

# Automatic Power Factor Correction by Continuous Monitoring

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**Abstract**—The Purpose of this paper is implementing a new technology for power factor improvement of 3 phase induction motor as well as for single phase induction motor, as improvement of power factor is necessary for industrial as well as domestic areas & to make power factor as close as unity without facing penalty from electrical distributors. As we know in industries most of motor which is usually used is induction motor and induction motor having low power factor also. Home appliances which are generally used are generally having low power factor. Hence there is need of power factor improvement in case of household appliances as well as in industrial purpose. Induction motor is most widely used motors in industries. As name of this motor specifies this motor having low power factor. Hence there is need of power factor improvement. [1]

**Index Terms**—A.C–Alternating current, D.C –Direct Current, P.F–power factor, P.F.C–power factor correction, ZCD–Zero Cross Detectors, P.T–Potential Transformer

## I. INTRODUCTION

Any motor that operates on alternating current requires apparent power, but apparent power is addition of active power and reactive power. Active power is the power which is actually consumed by the load. Reactive power is the power demanded by the load and returned to the power source. The simplest way to specify power factor is **“POWER FACTOR is the ratio between the useful (true) power whose unit is KW to the total (apparent) power whose unit is KVA consumed by an A.C electrical equipment or motor”**. Power factor is a measure of how effectively electrical power is used to perform an useful work. The ideal power factor is unity or one. If power factor is less than one it means that excess power is required to perform or achieve the actual work. [2], [5]

### A. Advantages of power factor improvement

Advantages which can be achieved by employing proper power factor correction scheme are:

- Efficiency increases due to Reduction of power consumption.
- Due to reduced power consumption their will be Less greenhouse gases
- Reduction of electricity bills
- Extra KVA available from the same existing supply
- Reduction of I<sup>2</sup>R losses in transformers and distribution equipment [8]

### B. Idea to improve power factor

The basic idea For Power factor correction of a motor or circuits we have to connect an capacitor in parallel with the device which having low power factor.

One of traditional method for power factor correction is static type compensation in which static type capacitors are used for power factor correction. However in this case Care should be taken when applying power factor correction star/delta type control so that the capacitors should not subjected to rapid on-off conditions. [5]

### C. Working of Capacitors

By representing active power & reactive power at sides of right angle we can determine the apparent power from the right triangle rule:

$$(KVA)^2 = (KW)^2 + (KVAR)^2$$

To reduce the KVA, total current requirement for any given load, one must have to shorten the line that represents the KVAR. This is precisely what capacitors do. The ratio of actual power to apparent power is usually expressed in percentage and is called power factor. [5]

$$PF = \frac{KW}{KVA}$$

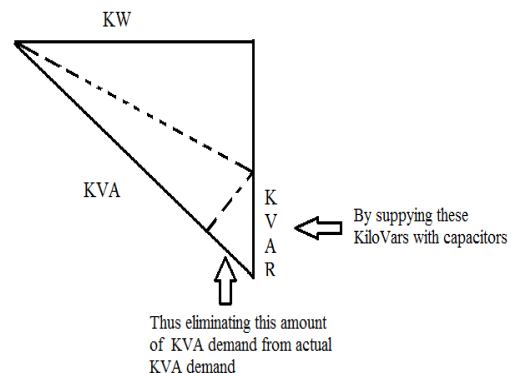


Fig-1. Power Triangle

## II. METHODS OF POWER FACTOR CORRECTION (P.F.C)

### A. Static compensation

In this method for power factor improvement static capacitors are connected in parallel with the device which works on low power factor. These static capacitors provide leading current which eliminates lagging component of load current and improves power factor. [7], [9]

**B. Synchronous condenser**

When a synchronous motor operates at no load and at over excited condition then it is called synchronous condenser. When a synchronous condenser is over excited then it provides leading current and works like capacitor. When a synchronous condenser connected across supply then it provides leading current and partially eliminates reactive component and thus improves power factor. [9]

**C. APFC scheme**

In my project I m going to use technique which is called automatic power factor correction. This system is based on technique of continuous monitoring of the systems parameters such as voltage and current with the use of potential transformer and current transformer respectively. Through continuous monitoring phase difference between the two quantities will be calculated continuously and depending upon phase difference correspondingly suitable amount of capacitors will be switched on or off in the system in order to improve power factor as close as unity.

