Active Power Factor Correction Method For A Single Phase System

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Abstract- *A few purpose use non-linear devices that influence the system power factor and introduce harmonics into the electrical system. In order to decrease harmonics and increase the power factor in the power system, various techniques are used. The presentations of the new system are used in this article to control the power factor using a boost converter. This converter works in average current control mode.*

Keywords- Average current control, non-linear nature, diode rectifier, Matlab.

I. INTRODUCTION

The many methods used to improve power factor correction. Most of two methods are used the active power factor correction method and passive power factor correction method. In the passive correction method LC filter is used for power factor correction, but LC filter which produces the slow response of the system. Another method is active power factor correction is used by the diode rectifier and dc-dc converter. This technique is more effective than passive techniques. In the ac-dc converter, the boost converter is almost exclusively. This technique is more efficient than other techniques [1-5].

Continuous conduction mode operation (CCM) boost PFC is the popular option for medium and high power applications. Active PFC topologies like buck-boost and buck converters. The continued existence of the input current of the boost converter leads to low induced electromagnetic interference (EMI). A pulsating current with large current harmonics is generated by the nonlinear load [6-10].

To function simultaneously as an active power filter, a new power factor correction technique using the PFC Boost converter. It is proposed to provide compensated currents equal to the harmonic currents. To control the current control of the lines concerned, a current hysteresis control is implemented. In this arrangement, the PFC boost converter can be used to remove the harmonic current generated by the diode rectifier [11-14].

The required harmonic current supplied by the non-linear load is supplied by the PFC step-up converter. Therefore, with an increased power factor, the general arrangement attracts an almost sinusoidal current. In the output point, using a buck inspired method; an inductor is used in a standard switching power supply. The current control mode is simply to regulate the output current, which has many performance advantages [15-18].

The inductor is used in the input stage in a very high power factor to make use of the boost technique. The peak / average error is very serious in the high power factor boost converter. Because it induces distortion of the current input waveform. Although the peak current is the ideal sine wave current, it is not the average current. At lower current rates, the peak / average error gets much worse, particularly once the inductance current becomes discontinuous when the undulation approaches zero in every half-cycle. The peak / average error should be small to get low distortion. To make the ripple current small, this includes the use of a large inductor. The resulting shallow current inductance ramp further exacerbates the already low noise tolerance [19-22].

The average current mode method can be used in any branch of a circuit to sense and control current. So it can precisely control the input current with buck and flyback techniques and can control the output current with boost techniques [23-25].

Many papers are working with different objectives to boost converters with different techniques. Improving the power factor with a boost converter is easy. Previous researchers use dsPIC, PID, ZVS and ZCS controllers. None of the latest work uses a boost converter. However, we will be using a boost converter in this thesis work to solve the problem. To minimize THD and increase power factor and performance, a boost converter is adopted. This paper includes new approaches which will be used with the ac-dc device to overcome those disadvantages and improvise the power factor. In this phase, the current at the rectifier side is controlled. The harmonic distortion is common by attaining the sinusoidal waveform of input current. From these techniques, it is clear that this model overcomes the all bad result and gives a high power factor and a current waveform in the almost sinusoidal form. Here, PI controllers are used to controlling the average current mode. Matlab does all the simulations. Also, there are four sections in this paper. The first is section introduction, the second power factor correction method, the third proposed method of PFC and the last simulation.

II. POWER FACTOR CORRECTION METHOD

It's the foremost preliminary step for proceeding with any research work writing. While doing this go through a complete thought process of your Journal subject and research for it's viability by following means: The power factor is this relationship between active power and apparent power. The concept of power factor, the power factor on the input side of the rectifier is the ratio of the active power to the apparent power on the input side of the rectifier.

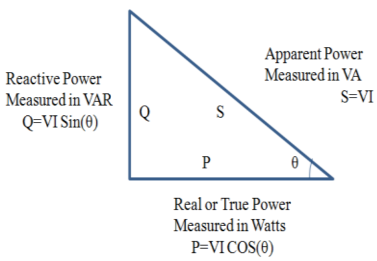

Fig. 1: Power Triangle

A power factor is less than one the voltage and current are not in phase. The instantaneous combination of voltage and current is real power. Apparent power is a mixture of current and RMS voltage. Due to the energy stored in the load and returned to the source. A non-linear load that distorts the waveform of the current drawn from the source, the apparent power may be greater than the actual power. When power is generated by the device and then returns to the source, a negative power factor occurs.

$$PF = \frac{Active\ power}{Apparent\ power} \tag{1}$$

$$P.F = \frac{P}{S} \tag{2}$$

$$PF = \frac{Vrms * Irms * cos\theta}{Vrms * Irms} \tag{3}$$

As for the THD,

$$P.F = \frac{Displacement\ power\ Factor}{\sqrt{1 + THD^2}} \tag{4}$$

The RMS value of the total voltage and current is Vrms and Irms respectively.

