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Power factor improvement of SMPS using PFC Boost converter

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ABSTRACT

The increasing growth in the use of electronic equipment in recent years has resulted in a greater need to ensure that the line current harmonic content of any equipment connected to the ac mains is limited to meet regulatory standards. This requirement is usually satisfied by incorporating some form of Power Factor Correction (PFC) circuits to shape the input currents, so, they are sinusoidal in nature and are in phase with the input voltages. There are multiple solutions to make line current is nearly sinusoidal. This paper presents a technique for single phase power factor correction of non-linear loads using an active power filter. This paper also deals with the control strategy of the boost converter in power factor correction (PFC) for SMPS.

Keywords: Power factor correction (PFC), Switch mode power supply (SMPS), Boost converter.

1. INTRODUCTION

The main ac supply convert in to dc consisting of a line frequency diode bridge rectifier with a large output filter capacitor is cheap and robust, but demands a harmonic rich ac line current. Using rectification circuit, the input power factor is poor [1]. Different power factor correction (PFC) techniques are employed to overcome these type of power quality problems [2] out of which the boost converter topology has been extensively used in various ac/dc and dc/dc applications for power factor correction. In fact, today's ac/dc power supplies with power-factor correction (PFC) is almost exclusively implemented with boost converter [3], [4], [5]. The low power factor and high pulsating current from the AC mains are the main disadvantages of the diode rectifier. Rectification used in SMPS. So, power factor of SMPS is very poor. A passive filter is often used to improve the power quality because of its simple circuit configuration but, bulk passive elements, fixed compensation characteristics, series and parallel resonances are the main drawbacks of this scheme. Several circuit topologies and control strategies of power factor correctors have been posed to perform current or voltage harmonics reduction and improve the power factor nearly unity [6], [7].

This paper initially involves simulation of basic SMPS circuit using boost topology and the analysis of the current and voltage waveforms. It starts with simple circuits and switches to advanced circuits by implementing advanced techniques such as active PFC and their subsequent effect on the current and voltage waveforms expecting better results, mainly focusing on the objective of improving the input current waveform i.e. making it sinusoidal by tuning the circuits. All the simulation work is carried out in PSIM.

2. POWER FACTOR

The power factor of electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit and dimensionless number between 0 and 1. Real power is the capacity of performing work in circuit in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power.

A load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred in an electric power system. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Electrical utilities will usually charge a higher cost to industrial or commercial customers because of the costs of larger equipment and wasted energy, where there is a low power factor.

The low power factor (such as induction motors) of linear loads can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, drawn from the system, distort the current. Generally, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The power factor correction devices may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

3. SMPS DIFFERENT TOPOLOGIES

The circuit configuration which determines how the power is transferred is called the TOPOLOGY. Different topologies are an extremely important part of the design process.

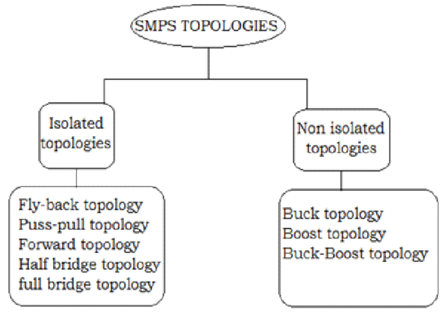

Figure 1 SMPS topologies

The S.M.P.S. topology contains a power transformer in most applications. This provides isolation, voltage scaling through the turns ratio, and the ability to provide multiple outputs. However, there are non-isolated topologies (without transformers), where the power processing is achieved by inductive energy transfer alone.

4. POWER FACTOR OF SMPS USING DIFFERENT TOPOLOGIES

The SMPS using Fly-back topology is shown in figure2. It is called isolated topology because of using transformer. The SMPS using Boost topology is shown in figure3. It is called non- isolated topology because of not using transformer.