As there is no moving part in capacitors hence switching losses are less as compare to that of static compensation also no extra motor is required for power factor correction and hence cost is much less as compare to that of power factor correction by synchronous condenser technique [2], [4]

**III. COMPONENTS, FUNCTIONAL BLOCK DIAGRAM AND SCHEMATIC DIAGRAM**

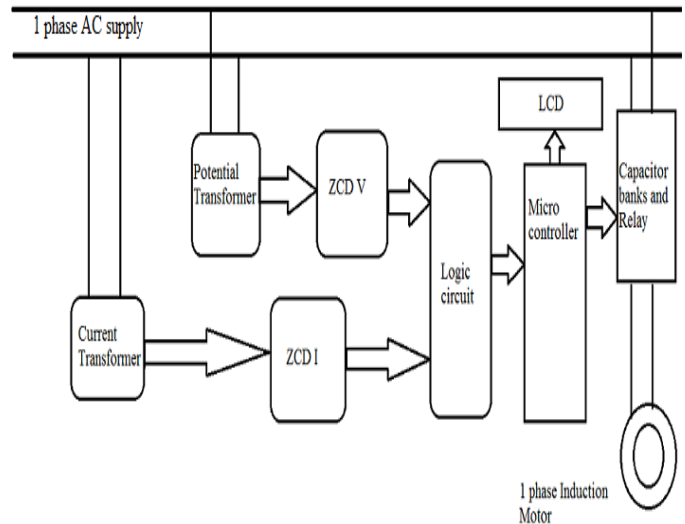
**A. Main components**

Main components used in this scheme for automatic power factor correction using microcontroller includes following components. [2]

1. Auxiliary power Supply:
  - Transformer
  - Bridge rectifier
  - Voltage regulator IC 7805
2. Microcontroller(AT-mega8)
3. LCD Display
4. Capacitor Bank
5. Potential transformer & current transformer
6. Relay & relay driver IC
7. Zero Cross Detector

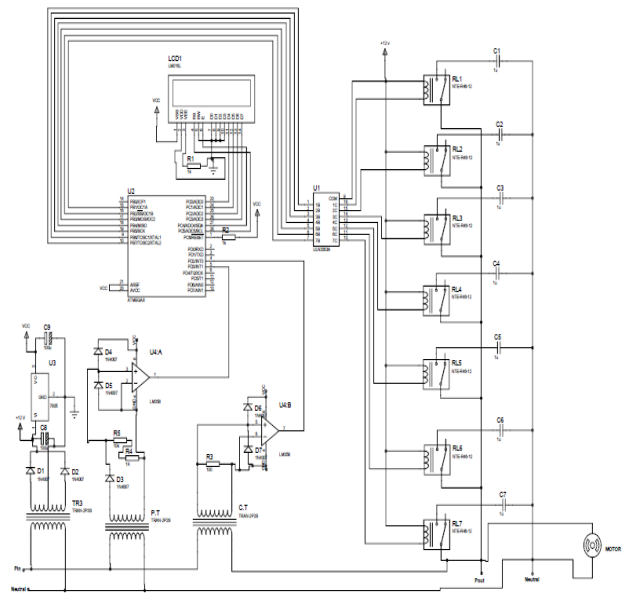
**B. Functional Block Diagram**

Zero crossing of voltage and current waveform from line is detected by ZCD from P.T and C.T respectively. Depending upon phase difference between voltage and current microcontroller sends out the signal to switch on capacitor through relay driver IC and improves power factor [2]



**Fig 2 Block Diagram of System**

**C. Schematic Diagram**



**Fig-3 Schematic Diagram of System**

**D. Description of Microcontroller: AVR AT mega 8L**

The ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1 MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed. The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The Atmel ATmega8 is a powerful microcontroller that provides a

highly-flexible and cost-effective solution to many embedded control applications. The ATmega8 AVR is supported with a full suite of program and system development tools, including C compilers, macro assemblers, program debugger /simulators, In-Circuit emulators, and evaluation kits. [8]

