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ACTIVE POWER FACTOR CORRECTOR CIRCUIT USING AVERAGE CURRENT CONTROL

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ABSTRACT

A basic electric vehicle charger consist mainly two stages. Stage one is AC to DC conversion and second stage is step up or step down the DC voltage. First stage is the AC to DC conversion stage, in this stage we use rectifier to convert AC supply in to DC supply. Output of full wave rectifier is pulsating DC voltage. This is not desirable for battery charging. To make this constant we required a filter circuit. Filter circuit make the output voltage constant but it reduces the input power factor. This low power factor is not good for grid. We can improve this power factor by using inductive filter. This inductive filter will improve the power factor considerably. Although PF is increased compare to without filter circuit, but still it is poor power factor. For a good power factor size of inductor will be large. Sizes of inductor filter also a major concern. It also increases the cost of the system. Due to these problems we move towards the active filters. Active power factor corrector circuit is the combination of bridge rectifier and the DC-DC converter. AC to DC conversion stage is replaced by the active power factor corrector (APFC) circuit in modern chargers. APFC circuit improves the input power factor and reduced harmonics in line current. It reduced the THD and increased the power factor. Boost circuit based power factor corrector circuit has designed average current control strategy. This circuit is operating in continuous conduction mode (CCM).

KEYWORDS: *THD, APFC, Average current control*

1. INTRODUCTION

One of the biggest successes of contemporary technologies is the creation of internal combustion engine vehicles in particular cars. Cars have contributed much in meeting many of their daily transportation demands to the progress of modern civilization. In contrast to any other industry, the speedy growth of the automobile industry has led human society to advance from an early one into a highly developed industrial civilization. The automobile sector and the other sectors it serves form the backbone of the economy of the word and employ the largest part of the work force. The activities of research and development connected to transport over the past couple of decades have highlighted the development of high efficiency and clean transport and development activities. In the near future electric vehicles, electric hybrid cars were usually recommended as the replacement of conventional automobiles and petrol automobiles. Demand of electric vehicle is increasing rapidly day by day. This rapid increment in demand of electric vehicle due to some major factor like, Electric vehicles are fuel efficient, less pollutant, reduced the carbon emission, less damage to environment. The high cost of electric vehicle also is major issue. Now a day’s electric vehicles starting cost is very high but maintenance cost is very low compare to the IC engine vehicles. This rapid increment in the demand of EVs might be transform0the automotive industries like never before. EVs use electricity as fuel. Electric vehicles use battery storage system power supply. These batteries are rechargeable. It can be charged with help any AC supply single phase or three phase. For charging of electric vehicle we require a charger which supplies electrical energy for the battery. These batteries are mostly Li- Ion battery. Because Li-ion batteries has some massive advantage compare to the other batteries. With the extensive modernization and electrification of the industries, the demand for power quality has significantly increased. They have a certain power quality need for personal computers, electronic equipment, mobile phones. Poor power quality can cause electrical equipment not to perform correctly or not to operate. Power quality is an important component that directly affects power factor. Small power factors are likely to create various undesirable impacts, such as waveform distortion of the power grid and substantial line loss, which can lower power device service time. As electricity in people's lives becomes more significant, a growing variety of power gadgets with various functions are available. Power is 220V and 50 Hz from the domestic grid. However, most power devices need a separate input than the voltage and current that we receive from the national grid. The following 4 kinds of converter circuits are present: AC-DC, DC-DC, D-CAC and AC-AC. Currently, the most often used conversion circuit of AC-DC, which converts power to direct current. And this type of circuit is known as rectifier circuit. Rectifier circuit has numerous uses, such as uninterrupted power supply devices (UPS). Rectifier may operate as an interface circuit between power grid and power electronic devices. The Power Factor is an important power system characteristic. Switching devices are widely employed in various power conversion devices by broad use of power electronics in industry. As we know electric vehicle require Dc supply for charging of the electric vehicle. But grid is AC supply with 220V, 50 Hz. So we cannot charge electric vehicle directly through the electric grid. We need a converter that convert AC electrical input into the DC supply. Rectifier is a circuit which converts electrical energy into DC energy. Input power factor of the rectifier is very low. Basic electric vehicle charger consist of two stage, one is AC to DC conversion other is DC to DC stage to step up or step down as per requirement of the output. AC to Dc conversion stage is known as the power factor correction state. We use APFC circuit to make power factor of input side to unity. This power factor is distorted by the input rectifier. In this project work, explain various methods of active power factor correction. Active power factor corrector circuit is consist two converter. One AC to DC converter and other one is DC to DC converter. DC to DC converter may be Buck, Boost, Buck boost, Flyback or Cuk converter. In these all type of DC-DC converter Boost converter best for power factor corrector application.