There are two types of PFC

1) Passive PFC
2) Active PFC

1) Passive PFC-

The simplest form of PFC is passive PFC. A passive PFC uses a filter for correction of poor power factor at the AC input. The passive PFC circuit only uses a passive part of the inductor and some capacitors (Fig.2). A passive PFC rarely achieves low total harmonic distortion (THD), although thankfully simple and robust. Also since the circuit operates at a low line supply frequency of 50 Hz, the passive elements are generally heavy and bulky. They do not produce EMI and provide a low-cost alternative to follow harmonic current cutoff determinations. The drawback of passive PFC is its size and weight, which is due in part to the associated inductor.

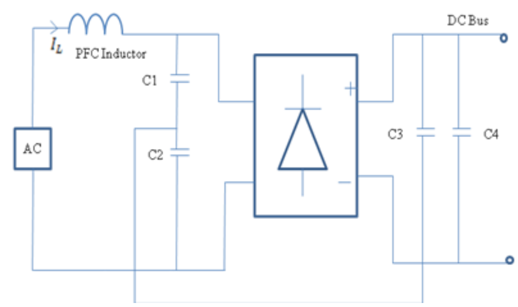

Fig. 2: A passive PFC circuit

2) Active PFC

The active PFC has a lower THD and is slightly smaller and lighter than the passive PFC circuit. (Figure.3). An active PFC operates at a higher switching frequency than the 50 Hz line frequency, given the size and cost of the passive filter components. Active PFC, Buck, Boost, Flyback and other topologies are used on the converters. The input electrical device of the dc-dc converter also good from the active PFC. The capacitor can be built in place of a much larger capacitor that would be needed to smooth the 50Hz input, to filter the high-frequency ripple of the active PFC circuit. The DC-DC Converter’s controlled input also demands a lower duty cycle range from the DC-DC Converter. Some advantages associated with active PFC include increased "hold-overtime". The holdovers (protection against brownouts) also use the highest voltage and since power is attached to the capacitor.

Advantages of Active Power Factor-

- Lower harmonic input current compared to passive output the factor correction technique.
- A power factor close to unity and a lower THD is possible.
- Effective power factor correction techniques for higher power rates can result in size, weight and cost advantages over the strategies of passive power factor correction.

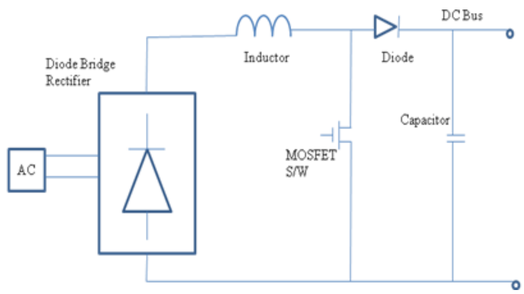

Fig. 3: An Active Power Circuit

Boost converter-

An active PFC is the best power factor correction method. A boost converter is connected in the middle of the bridge rectifier and also the load. The converter aims to keep up a continuing dc output bus voltage and attracts current together with and at identical frequency because of the line voltage. Through using this process, it is clean to adjust the boost converter output to keep the source current waveform is sinusoidal and in phase with supply voltage. It allows the component of force to be held as close to unity. PFC pulsed input current techniques are used to avoid the problem. The use of active PFC techniques supported switching power converters can give the most effective performance. The amplification topology is much more common than other PFC techniques. A boost converter circuit diagram is shown in Figure.4.

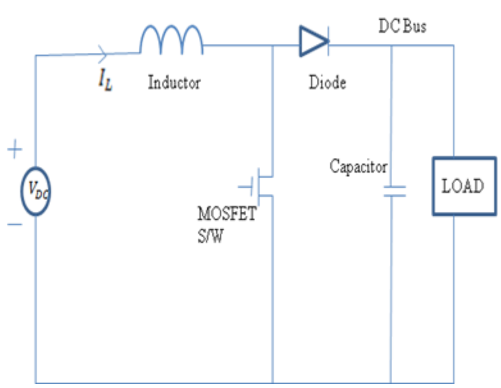

Fig. 4: Boost converter

The inductor goes up and in when the switch is set to current. The current I_L decreases when the turns S is off and discharge into inductor, Diode, capacitor and load. The current drops before the switch S is still on.