**Features:-**

1. 8K bytes of In-System Programmable Flash with Read-While-Write capabilities.
2. 512 bytes of EEPROM, 1K byte of SRAM.
3. 23 general purpose I/O lines.
4. 32 general purpose working registers.
5. Three flexible Timer/Counters with compare modes. Internal and external interrupts.
6. A serial programmable USART.
7. A byte oriented Two-wire Serial Interface.
8. A 6-channel ADC (eight channels in TQFP and QFN/MLF packages) with 10-bit accuracy.
9. A programmable Watchdog Timer with Internal Oscillator.[8]

**E. Pin Configuration**

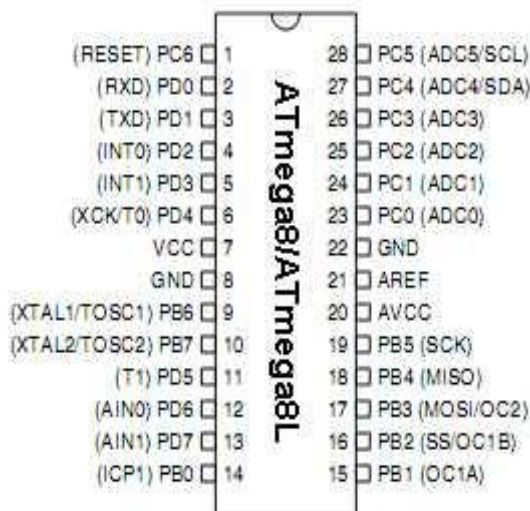


Fig-4. Pin configuration of at mega 8L microcontroller

**Pin Descriptions**

1. VCC- Digital supply voltage.
2. GND- Ground.
3. Port B (PB7-PB0)-Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit).
4. Port C (PC5-PC0)-Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit).
5. PC6/RESET- If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C. If the RSTDISBL Fuse is un programmed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a Reset.

6. Port D (PD7-PD0)-Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit).
7. RESET-Reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a reset.
9. AVCC-AVCC is the supply voltage pin for the A/D Converter, Port C (3-0), and ADC (7-6). It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter. Note that Port C (5-4) use digital supply voltage, VCC.
9. AREF- AREF is the analog reference pin for the A/D Converter.
10. ADC7-6 In the TQFP and QFN/MLF package, ADC7-6 serves as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.[8]

**IV. METHODOLOGY**

The methodology on which my paper based is consisting of three main parts.

**A. Auxiliary power supply**

A bridge rectifier connected across main line which converts AC signal to DC. A capacitor is connected at output of rectifier to get pure DC. The output of bridge rectifier is +12V but as microcontroller works on +5V hence output of this bridge rectifier is further given to IC 7805(Voltage regulator IC) which gives fixed output voltage +5V. A capacitor is connected at output of IC 7805 in order to get pure DC voltage (remove unwanted ripples). [2]

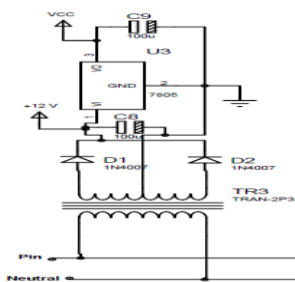


Fig-5. Auxiliary power Supply

**B. Zero cross detector (ZCD)**

The current and voltage signal are measured from the main AC line by using Current Transformer and Potential Transformer respectively the output of these CT and PT's are given to Op-Amp LM 358 the combination of potential transformer and OP-Amp forms zero cross detector (ZCD V) also combination of current transformer and OP-Amp forms zero cross detector(ZCD I).these zero cross detectors individually converts both current and voltage waveforms to square wave and detects zero crossing of voltage and current [4], [2]