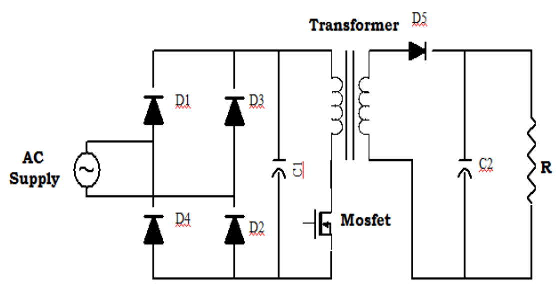

Figure 2 SMPS using Fly-back topology

These both topologies have poor power factor because of input current is pulsating type. So, improvement of power factor is necessaries.

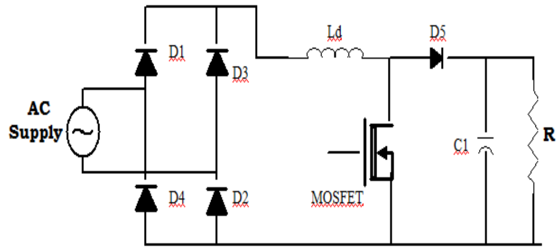

Figure 3 SMPS using boost topology

5. POWER FACTOR CORRECTION

It is a technique of the undesirable effects of electric loads that create a power factor less than 1. The apparent power delivered to the load is greater than the real power which the load consumes when an electric load has a power factor lower than 1. The apparent power determines the amount of power that flows into the load and the real power is capable of doing work, combining both active and reactive components.

The purpose of the power factor correction circuit is to minimize the input current waveform distortion and make it in phase with the voltage one. Most of the research on PFC for nonlinear loads is related to the reduction of the harmonic content of the line current. There are several methodologies to achieve power factor correction. They can be categorized as “Passive” or “Active”.

In “Passive” PFC, only passive elements are used in addition to the diode bridge rectifier. This method improves the shape of the line current but the output voltage is not controllable.

For "Active" PFC, active switches are used in conjunction with reactive elements in order to increase the effectiveness of the line current shaping and to attaining controllable output voltage. The switching frequency range further categorizes into two classes. In "low-frequency" active PFC, switching takes place at low-order harmonics of the line-frequency, thus synchronized with the line voltage. In "high-frequency" active PFC, the switching frequencies are much higher than the line frequency. For power factor correction, Boost converter is widely used.

6. CONTROL STRATEGY

The AC supply voltage is rectified and supplied to the Boost topology. It mainly consists of an inductor, a power MOSFET, power diodes and bulk capacitors. The Error Amp 2 with predetermined reference voltage senses the DC output voltage across the bulk capacitor. The error voltage Ve2 from the amplifier then is fed to the multiplier and multiplied with the template sinusoidal input voltage to get the reference current, i_L(reference). The error Ve1 that is the output of Error Amp 1, as the difference of i_L(actual) and i_L(reference) provides the correct timing logic for the switching driver circuit to turn on and turn off the MOSFET in the Boost converter. Hence, this method ensures continuous conduction of current flow for the full cycle of the input voltage. The PFC control strategy block diagram as shown in fig.4.

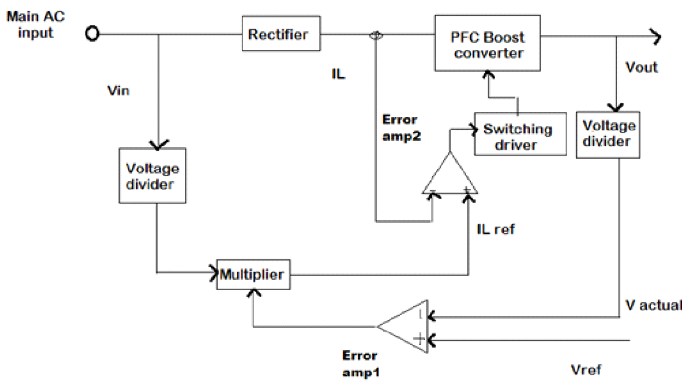

Figure 4 The PFC control strategy block diagram

7. SIMULATIONS AND RESULTS

This paper involves simulation of basic SMPS 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. All the simulation work is done in PSIM.