A voltage and current relation for the inductor L is

$$V = L\frac{di}{dt} \quad (5)$$

For a constant rectangular pulse

$$i = \frac{Vt}{L} + io \quad (6)$$

When S switch is on, then:

$$\Delta i = \frac{(V_{in} - V_{switch})T_{on}}{L} \quad (7)$$

If the switch is off again:

$$\Delta i = \frac{(V_{out} - V_{in} + V_D)T_{off}}{L} \quad (8)$$

Hence V_D is the voltage drop across the diode D and V_{switch} is the voltage drop across the MOSFET.

By equating equation (5) and equation (6), we get

$$\frac{(V_{in} - V_{switch})T_{on}}{L} = \frac{(V_{out} - V_{in} + V_D)T_{off}}{L} \quad (9)$$

$$V_{in} - V_{switch} D = (V_{out} + V_D)(1 - D) \quad (10)$$

$$V_{out} = \frac{V_{in} - V_{switch} D}{1 - D} - V_D \quad (11)$$

Neglecting the voltage drops across the diode and MOSFET

$$V_{out} = \frac{V_{in}}{1 - D} \quad (12)$$

And the output voltage is directly related to the duty cycle. The biggest challenge is what type of inductor to use when designing a converter. From the above calculations, it can be seen that the inductance is inversely proportional to the current of the ripple. But a bigger inductor should be used to popular the ripple.

The boost inductance value is

$$L = \frac{D * V_{in}}{f_s * \Delta I} \quad (13)$$

The boost capacitance value is

$$C = \frac{I_0 * D}{f_s * \Delta V} \quad (14)$$

And the boost converter draws the input current continuously. Using the average current mode control technique, this input current will be regulated to observe a sinusoidal relationship.

III. PROPOSED METHOD OF APFC

An APFC is the best power factor correction method. The block diagram is shown in the figure. 5. A boost converter in the middle of the bridge rectifier and the load is also in operation. The converter aims to keep up a continuing dc output bus voltage and attracts current in combination and the identical frequency because of the line voltage. A full-wave rectifier is a circuit structure that uses all half input alternating current (AC) cycles and transforms them into direct current (DC). And a full-wave rectifier is much more powerful than a half-wave rectifier. This method of transforming all input half-cycles to direct current is called full-wave rectification. Average Current control boost Converter was used in this work for power factor improvement and total harmonic distortion. The convertor aims to keep up a continuing dc output bus voltage.

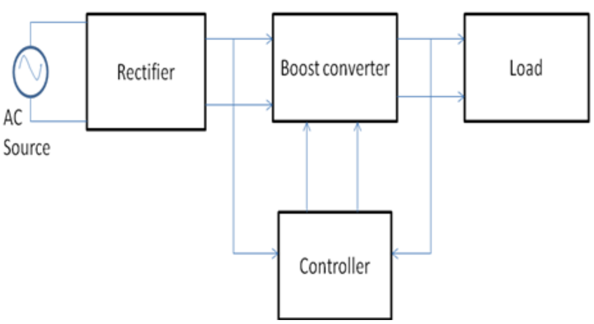

Fig. 5: Block Diagram

The circuit diagram using Boost Converter for the Average Current Control method as shown in Figure.6 below. The step-up converter is a very efficient DC / DC switching converter for boosting power. A MOSFET is used and the converter to modulate the voltage. In inductor side rectangular voltage pulses at that time current are triangular. In this method continues mode is used. Because the current in inductor side not to zero. The negative feedback is also important for regulating the output voltage. The feedback regulates the current of an inductor with a particular point and also supports the dc voltage close to unity power factor. The typical current control system for managing the power factor approach is used here.