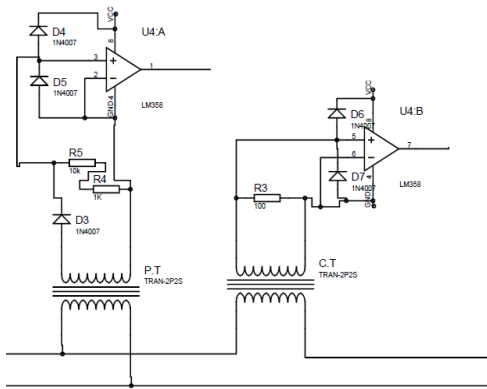


Fig-6. Circuit of Zero Cross Detector

C. Capacitor and relay matrix

Depending upon zero crossing of voltage and current wave microcontroller either switches on or switches off required number of capacitors through electromagnetic relays. And power factor is shown on LCD display for various load. [2]

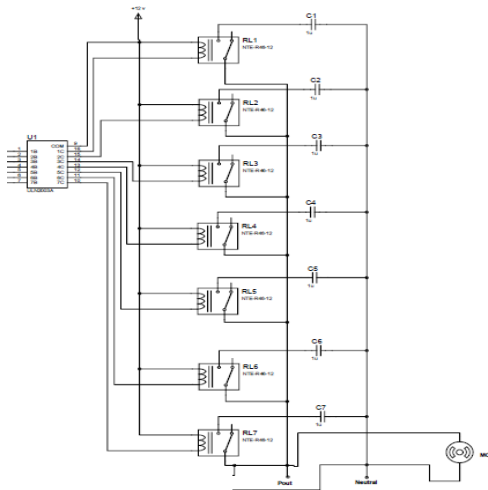


Fig-7 Connections of Capacitor & Relay Matrix Circuit

D. Interfacing of Microcontroller to LCD and Relay Driver IC

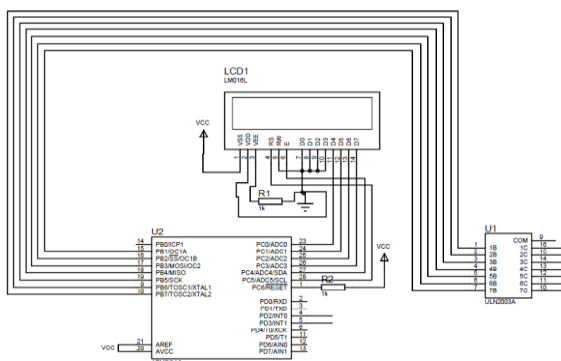


Fig-8 Interfacing of Atmega-8L microcontroller to LCD and Relay Driver IC ULN 2803 [2]

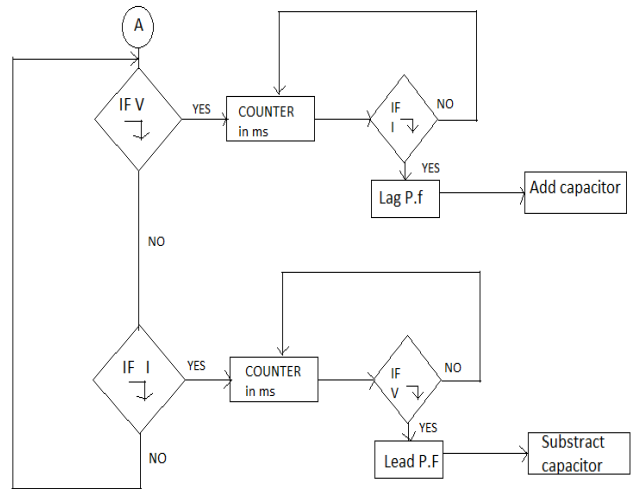


Fig-9. Flow Chart for system

Microcontroller first detects whether first voltage edge is falling down or current edge. Depending upon this logic it detects whether power factor is lagging or leading, accordingly it switches on or off number of capacitors in order to improve power factor [4]