2. LITERATURE REVIEW

In this section we will disused about the various technique of power factor correction and analyze them briefly. There are mainly two type of power factor corrector circuit. These are the passive power factor correction and Active power factor Correction Circuit. Passive PFC method is only useful for low power application. Passive power factor corrector circuits are bulky in size. Passive PFC is not able to correct power factor in good manner. It can correct power factor 0.65 to 0.80. Up to these values, size of inductor is not large. In passive PFC circuit inductor and capacitor (Filter circuit) is design according to the supply frequency. Supply frequency is low. Due to low frequency Size of filter circuit is large. The size of inductor is inversely proportional to the line frequency. Lower the frequency larger the size of inductor filter. Size of inductor is very much reduced in APFC. In APFC size of inductor is small. Here we will discuss both type PFC circuits.

A. Conventional methods of PFC

Conventional power factor correction method consist only passive component. Combination of inductor and capacitor and capacitor is can be connected at output or input side of rectifier as per the load requirement. Figure 2.1 illustrates a famous system with an inductor is placed between the rectifier output and the capacitor. This inductor increases the input side power factor. This inductor also increased the conduction angle of current pulse. But it also reduced the peak and RMS values of the current. This type of filter can correct the power factor up to 0.75

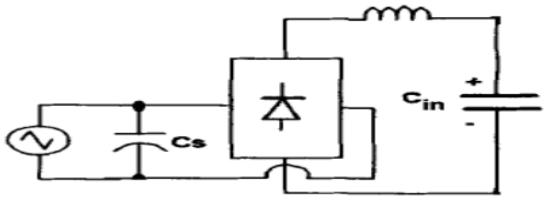

Fig. 2.1 Passive power factor correction

B. Active power factor corrector (APFC)

APFC consist two circuits, one is rectifier (AC-DC) and other is DC – DC converter. In APFC rectifier is cascaded with a DC-DC converter. In most of the cases we use bridge type rectifier. In case of DC–DC converter we can use various type converters like, Boost Converter, Buck Converter, Buck-Boost Converter, SPIC converter, Flyback converter. These all type of converters has some advantages and disadvantages. Fig 2.2 shows the basic circuit Diagram of Active boosts PFC. There are several type of topology APFC. Here we will discuss them

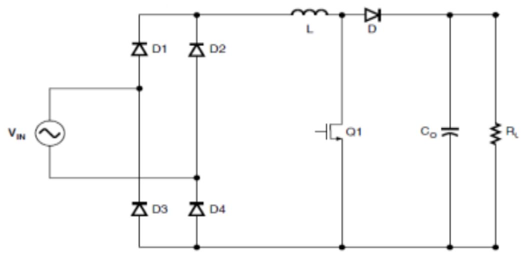

Fig. 2.2 Active boost PFC circuit

Boost APFC is most basic type of power factor corrector circuit. A bridge rectifier is cascaded with the Boost converter. Boost Converter is operating in the CCM mode. Hysteresis current control method is used for input wave shaping. In HCC we did not require any ramp compensator. Distortion in input current is very low [8]. HCC also has some disadvantages. In HCC switching frequency is not constant. HCC is sensitive to the commutation noise [11]. Flyback converter based topology of Active power factor corrector circuit has proposed in [14]. Flyback topology is also known as the isolated APFC. Flyback converter based topology is compare with the boost topology and observe that the power loss in Flyback converter based topology is low [16]. It is good for high power application. The response time of Flyback topology is very fast. These all APFC circuit is suitable for low power application. If we connect two circuits in parallel then this will increase the current rating. This method is known as interleaving of converter. With help of interleaving we can use any circuit for high power application. Rating of the circuit will increase but it leads to high conduction losses in converter. These losses will reduce the efficiency of the converter circuit. Controlling of this type of converter also very complex, due to this these type of converter are not uses for high power application. Efficiency of rectifier based Active power factor circuit is low. In rectifier based APFC minimum 3 diode conducts at time. High conduction losses of diode cause the poor efficiency of APFC. If we reduces number of diode conduction per switching cycle, than conduction losses will be decreases. Efficiency of the converter will be increased. Bridge topologies are suitable for high power application [19]. Bridgeless topology of APFC has present in [19]. In bridgeless topology of APFC rectifier is not present. Bridgeless buck boost APFC circuit has been shown in the fig 2.3 Conduction losses in the BL active power factor corrector circuit are very low. This leads to high efficiency of the circuit. Due to low losses, this type of converter can be work in the discontinuous conduction mode. In DCM mode input current is nearly sinusoidal.

