Power Factor Correction based on PWM waves using PIC

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Abstract

Power factor correction (PFC) is a technique of counteracting the undesirable effects of electric loads that create a power factor that is less than one.Many control methods for the Power Factor Correction (PFC) have been proposed. This work describes the design and development of a power factor corrector using PIC (Programmable Interface Controller) microcontroller chip. Measuring of power factor from load is achieved by using PIC Microcontroller-based developed algorithm to determine and trigger sufficient switching of capacitors in order to compensate demand of excessive reactive power locally, thus bringing power factor near to unity. In the great majority of cases, poor power factor is due to inductive loads which can be compensated by adding electrical devices called capacitors into the circuit and this is nothing but the PFC. The technique described is clearly apparent as a simple and cost effective power factor (PF) measurement and correction scheme by using Programmable Interface Circuit (PIC) microcontroller. The system senses the power factor and with the help of microcontroller switches required number of capacitors in the capacitor bank.

Keywords: *Power factor; Reactive power; PIC microcontroller; Capacitor bank; Pulse Width Modulated wave.*

1. Introduction

Power factor (PF) is a measurement by which we can measure the efficiency of the electrical equipments as well as ac electric power system on the basis of electrical energy consumption. It determines power quality. Power factor is generally defined as the ratio of the Real power (measured in Watts) to the Apparent power (measured in VA). The classical definition of power factor is the cosine of the phase angle i.e. cosΦ between voltage and current . Due to reactive loads, the apparent power becomes greater than the real power that increases the phase difference between voltage and current. So, the power factor drops below unity and the system becomes less efficient.

Reducing the effects of reactive power will cause the angle Φ to get closer to 0º, meaning the power factor will get closer to unity.Poor power factor has many disadvantages so power factor correction techniques are used to improve it.

The simplest way to control the harmonic current is to use a filter: it is possible to design a filter that passes current only at line frequency (50 or 60 Hz). This filter reduces the harmonic current, which means that the non-linear device now looks like a linear load. At this point the power factor can be brought to near unity, using capacitors or inductors as required. This filter requires large-value high-current inductors, however, which are bulky and expensive. A passive PFC requires an inductor larger than the inductor in an active PFC, but costs less. This is a simple way of correcting the nonlinearity of a load by using capacitor banks.

2. Implementation Details

The system senses the power factor and with the help of microcontroller switches required number of capacitors in the capacitor bank. The proposed system block diagram is shown in Figure 1.

2.1 Power Factor Sensing Section

To measure displacement power factor on one phase, we need to have a square wave representative of the polarity of the voltage and current waveform on that phase. To facilitate this purpose potential transformer (PT) used to sense the voltage wave and current transformer (CT) to current wave.Secondary of the CT is terminated in a shunt resistor and followed by a low pass filter and amplifier to enhance the wave amplitude. A low-pass filter at the secondary of PT and CT can effectively reduce the constant or transient noise of power line produced due to fluorescent lighting tubes, solidstate converters or drive systems, welding equipment etc. Generated square waves are ac signals which are then sent to clipper section to convert it to rectangular wave or pulse.

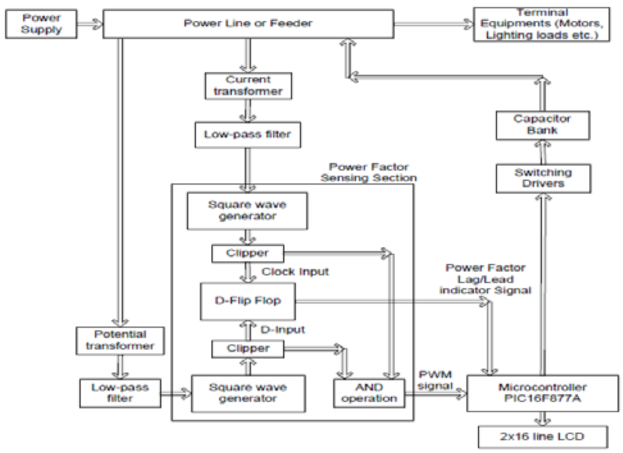

Fig.1 Block Diagram of Proposed System

2.2 PIC Microcontroller Unit

Microchip Technologies' 16 bit microcontroller PIC16F877A has several useful stand-alone features like built in Flash Program Memory, EEPROM (Electrically Erasable Programmable Read Only Memory), Data Memory, A/D (Analog-to-Digital) converter, 8 and 16 bit Timers, watchdog timer, Capture/ Compare/ PWM modules, serial and parallel communication interface etc.