E. Motors Parameters

- 1 phase Induction motor
- 0.75KW/1Hp
- 230 volt, 7.5amps
- 1420

F. PCB 3D View and PCB Design

PCB 3D view

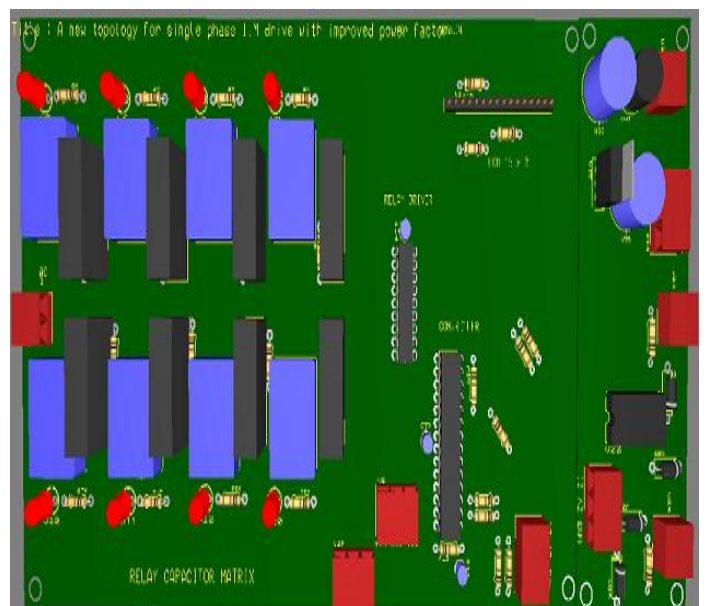


Fig-10 Proposed 3-D View of System

PCB Design

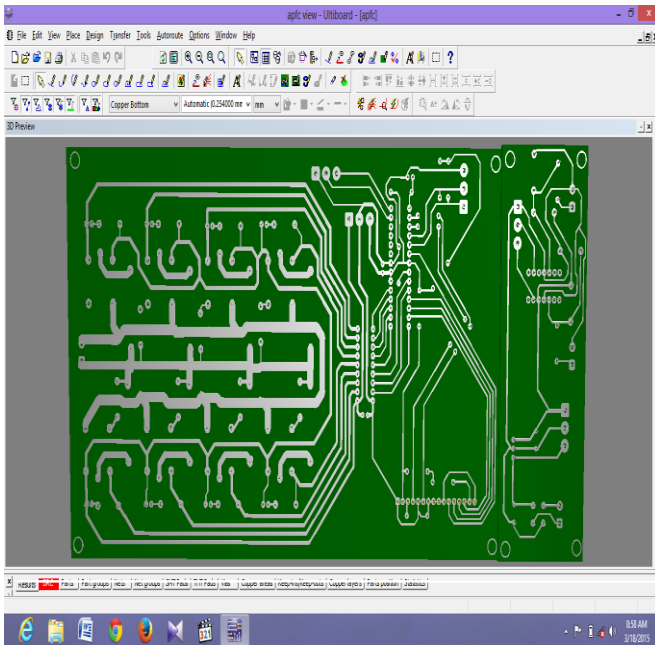


Fig-11. PCB Design of System

G. Zero Cross Detector Waveforms

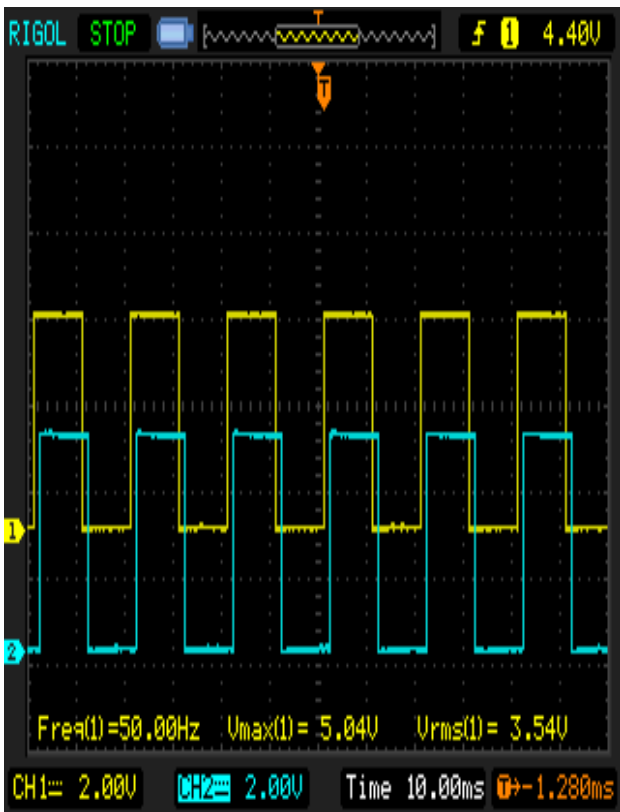


Fig-12. ZCD Waveform Viewed at CRO at lagging Power Factor [4]

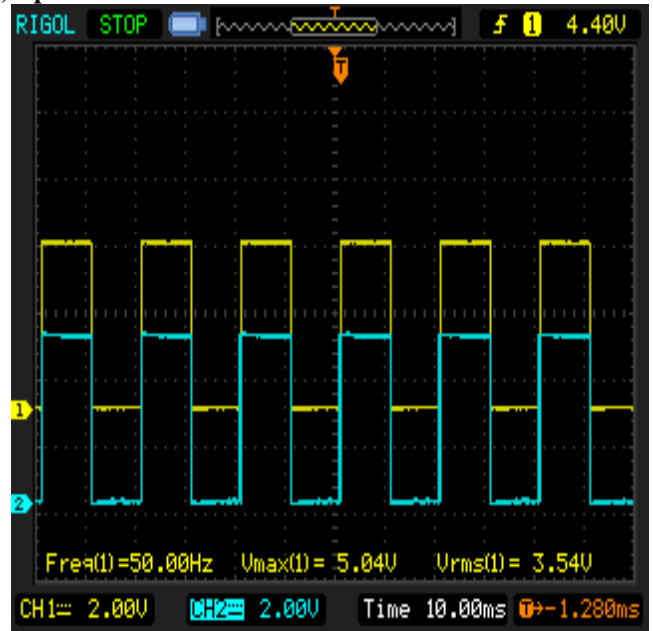


Fig- 13. ZCD Waveform Viewed at CRO after power factor correction [4]

V. OBSERVATION TABLE

I. Before APFC Circuit Insertion

Above table shows power factor of Induction motor Drive before APFC circuit insertion under various loading condition [5]

Load	W(watts)	V (Volts)	I (Amps)	P.F
NO Load	50*8=400	236	5	0.339
0.5KW	110*8=880	236	5.9	0.632
1KW (Full load)	128*8=1000	236	6.4	0.662

II. after APFC Circuit Insertion

Load	W(watts)	V(Volts)	I (Amps)	P.F
NO Load	50*8=400	236	1.9	0.892
0.5KW	105*8=840	236	3.7	0.962
1KW (Full load)	115*8=920	236	4	0.974

Table shows P.F of I.M after APFC circuit insertion. Under

VI.RESULT

Comparative observation of Power factor of Induction Motor Drive before APFC circuit insertion And After APFC Circuit insertion [5]

Load	P.F (Before APFC Circuit)	P.F (After APFC circuit)
NO LOAD	0.3389	0.89
0.5KW	0.6320	0.9619
1KW(FULL LOAD)	0.6620	0.9745

Before insertion of APFC circuit Power factor of induction motor at no load is observed as 0.3389, while after insertion of APFC circuit power factor gets improve to 0.89

While at full load i.e. at 1KW after insertion of APFC circuit power factor gets improve to 0.974 by 53 Microfarad provided by capacitors.

