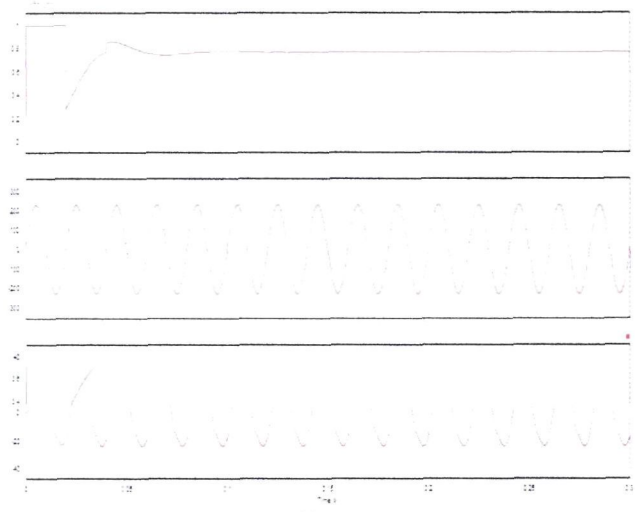


(b)

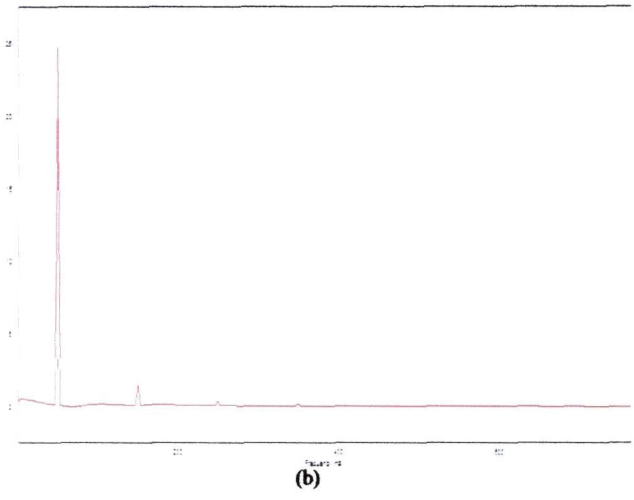
Figure 10: (a) PF, Vin and Iin waveforms (without PFC) and (b) THD current waveform

ii. With Passive Power Factor

The first step of the simulation is designed for non linear load. With a passive element the inductor is added to improve the nature of the line current. From these figure, the power factor increased to 0.76. The shape of input current also not behaves like the input voltage such is shown in Figure 11(a). But it was better compare to using without PFC. The inductor and capacitor are filter out the harmonic. The THD current for this circuit is decreased to 6.82%. The THD current waveform is shown in Figure 11(b).



(a)



(b)

Figure 11: (a) PF, Vin and Iin waveforms (PASSIVE PFC) and (b) THD current waveform

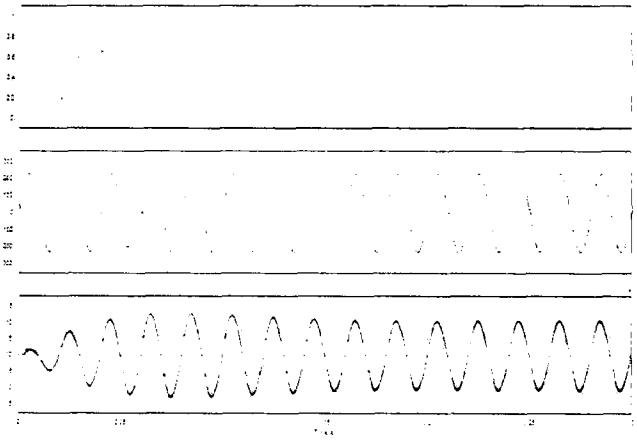
iii. With Active Power Factor Correction by using Boost Converter

In this step, the boost converter replaced the passive element by using the MOSFET as the switch. Through the simulation, the power factor is improved to 0.97 from 0.2 seconds onwards and the total harmonic distortion (THD) is decreased to 4.46%. The Figure 12(a) and 12(b) show that the waveform of power factor,input voltage, input current and total harmonic distortion current waveforms.

The process of reshaping the input current happened. The shape of input current also likely of the shape input voltage. From this simulation, by using the

boost converter is obtained to get the power factor as close as possible to unity.

The main of AC input voltage is rectified to the boost converter that mainly consisting of an inductor, MOSFET, a power diode, and a bulk capacitor. The boost converter is one of the high switching frequency topologies.



(a)

(b)

Figure 12: (a) PF, Vin and Iin waveforms (ACTIVE PFC) and (b) THD current waveform

TABLE 1: THE VALUE OF POWER FACTOR AND THD FROM SIMULATION

Types	Power factor	THD (%)
Without PFC	0.74	53.69 %
Passive PFC	0.76	6.82 %
Active PFC	0.97	4.46 %

Table 1 shows that the power factor increased from 0.74 to 0.97 and the THD decreases from 53.69% to 4.46% .We get these values from the simulation of the three circuits. The rectifier with power factor correction was developed to show objective of this project. Power factor was improved from 0.74 to 0.97 by using passive and active PFC. In the simulation results of this project shows that the theories involved is proven.

VI. CONCLUSION

This paper presents a research about power factor improvement by using power factor correction. The use of the power factor correction is to improve the low power factor and to make the input of power supply behave like to the purely resistive. The PFC circuitry that controls the Boost converter is having the limitation when the loads current are smaller. The circuit will avoid the AC current to flow exceeding to the load demand. From the simulation results, the power factor is almost unity and purely sinusoidal input current followed the input voltage. In conclusion, the simulation results matched to the theories involved.

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RECOMMENDATION

The future works that can be considered includes hardware implementation of the improvement low power factor using passive and Active power factor correction as an extension to the simulation project for verification purposes. Then, comparing other software such as MATLAB or PSCAD and PSIM for the reduction THD and improvement power factor can also be considered as future work.

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