2.3 Capacitor Bank

When power factor improvement capacitor banks are designed and arranged properly, the PF correction scheme becomes efficient. The capacitor bank is comprised of individual capacitor elements. The individual capacitors for PF correction applications may be metal-enclosed oil-filled or dry units (epoxy filled in a plastic case), and should be capable of working over the temperature range of up to +700C. Some salient features of PF correction capacitor banks are: extremely high reliability with self-healing capabilities; capable of controlling the requirement of kVARs to achieve PF as close as unity; compact, efficient and long service life; protected against over-voltage, over-current, over temperature, switching surges and harmonics .The actual capacitor values in farads of a capacitor bank can be calculated using the following equation .

$$C = \frac{VAR}{2\pi f \times V_R^2}$$

Where VAR=capacitor unit's VAR rating; C=Capacitor (Farads); f= frequency (Hz or Cycles/Second); VR=Capacitor unit's rated voltage. Standard capacitor sizes are 50, 100, 150,200, 300 and 400kVAR

Switching drivers may consist of transistors and relays. On receiving output signal from the microcontroller port, the transistor energizes the relay coils and the relay then switches the capacitors parallel to the power line. A 2x16 line LCD is used to display value of power factor, lead/lag and label of switched capacitor bank.

3. Generation Of PWM Wave

Applying pulses to an AND gate, a Pulse Width Modulated (PWM) wave is obtained where the displacement angle between voltage and current wave determines the pulse width as shown in Figure 2.

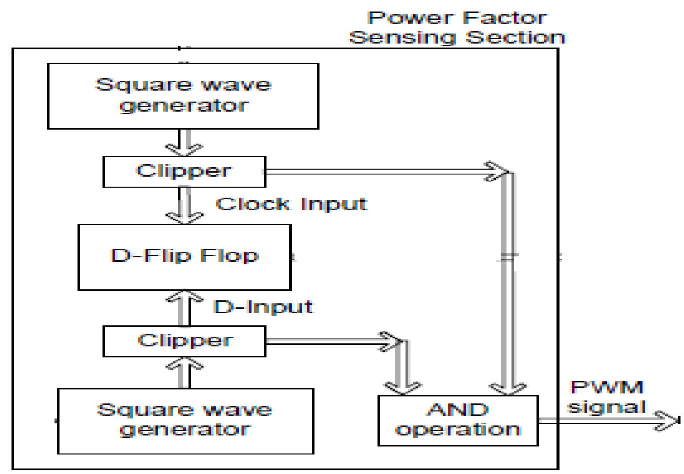

Fig.2: Generation of PWM waves

For power factor measurement,angle of concern is between 0 and 90 degrees. At 0 degree, the two waveforms are in phase, and so the PWM output is 100% ON. At 90 egrees, there is a 50% overlap, so the PWM output has a 50% high state.

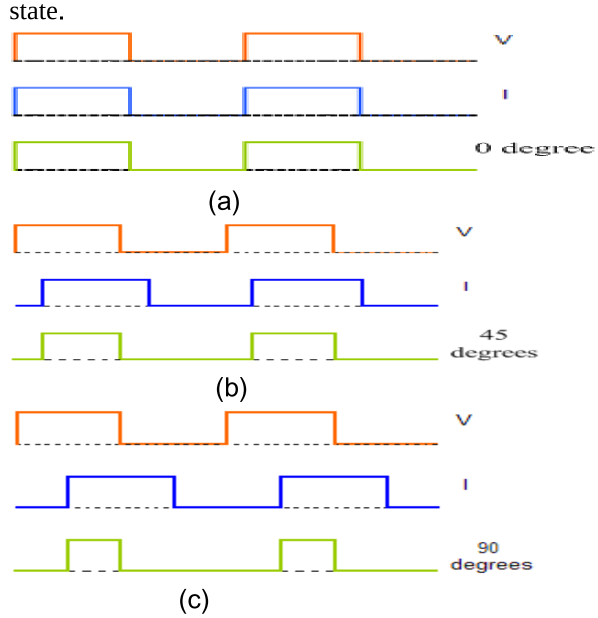

Fig.3: Generation of PWM wave from equivalent voltage and current pulse, (a) at Power Factor=1, (b) at Power Factor=0.5, (c) at Power Factor=0.

4. Programme Flow Chart

Simplified flowcharts for the developed software are shown in Figure 4. MikroC compiler was used to code and compile the program and WinPIC to load HEX code to microcontroller unit. The main program, Figure 4 a, initializes and configures the LCD and I/O ports.