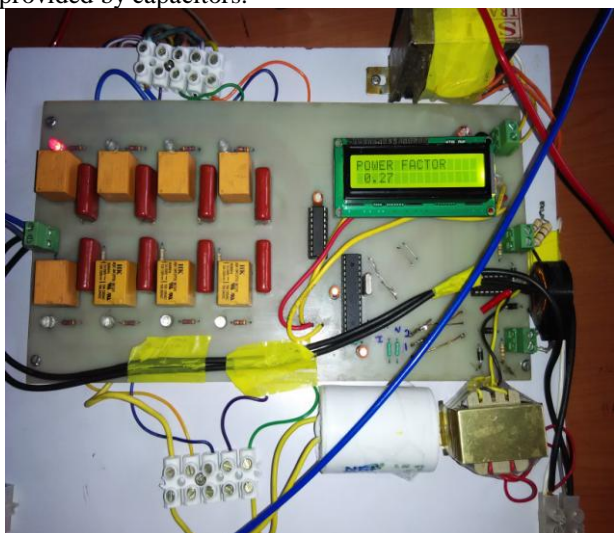


Fig-14. Pictorial view of system a lagging power factor.[2]

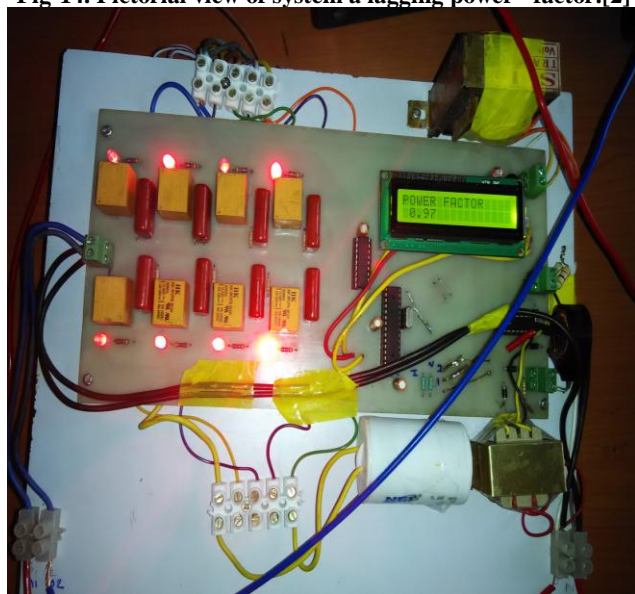


Fig-15 Pictorial View of System with Improved Power factor. [2]

### VII. CONCLUSIONS

This paper deals with advance method of power factor correction by using microcontroller. As Switching of capacitors are done automatically hence we get more accurate result, Power factor correction techniques makes system stable and due to improvement in power factor its efficiency also increases. Power factor correction scheme can be applied to industries, power systems as well as in house hold purpose. The use of microcontroller reduces the costs. By using microcontroller multiple parameters can be controlled and the use of extra hard wares such as timer, RAM, ROM and input output ports reduces. Before APFC Circuit insertion

### VIII. FUTURE ENHANCEMENTS

The automotive power factor correction using capacitive load banks is very efficient as it reduces the cost by decreasing the power drawn from the supply.

As it operates automatically, manpower are not required and this Automated Power factor Correction using capacitive load banks can be used for the industries purpose in the future. In future PWM techniques can be employed in this scheme. Along with power factor correction also speed control can be done in future. In future, Work can be done for harmonics reduction.

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**Publications**

1. IJFEAT, Manthan-2015, International conference by Shri Shankarprasad College of Engineering, Wardha "A New Topology for single phase Induction Motor Drive with improved Power Factor"
2. IJEET 2011 "Fault detection of Induction motor based on ANN" National – 03 paper published  
International- 06 paper published

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Aparna Sarkar has received her bachelor's degree in 2013 from RTMNU University INDIA. She is doing her M-Tech From RTMNU university.

**Publications**

1. National conference UNNATI'15 organized in PCE, Nagpur by Department of Mechanical Engineering "A New topology for single phase Induction motor drive with improved power factor"
2. IJFEAT, Manthan-2015, International conference by Shri Shankarprasad College of Engineering, Wardha "A New Topology for single phase Induction Motor Drive with improved Power Factor"

National- 03 paper published

International- 01 Paper published

**Achievement:** Achieve 2<sup>nd</sup> position in National Conference UNNATI'15 organized by Priyadarshini college of Engineering,

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