Design an Interleaved Boost Converter for Power Factor Improvement of Single Phase Ac-Dc System

Deepak Kumar[1] Naveen Kumar Tiwari[2] Deepam Dubey[3]
[1,2]Department of Electronics Design & Technology
[1,2]NIELIT, Gorakhpur, India

Abstract— Power factor in an AC electrical power system is described as the ratio of the actual power passing though the load to the virtual power flowing through the circuit or the cosine angle of the potential and charge of an AC circuit. A phase difference Ø exists between the potential and charge of an AC circuit and cosine which is called the circuit's power factor. Suppose we get an inductive circuit we generally get the lagging by the voltage and that will be called a lagging power factor. And suppose we get the capacitive circuit then the current will be leading by the voltage and that will be referred as a leading power factor. The usage of power electronic system has reached to a new application stage that include residential, commercial, and aerospace and many others. Power electronic interfaces e.g. Switch Mode Power Supplies (SMPS) have proved to be superior over traditional linear power supplies. However their nonlinear behavior puts a question mark on their efficiency. The current drawn by the SMPS from the line is distorted resulting in a high Total Harmonic Distortion (THD) and low Power Factor (PF). Other adverse effects on the power system includes increased magnitudes of neutral current in three phase systems, overheating of transformers and induction motors etc. Therefore there is a continuous need of power factor improvement and reduction of line current harmonics. A large range of PFC circuits have been proposed with diverse operating modes to solve the situation. These PFC circuits adjust the waveforms of the current in the input side so that the maximum power can be tapped from the supplies. The current in this situation is free from all the lower as well as higher order harmonics thus copies the input voltage waveform. So this causes the current in the circuit to be at the lowest possible value to do the same work. the losses associated with circuit are reduced. Hence the consumption in power is reduced greatly. Boost converter accomplishes this active power-factor correction (ACMC) in discontinuous as well as in continuous modes.

Key words: Input Output Power, PWM Kit, Interleaved Boost Converter, Matlab 2009

I. Introduction

Power factor in an AC electrical power system is described as the ratio of the actual power passing though the load to the virtual power flowing through the circuit or the cosine angle of the potential and charge of an AC circuit. A phase difference Ø exists between the potential and charge of an AC circuit and cosine which is called the circuit's power factor. Suppose we get an inductive circuit we generally get the lagging by the voltage and that will be called a lagging power factor. And suppose we get the capacitive circuit then the current will be leading by the voltage and that will be referred as a leading power factor.

In an electrical power system, a low power factor load draws greater current than a higher power factor load for the equivalent ratio necessary power passed.

Power factor provides a ratio which shows the effectiveness of the actual power utilized in the system. It is a measure of distortion of the line current and their phase change.

Power factor= Real power (average)/Apparent power

The virtual power is known as the multiplication of the rms value of current and voltage. We can describe the real power like the power of the circuit for doing work in some known interval of time.

A. Linear System

For linear system, the load generally puts out clear sine voltage and current, so we can know about the Power factor jut by the change in phase of voltage and current.

I.e. PF=cos Ø

In a totally resistive circuital current and voltage graphs are in step (or in phase), if we reverse the polarity at the same interval for every cycle. The power getting into the load is utilized. A linear load never changes the structure of the graphs of the current, but it may differ the combined timing of the generated current and voltage

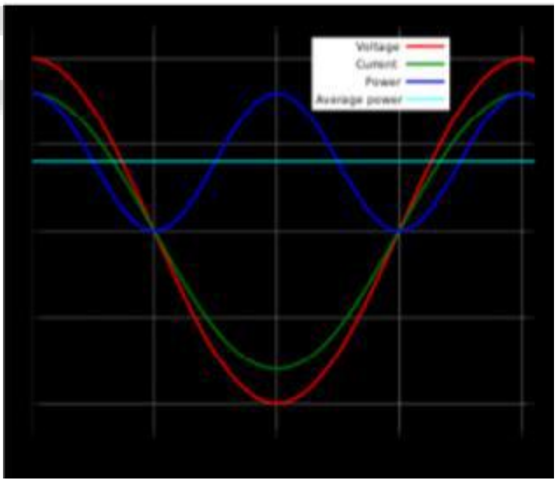


Fig. 1: Purely resistive load waveform

Some loads which are inductive like transformers and also motors intake power which is reactive and we get the lagging current waveform than the voltage. Capacitor banks which gives loads which are Capacitive produce extra power which is reactive and we get the leading current phase than the voltage.