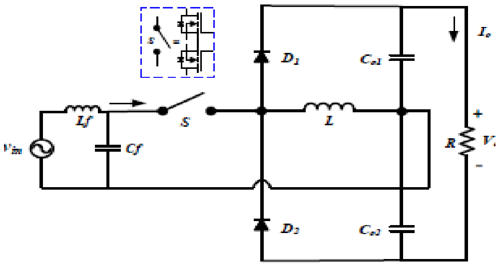

Fig.2.3 Bridgeless APFC Circuit

3. OPERATION OF ACTIVE BOOST PFC CIRCUIT

Figure 3.1 depicts a Boost PFC converter power stage circuit schematic initially input voltage is rectified by Input Bridge rectifier after this, it is provide to the boost converter. Boost converter make input in phase with input voltage.

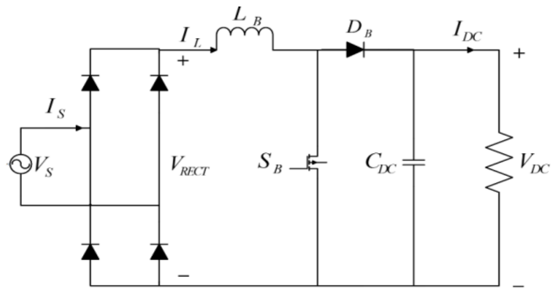

Fig 3.1 Boost APFC circuit

A. Switching operation

Before the boost converter, the line voltage is transformed into a rectified DC voltage by a diode rectifier. Electrically rectified voltage, from nil to the peak of the supply voltage, is the input voltage of the Boost converter. For any instance of theta this voltage varies sinusoidal. Rectified Dc output is assumed as constant voltage for the purpose of boost converter analysis. This circuit operation can divide into the two stage one for positive half cycle and other for negative half cycle.

fig 3.3 shows that switch is on(0 < t < DT). MOSFET is triggered by suitable gate pulse. During on time inductor stores the energy directly through rectified voltage and load is supplied by output capacitor. Figure 3.4 shows that switch is between (DT< t < T) in this time period inductor start releases his energy and supply to the load.

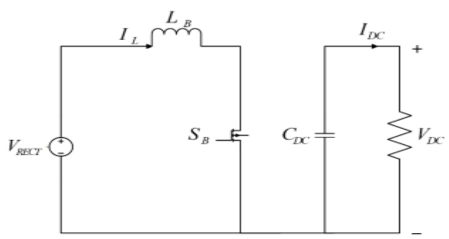

Fig 3.2 Boost Converter Operation, when Switch is on

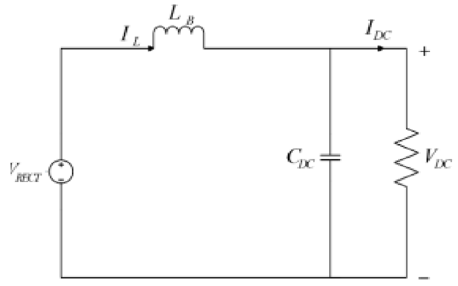

Fig 3.3 Boost converter operation when Switch is off

B. Control strategy

The APFC circuit has two sections, one of which is the main circuit, the other the controller. Fig 3.4 shows a diagram boost APFC with using average current control technique. Now we will discuss operating principle of power factor correction circuit. Firstly output voltage is compare with desired output voltage (reference voltage) after comparison resulted output goes into the voltage error amplifier. Now after this the output of voltage error amplifier and rectifier input voltage goes into the multiplier circuit and multiply with reference voltage and generate reference current in this will goes into the current amplifier and it will be compare with the input current. Now the output of the current error amplifier goes into PWM generator. PWM generator will be control the duty cycle of the mosfet and make the input current and voltage in same phase.

