Original Research Article

# FPGA BASED POWER FACTOR CORRECTION IN DC MOTOR DRIVE

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## Abstract

The objective of active power factor correction is to make the input to a power supply look like a simple resistor. An active power factor corrector does this by programming the input current in response to the input voltage. As long as the ratio between the voltage and current is a constant the input will be resistive and the power factor will be 1.0. When the ratio deviates from a constant the input will contain phase displacement, harmonic distortion or both and either one will degrade the power factor. The project aims at correcting the power factor of the circuit i.e. to bring it as close as possible to unity so as to increase efficiency. Digital control (FPGA based) methodology has been used wherein input current, input voltage, output voltage and load current are sensed.

**Key words** – Power factor correction, PWM signal, FPGA, Boost Converter, Buck converter

## Introduction

The objective of active power factor correction is to make the input to a power supply look like a simple resistor. An active power factor corrector does this by programming the input current in response to the input voltage. As long as the ratio between the voltage and current is a constant the input will be resistive and the power factor will be 1.0. When the ratio deviates from a constant the input will contain phase displacement, harmonic distortion or both and either one will degrade the power factor. The most general definition of power factor is the ratio of real power to apparent power. Where P is the real input power and Vrms and Irms are the root mean square (RMS) voltage and current of the load, or power factor corrector input in this case. If the load is a pure resistance the real power and the product of the RMS voltage and current will be the same and the power factor will be 1.0. If the load is not a pure resistance the power factor will be below 1.0. Phase displacement is a measure of the reactance of the input impedance of the active power factor

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corrector. Any amount of reactance, either inductive or capacitive will cause phase displacement of the input current waveform with respect to the input voltage waveform. The phase displacement of the voltage and current is the classic definition of power factor which is the cosine of the phase angle between the voltage and current sinusoids. The amount of displacement between the voltage and current indicates the degree to which the load is reactive. If the reactance is a small part of the impedance the phase displacement will be small. An active power factor corrector will generate phase displacement of the input current if there is phase shift in the feed-forward signals or in the control loops. Any filtering of the AC line current will also produce phase displacement. Harmonic distortion is a measure of the non-linearity of the input impedance of the active power factor corrector. Any variation of the input impedance as a function of the input voltage will cause distortion of the input current and this distortion is the other contributor to poor power factor. Distortion increases the RMS value of the current without increasing the total power being drawn. A non-linear load will therefore have a poor power factor because the RMS value of the current is high but the total power delivered is small. If the non-linearity is small the harmonic distortion will be low. Distortion in an active power factor corrector comes from a high input power factor, usually much greater than 0.9.
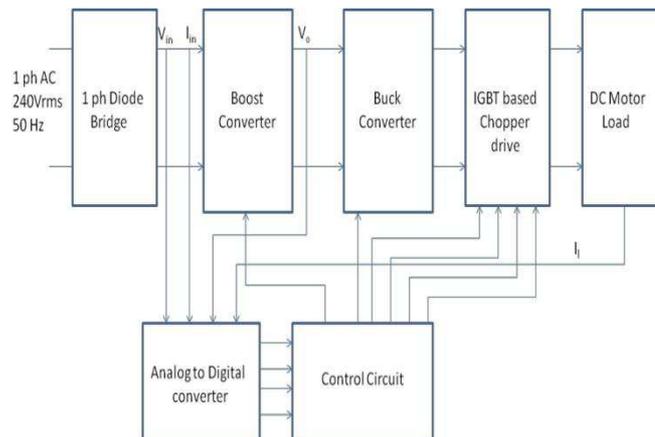
Innovation

Many circuits with analog control of the input current are available. These make use of a power factor corrector integrated circuit (ICs). These ICs are fed with input current, input voltage, load current and output voltage. These ICs compute and provide a reference current which is sinusoidal in nature and is then compared with the output current. The comparator output drives an S R flip flop which generates a PWM output. This PWM signal drives the MOSFET in the boost converter.

The project makes use of digital control to generate the PWM signal.

Digital control allows more accurate arithmetic computation than that of the analog control. This helps us to acquire the power factor, closer to unit.

**Design Description**



**A. Rectifier:**
Type: 1ph Diode Bridge.
Input: 240 Vac 1ph 50Hz.
Output: 216.07 Vdc.

**B. Boost Converter:**
A boost regulator is an excellent choice for the power stage of an active power factor corrector because the input current is continuous and this produces the lowest level of conducted noise and the best input current waveform. The disadvantage of the boost regulator is the high output voltage required. The output voltage must be greater than the highest expected peak input voltage.

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$$V_o = V_{in} (1-D)^{-1}$$

Type: IGBT based boost converter
Input: 216.07 Vdc.
Output: 410 Vdc

**C. Buck Converter:**

Type: IGBT based buck converter
Input: 410Vdc

Output: 220Vdc

$$V_o = V_{in} D$$

A buck converter is used as we need to reduce the output to 220Vdc bus voltage.

**IGBT based chopper drive:**
It is an H bridge IGBT based DC motor drive. It allows 4 modes of motoring, viz. forward motoring, forward regeneration, reverse motoring and reverse regeneration. It controls the current amplitude to stay within a desired band. It is a bidirectional power flow circuit.

**Analog to digital converter:**
This block is used to convert the sensed analog current and voltage parameters into their digital representation. Here we need a 4 channel ADC to sense input current, input voltage, output voltage and load current. The data is given to the control circuit.

**Control Circuit:**
Boost converter :
This block receives the digitized data from the ADC. The main control element inside is an FPGA. It has to make certain arithmetic computation and generate a PWM output signal. The computation is as follows:
A reference voltage of 7.5V is multiplied with the sensed output voltage of the boost converter and the sensed input ac current.
The resultant is divided by the sensed input voltage. This gives a reference current value. The load current sensed is then compared with this reference current .The comparison output is a two state output, high or low. This output is given to an S R flip flop. This flip flop will generate the PWM gate driving

signal. The PWM output is given to the gate driving circuit. It consists of isolated driver and a level shifter circuit. This circuit provides output in two analog voltage levels as +15V and -5V. This signal actually drives the IGBT of the boost converter circuit.

Buck converter :
The control circuit is supposed to generate a 0.5 duty cycle pulse signal for driving the IGBT in the buck converter. This signal is first given to the gate driving circuit. This circuit then generates the actual gating signal.

4 Quadrant Chopper :
The gating signal of variable duty cycle for the DC MOTOR driver also is generated by the control circuit.

**G. Load:**
The load to be driven is inductive in nature. A separately excited DC motor is to be driven. The motor specifications are as follows.

Armature voltage: 220V
Armature current: 2 A
Field voltage: 220V
Field current: 0.2A
KW: 0.373
HP: 0.5
R P M: 1500

**References**
- Application note of power factor corrector UC 3854.
- ON semiconductor SPMS Reference manual.
- Application Report SPRA902A–July 2005.
- Application note Vishay Semiconductors**.**
- https://www.ti.com
- https://www.vishay.com
- www.ieee.org
- Rashid M.H, Power electronics Handbook, ed : 2001, Academic Press.

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