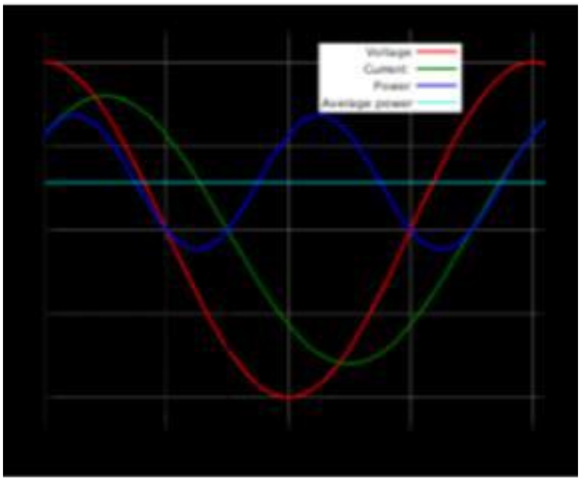


Fig. 2: Purely inductive load waveform

The different applications for AC-DC converters are speed drives which are adjustable. Switched Mode Power systems (SMPS), UPS, etc. Diode rectifiers can be utilized for the applications of different Power Electronic devices which are in connection with the AC utility mains. We can get the non-linear nature of the Diode rectifier and due to this we get harmonics in the current line, so due to this the destruction of the power quality which in turn increase the various losses in the device. In the beginning the capacitors and the inductors were very costly and they were used or decreasing the harmonics. Active Power Line Conditioners (ALPC) that were utilized for decreasing the harmonics are switched hard, which causes low efficiency. There are the Boost converter topology in which there is a continuous conduction mode (CCM) is put in medium power AC/DC converter, as they provide a power factor which is nearly equal to unity if we see from the input side of the terminals which is in this case is AC.

B. Harmonics

As the non-linear interrelation of the voltage and current throughout the switching devices, harmonic is produced by each type of switching converters. We can also produce Harmonics by the equipment's which are conventional which includes:

- Equipment that generates power (slot harmonics).
- Induction motors (saturated magnetics).
- 3. Transformers (saturation happens due to over excitation).
- 4. Magnetic-ballast fluorescent lamps (arcing) and
- 5. AC electric arc furnaces.

Low power factor means poor electrical efficiency. The lower the power factor, the higher the apparent power drawn from the distribution network. When low power factor is not corrected, the utility must provide the non-working reactive power, in addition to the working active power. This results in the use of larger generators, transformers, bus bars, cables and other distribution systems devices, which would otherwise be unnecessary. As the utility's capital expenditures and operating costs are going to be higher, they are going to pass these higher expenses down the line to industrial users in the form of power factor penalties.

II. PROBLEM FORMULATION

The primary directive extends to translate a PWM scheme in order that it offers a facility to shape the input current waveform to a sinusoidal fashion and provide an impetus to correct the input power factor. The exercise incites to evaluate its performance through both simulation and hardware implementation over a range of operating loads.

III. PROPOSED METHODOLOGY

Interleaved boost converter converters give greater efficiency as their capacity is enhanced. But it can act in different unknown ways due to the non-linear nature of the system.

Designing this system aims to make the current share between the two converters. Practically two voltage sources are impossible to be connected in parallel connection. But it may work if a proper control circuit is designed. Hence the Average current mode control is used to solve this problem.

In this method one converter is phase shifted from its counterpart. The main advantages of this method are:

- High reliability.
- Cheap, portable and compact.
- Greater reduction of ripples in input current.
- Reduction in loses due to conduction.
- The size of the inductor and capacitor is also reduced .