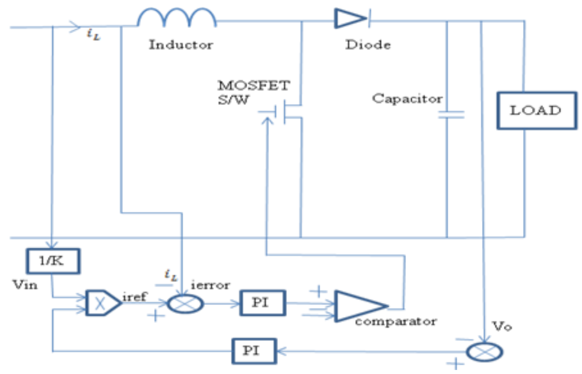

Fig. 6: Average Current Mode Control

The current control loop and the voltage control loop are used in the average current mode. The output voltage is compared to the reference voltage of the PI controller and the inductor current i_L is compared to the i_{ref}. The i_{ref} obtained by a resistive divider with a scaling factor of decrease the line voltage and multiply it by the voltage of the PI controller. and the i_{error} get from the inductance gives controller PI. The result is relative to the saw wave, giving the active PWM signal switch. Each has its drawbacks and qualities all of the obtainable methods for improving the power factor. The average current control method is good for another method. The THD is low and input current in sinusoidal form.

IV. SIMULTION AND RESULT

In this paper, simulation is completed in MATLAB programming. In the first simulation model of simple bridge rectifier shows an actual issue with the power factor, THD and waveform distortion. Understanding issues is a decent beginning stage for taking care of any issue. This model doesn't utilize any remedial against the present issue. Second simulation model of the nonlinear load is finished with remedial against the previously mentioned issue and result improves waveform of line current, power factor and THD. The main object of these studies is to enhance the shape of input current waveform and keep the power factor close to unity.

Case - With RL load

A. Simulation diagram of simple bridge rectifier

The simulation of a simple bridge rectifier model is shown in Fig.7. Single-phase complete bridge diode rectifier with broad capacitor estimate has a poor power factor on the supply side. The inductor is set 0.01H; capacitor is 47uf and load 400ohms. Input current waveform and input voltage waveform shown in Fig.8 and Fig.9. Also, THD analysis shown in Fig.10.

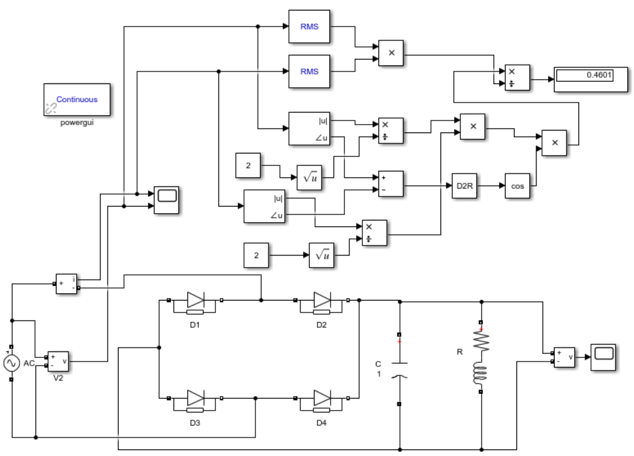

Fig.7: A simulation model of a simple bridge rectifier

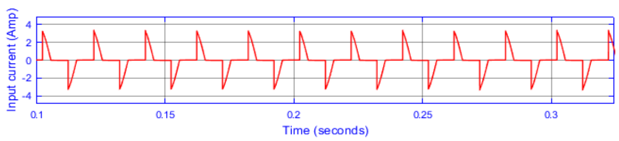

Fig.8: Input current waveform

Fig.8. shows scale input current of a simple bridge rectifier. This waveform shows that the input current non-sinusoidal.

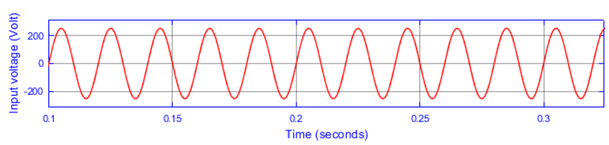

Fig.9: Input voltage waveform

Fig.9. shows the input voltage of simple bridge rectifier. Above voltage waveform is sinusoidal.

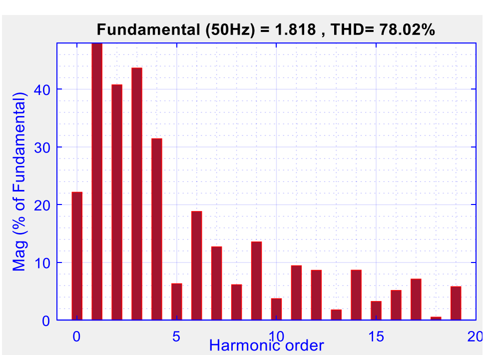

Fig.10. Total harmonic Distortion

The total harmonic distortion of the simple bridge rectifier is shown in above fig.10. If the THD is 78.02%. So the minimize the THD by using average current control mode. The input power factor, in this case, is about 0.46.