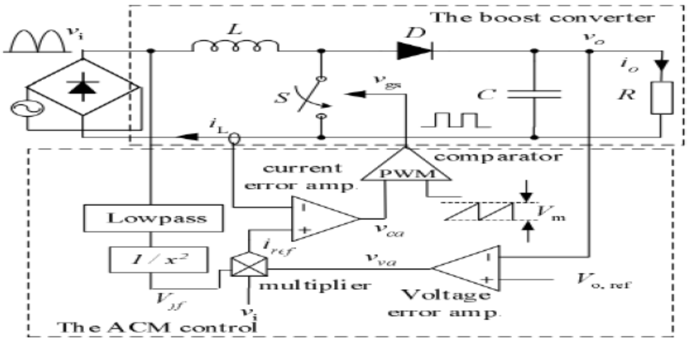

Fig 3.4 Controlling diagram of boost PFC circuit

4. SIMULATION RESULT

Table. 4.1 Specification of converter

Parameter	Value
Output power	1 Kw
Output voltage	400 volt
Input voltage	230 volt
Input frequency	50Hz
Switching frequency	250 KHz

Boost active power factor corrector circuit is simulating in MATLAB/Simulink. Converter design specification is given in table 4.1. For 1 Kw system at output voltage 400 volt and input frequency 50 Hz simulation is perform. From the output waveform we can observe that input current is in the same phase with Supply voltage. Hence we can say converter is operating under the UPF operation. FFT analysis of input current is performing. From FFT analysis we can see THD is reduced up to 6%. It is near to the IEEE standard. We can further decrease the THD by tuning the PI controller. This much reduction in also improve the power factor of the supply side.

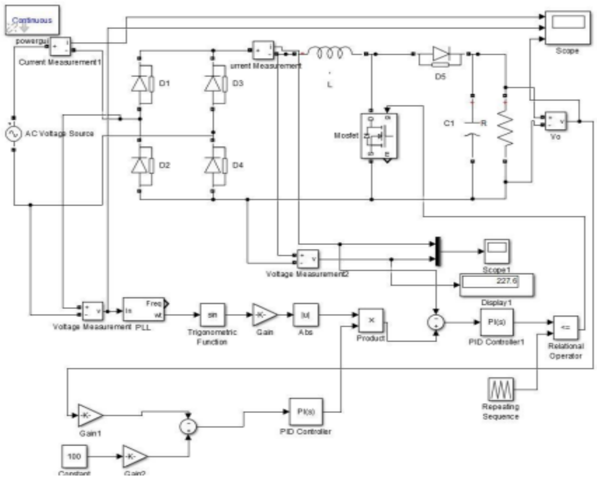

Fig 4.1 Simulink model of Boost Active Power factor correction circuit

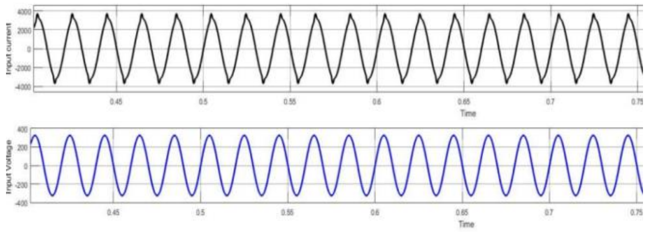

Fig 4.2 Boost active Power factor corrector circuit wave form of Supply voltage and supply current

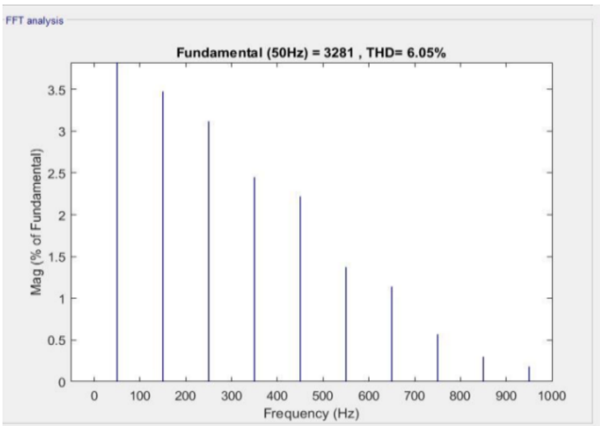

Fig 4.3 FFT analysis of input current

5. Conclusion

Study the various topology of Active power factor correction circuit. Active boost power factor corrector has design. This circuit is design for low power application. This circuit is operating under the continuous conduction mode (CCM). Average current mode (ACM) control method is used for make input current sinusoidal. In ACM two controller is require one for control the current and other is for control the output voltage. These two controllers make the converter controlling complex. Controlling is complex but efficiency of circuit is high. Power losses are low in this converter. Design converter having a power factor near to unity. The converter has total harmonic distortion (THD) of

6.05%. Active power factor corrector circuit operating at switching frequency of 250 KHz. Efficiency of converter is 94%.

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