Boost converters are used in active power factor corrector. In recent years dual boost converters are used where two boost converters are connected in parallel. The circuit diagrams are shown below:

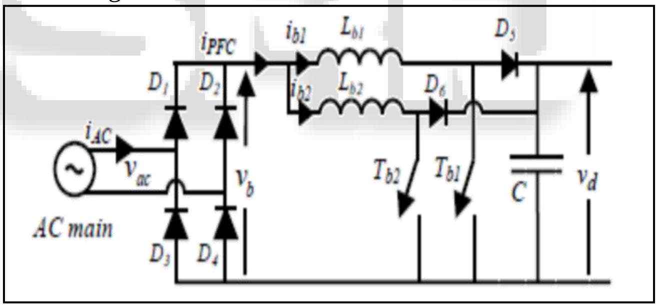


Fig. 1: Interleaved boost converter

The interleaved boost converter is a dc-dc converter which is a parallel connection of two ordinary boost converter with the pulses 180° phase shifted between them. It consists of two MOSFET switches, two inductor and two diode circuitry. The 180° phase shift was provided to the MOSFET switches, by using pulse generator. This phase shift was attained by direct connection of pulse generator ton one switch and the inverse was connected to other switch. This interleaved boost converter was better than the ordinary boost converter because it produces the output waveform with fewer ripples than the ordinary boost converter and output gain from the interleaved boost converter is also high.

Parallel scheme is used here where the choke L_{b1} and the switch T_{b1} are for main power factor corrector and choke L_{b2} and switch T_{b2} are for active filtering. The filtering circuit improves the quality of line current reduces the switching losses. Switching losses are reduced because of different values of switching frequencies and current amplitude.

IV. CONTROL ALGORITHM

The methodology echoes to design the PWM algorithm with a primary focus to generate the PWM pulses for the two power switches. It enforces the requirements of regulating the load voltage and improving input power factor. The input ac voltage is converted to the dc voltage through the use of diode bridge rectifier. The variable dc voltage acquired from is given to the load from where the error between the load voltage and actual voltage is calculated.

The voltage error is multiplied with constant gain K to determine the equivalent conductance.

The equivalent conductance is compared with the input voltage to generate the reference current

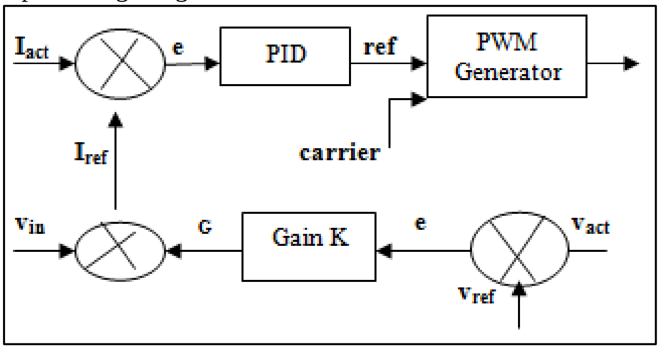


Fig. 2: control algorithm

The current reference is compared with the actual current to estimate how far the actual current is away from the sinusoidal reference voltage. The error is corrected through the PID controller as a part of wave shaping mechanism to produce the reference wave for the PWM pulses. The two level sawtooth carrier along with reference produces PWM pulses for the two power devices.

V. SIMULATION RESULTS

The procedure travels to investigate the methodology on a MATLAB platform. The specifications reiterate to support nov, 3.5kW RL load.exhibits the PWM pulses of the concurrent operation of both interleaved modes. The dc output voltage for two distinct interleaved set points shown in respectively further elaborate the regulating ability in both modes. The result of regulatory disturbance projected in explains the fortitude of the strategy to remain regulated at their respective operating points even when it is subjected to a sudden 10% change in load. The input voltage and current waveforms seen in refer to the open and closed loop modes and bring out the ability of the control scheme to improve the input power factor at the kW operating point.