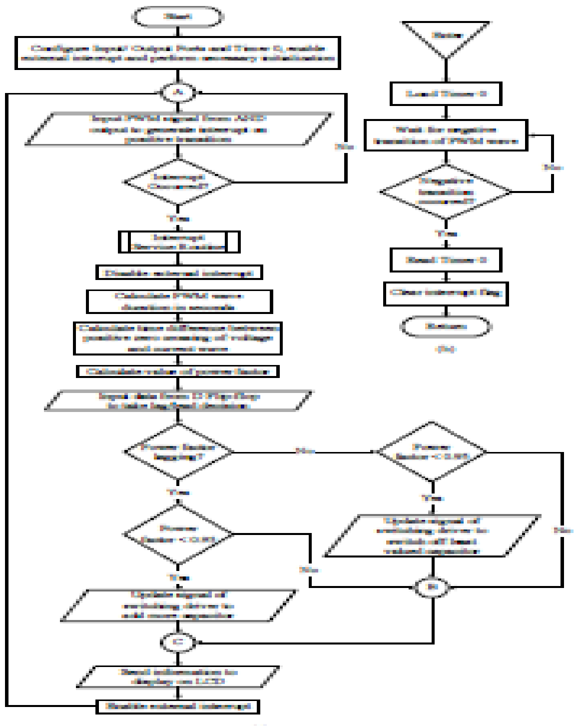

Fig. 4: Program flow charts, (a) main program (b) interrupt service routine.

5. Hardware and Oscilloscope records

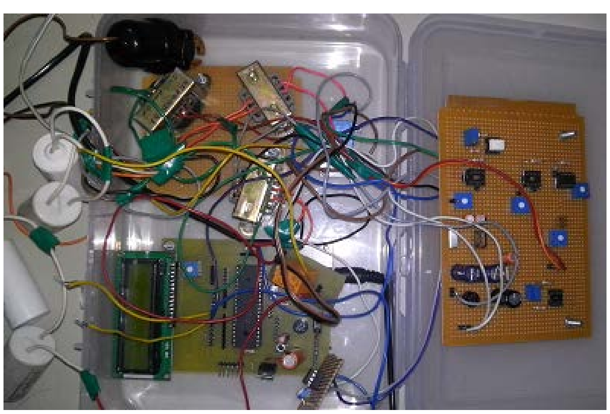

Fig 5 Hardware

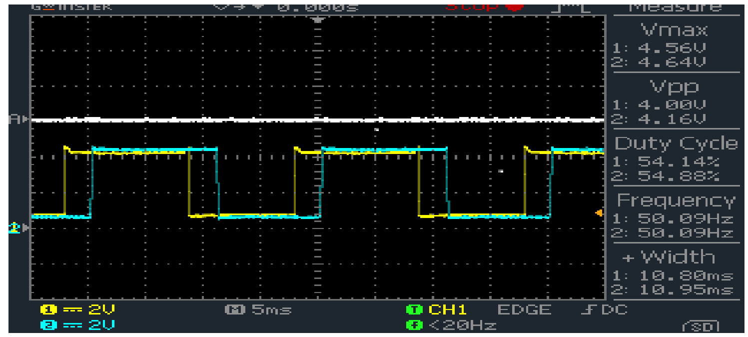

Fig.6 Before PF correction

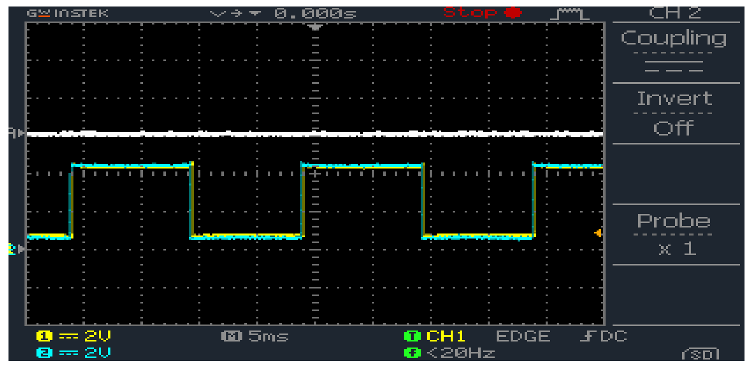

Fig 7 After PF correction

6. Conclusion

The system has the ability to sense power factor effectively and by using proper algorithm sufficient capacitors are switched on in order to compensate the reactive power. PWM based power factor measurement and correction unit can improve the power factor close to unity in an automatic way and can remove the capacitor banks when the power factor is leading.

The system gives reliable and economic solution for industries and multi-storied building applications. We can improve its efficiency in abnormal situations as well as we can include protective relaying facility to protect the system from hazards.

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