B. Simulation model APFC

Average current control technique a boost converter in the middle of the bridge rectifier and the load. The inductors are set to 0.01H; capacitors are 10uF, resistance 400ohms. And input RMS voltage 230V supply. So the switching frequency is 10 kHz. Figure 11 shows a simulation model APFC.

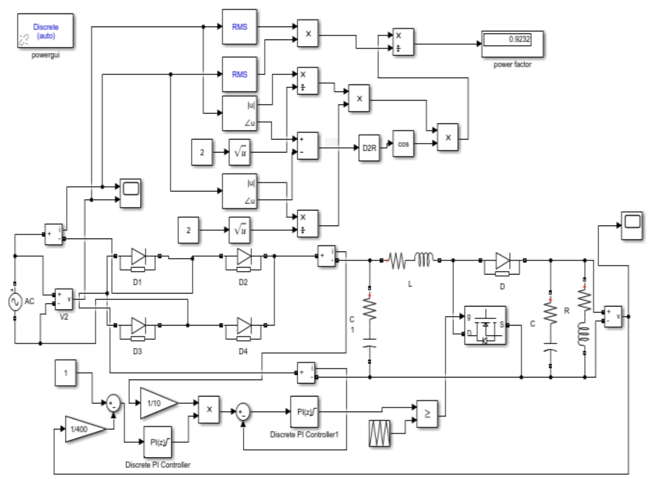

Fig.11: A simulation model APFC

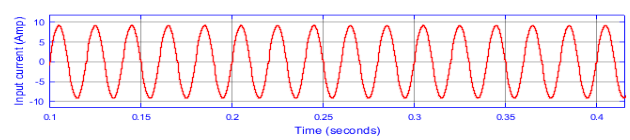

Fig.12: Input current waveform

Fig.12.shows scale input current waveform with power factor improvement. This waveform shows that the input current is sinusoidal wave shape.

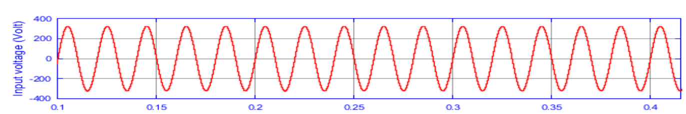

Fig.13: Input voltage waveform

Fig.13. shows the input voltage of simple bridge rectifier. Above voltage waveform is sinusoidal.

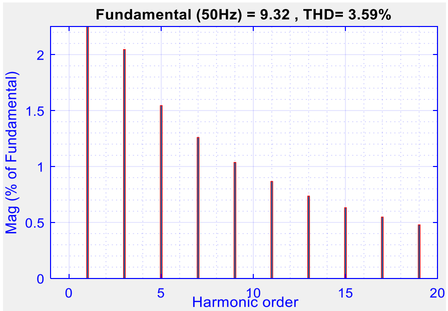

Fig.14. Total harmonic Distortion

The total harmonic distortion (THD) of the input line current of the simple bridge rectifier is shown Fig.14. The THD is 78.02% reduced to around 3.59%. The input power factor, in this case, is about 0.92.

Comparison of Result

Form the simulation; it is clear that a simple bridge rectifier with a large value of capacitor has poor power factor at the supply side. Which creates odd harmonic which is very harmful and line current does not follow sinusoidal waveform. But all these poor results overcome in the second simulation and it gives high power factor, low THD and current is sinusoidal in shape.

Table.1. Comparison of Result

Parameter	Bridge Rectifier	APFC
Power factor	0.46	0.92
THD	78.02%	3.59%
Current shape	Pulsating	Sinusoidal

V. CONCLUSION

APFC is preferable the power factor improvement on the delivery side while the load RL is connected to the converter side. The boost converter is attached as the interface between the bridge rectifier and the load. In rectifier power factor is low and THD is high. To overcome this problem by using APFC. The result of the simulation the source side power factor is improved and THD will decrease. The power factor of the source side is 0.46 lagging to 0.92 and THD is decreased from 78.02% to 3.59%.

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