A. *Simulation Model:*

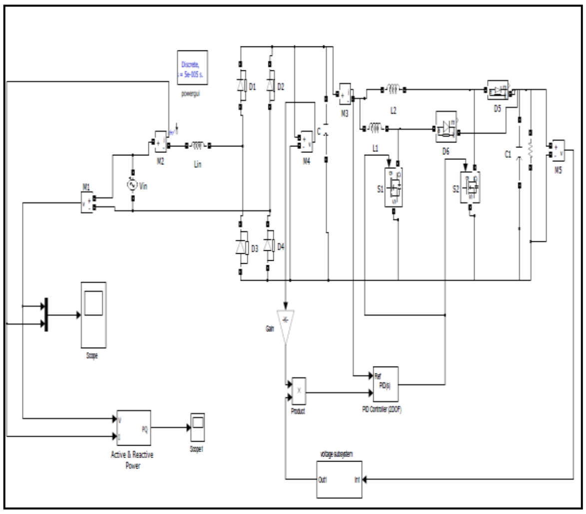
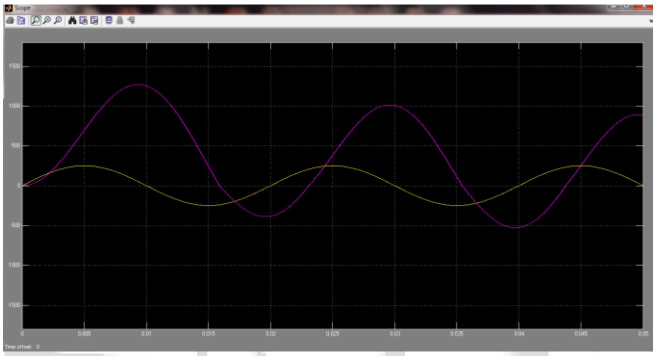
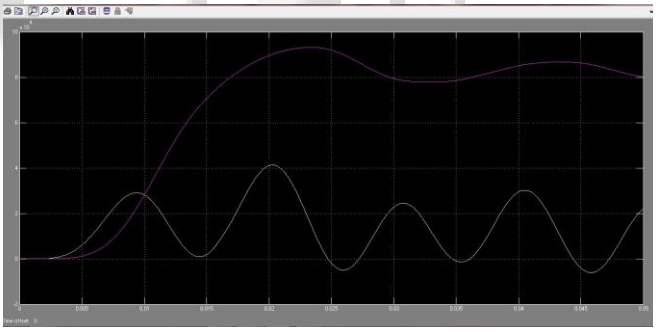


Fig. 3: Simulation Model

B. *Simulation Results (Input Current & Voltage)*



C. *Active and Reactive Power:*



1) *Rectifier circuit with a interleaved boost converter :*

Active Power, P= 180.53 KW
Reactive Power, Q= 23.98 KVAR
Power Factor = 99.12%
THD = 0.1241

VI. HARDWARE IMPLEMENTATION

The task extends to validate the performance using a prototype of the iinterleaved boost converter. It etches the role of P89C5IRD2 micro controller to function as a PID controllerand also serves to generate PWM pulses for the power switches in the converter. The feedback arrangement is built through a signal conditioning circuit and an associated ADC. The micro controller P89C51 RD2 derives its input from ADC and the process value acquired through ADC is compared with a set point to determine the error. It uses the algorithm stored in it to gather the control signal, which is in turn processed to generate the new trigger pulses for the devices in the converter in order to regulate the output voltage and simultaneously improve the input power factor. The trigger pulses migrate through the opto-coupler and accomplish high-speed logic interfacing, input/outputbuffering as line receivers in environments that conventional line receivers cannot tolerate. The signals from the opto- coupler are inverted using NOT gate and then fed to the driver to strengthen the PWM pulses. The Figs. 4 show the flow diagram responsible for generating the PWM pulses and the experimental prototype. The output voltage waveforms seen in Fig 5 repudiate the capability of the algorithm to maintain a constant output voltage even when it experiences a sudden disturbance in load. The entries in Table I compare the simulated and experimental readings to substantiate the viability of the scheme over a range of operating loads.