7.1 Simulations and results for SMPS using fly-back topology

Fig 5 shows SMPS circuit using fly-back topology. The circuit is simulated using PSIM and input current with respect to input voltage waveform are plotted in graph as shown in figure 6 and output waveforms are plotted in graph as shown in the figure 7. The input current waveform consists of Total Harmonic Distortion.

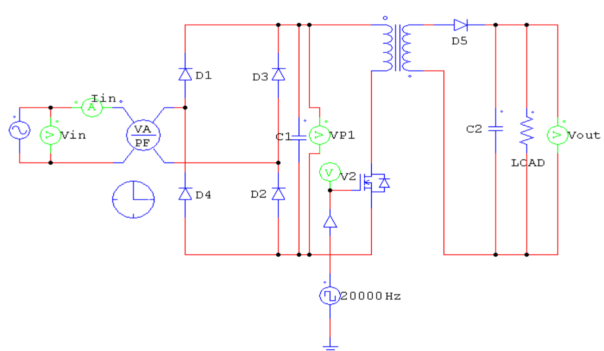

Figure 5 SMPS using Fly-back topology

Vp-p = 230V, C1 = $460*10^{-6}$F, C2 = $500*10^{-6}$F, R = 144 Ohm, F =50 Hz, switching Frequency =20 khz

It is clear that the Power Factor is 0.390 by the measuring which is very low and it needs to be improving by using proceeding methods.

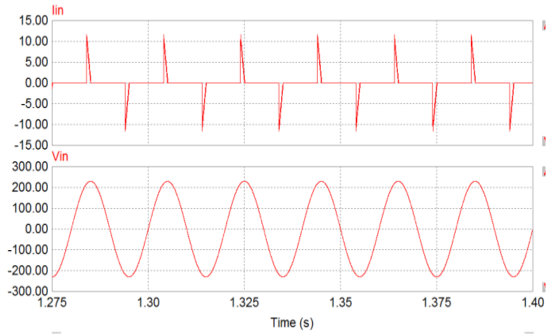

Figure 6 Input current and input voltage

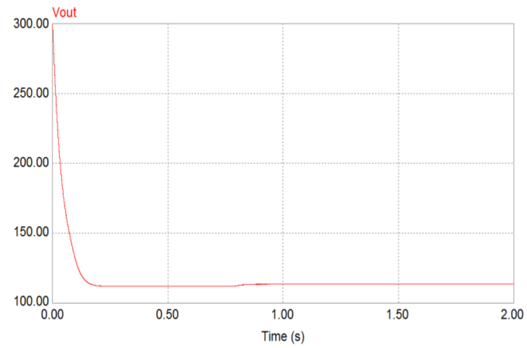

Figure 7 Output voltage at initial condition

7.2 Simulations and results for SMPS using boost topology

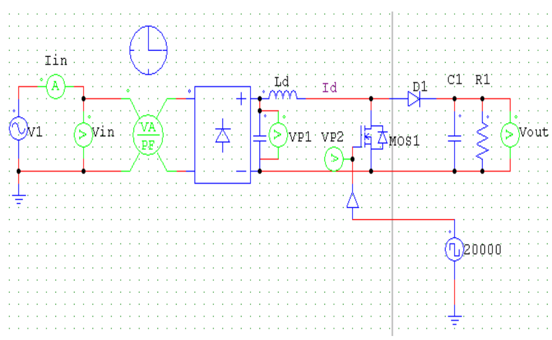

Figure 8 SMPS using boost topology

Vp-p=230V, C2 = 300×10^{-6}F, L_d =0.001H, C1 = 0.002F, R = 144 ohm, F= 50Hz, switching frequency = 20khz

The circuit is simulated using PSIM and input current with respect to input voltage waveform are plotted in graph as shown in the figure 9 and output waveforms are plotted in graph as shown in the figure 10.