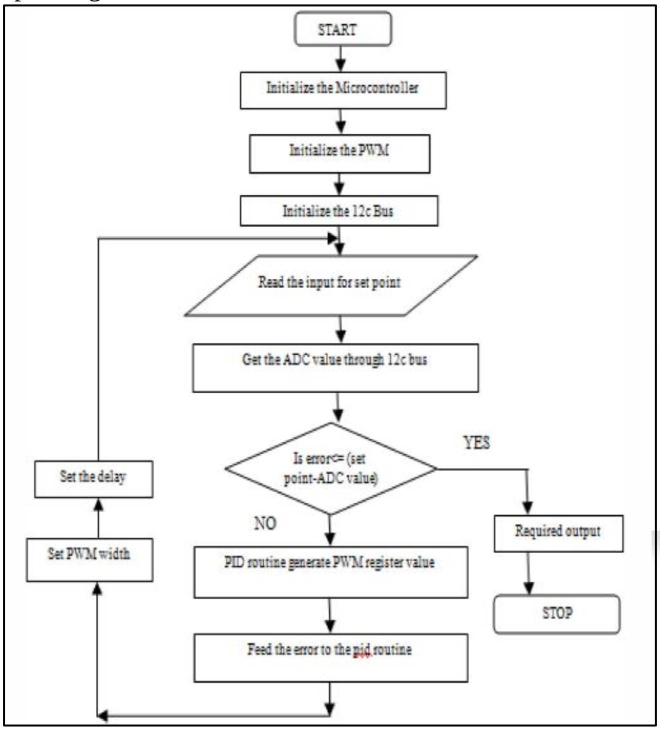


Fig. 4: flow chart

A. *Volatage Graph of Hardware Implementation:*

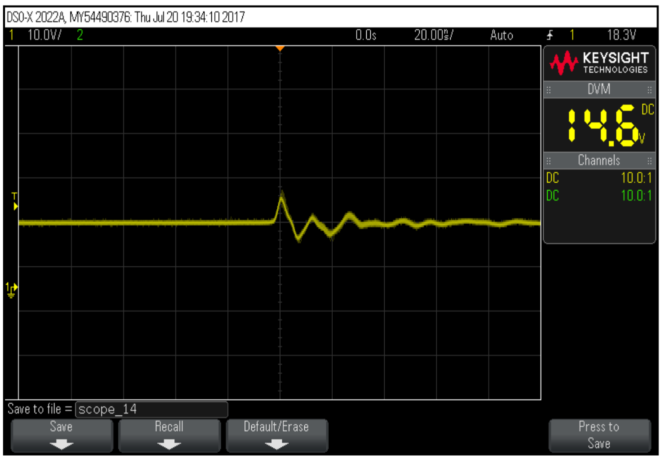


Fig. 5: voltage waveform

VII. CONCLUSION

The main objective throughout the project has been to improve the input Power Factor with simultaneous reduction of input current harmonics. Simulations were initially done for elementary rectifier circuits without employing any PFC circuit. These simulations included circuits with and without source side inductors and capacitors. The changes in the input current waveform were observed and studied. A PFC circuit having a parallel boost converter i.e. two boost converters arranged in parallel was designed. The control strategy was based on average current mode control due to its relative advantages over voltage mode control and peak current mode control.

The key points that were taken into account while designing were:

1) Placing the two poles at origin and somewhere near the switching frequency.
2) Placing the zero at half the crossover frequency.
3) Gain of the inner current control loop should be in accordance to the switching frequency of the PWM modulator.

Calculation of Power Factor was done base on active and reactive power measurement with the inbuilt MATLAB block for the same.

VIII. FUTURE SCOPE

AC to DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. Electrical and electronic equipment is designed to operate on standard supply voltage .When the supply voltage is constantly too high or too low, the equipment fails to operate at maximum efficiency. So we need of boost converter to change the level of voltage from low to high in some applications. There are two types in boost converter.

They are single boost and dual boost converter. We are applying same dc input voltage from bridge rectifier to both boost converters. Then we get different voltages for both boost converters from hardware model. But it should be Vo>Vi and dual boost output voltage should be greater than single boost output voltage.

In this project, it is noticed that the Power Factor is better and

THD is less for interleaved Boost Converter Circuit.

– This can be further improved by using PI and Fuzzy Controllers. For further improvement, we can introduce predictive control strategy in which the active filtering approach can be utilized so as to further reduce the current ripples and switching losses. The switches can be made to be work under softswitching condition.

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