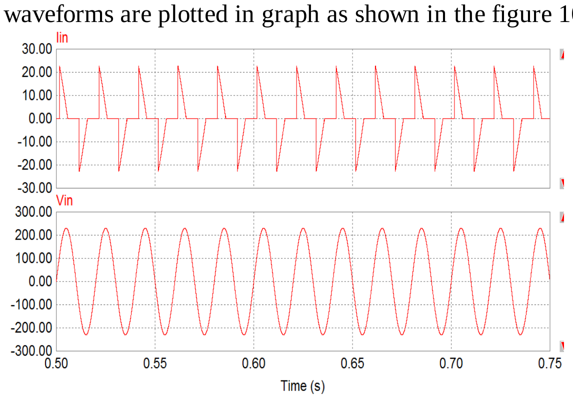

Figure 9 Input current and input voltage

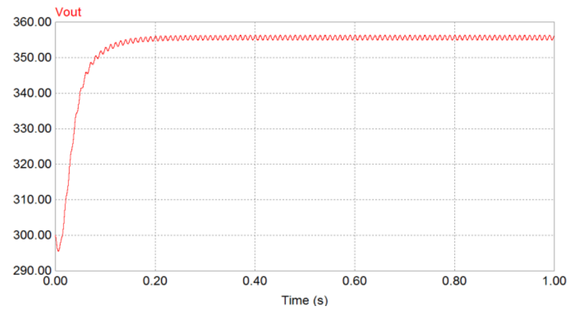

Figure 10 Output voltage at initial condition

From the simulation get the idea that Power Factor of SMPS using boost topology is poor. It is 0.619.

7.3 Simulations and results of SMPS using PFC boost converter

Using the control strategy for power factor improvement of SMPS, It called PFC circuit. Power factor correction in SMPS using boost topology shown in figure11.

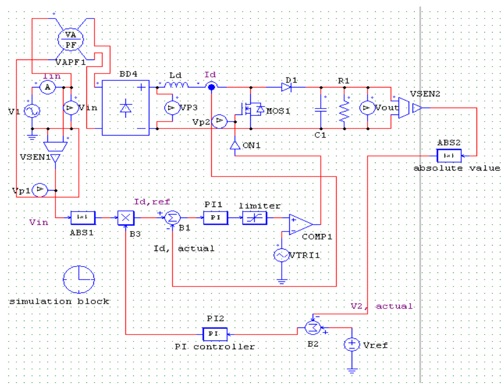

Figure 11 SMPS using PFC boost converter with Ld = 0.005H

Input current wave shape nearly sinusoidal. Input current and voltage shown in figure12 and output voltage shown in figure13.

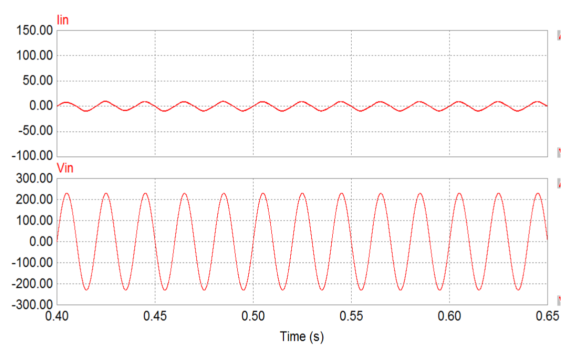

Figure12 Input current and input voltage

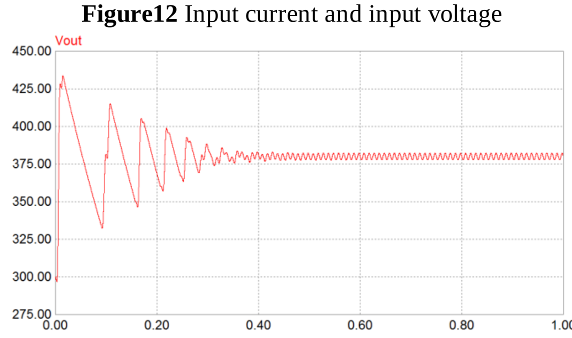

Figure13 Output voltage

Using PFC boost converter in SMPS, Power factor is improve nearly unity.

Table 1: Measuring of power factor

Sir. No.	SMPS topology	Power factor
1.	Fly-back topology	0.390
2.	boost topology	0.619
3.	PFC boost converter	0.999

8. CONCLUSION

From the simulation SMPS using fly-back topology and boost topology, power factor is poor. When SMPS with PFC boost converter, power factor is improved nearly unity.

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