# Automated Power Factor Correction and Energy Monitoring System Using Static Compensation Method

**Sudharani**

**M.Tech Student**

**PDA College of Engineering, Kalaburagi 585102**

**M.S Aspalli**

**Professor**

**PDA College of Engineering, Kalaburagi 585102**

***Abstract:*** The thirst for new sources of energy is unquenchable, but we seldom realize that we are wasting a part of the electrical energy everyday due to the lagging power factor in the inductive loads we use. Hence, there is an urgent need to avoid this wastage of energy. Before getting into the details of Power Factor Correction, let us just brush our knowledge about the term ―power factor‖. In simple words, power factor basically states how far the energy provided has been utilized. The maximum value of power factor is unity. So the closer the value of power factor to unity, better is the utility of energy or lesser is the wastage. In electrical terms, power factor is basically defined as the ratio of active power to reactive power or it is the phase difference between voltage and current. Active power performs useful work while reactive power does no useful work but is used for developing the magnetic field required by the device. Most of the devices we use have power factor less than unity.

## I. INTRODUCTION

The power factor correction is a technique of increasing the power factor of a power supply. Switching power supplies without power factor correction draw current in short, high-magnitude pulses. These pulses can be smoothed out by using active or passive techniques. This reduces the input RMS current and apparent input power, thereby increasing the power factor. The power factor correction shapes the input current in order to maximize the real power from the AC supply. Ideally, electrical equipment should present a load that emulates a pure resistor, meaning that the reactive power would be zero. And the current and voltage waveforms would be the same sine wave and in phase with one another. However, due to the reactive components in a majority of circuits, there is always a power lag that leads to lower power factors. In an ideal system, all the power drawn from the AC mains is utilized in doing useful work. This is only possible when the current is in phase with the voltage. When the phase between the two varies, some of the energy from the AC outlet does not perform useful work and is lost.

The power generating company must therefore produce more power to meet the demand for the useful power and the one that is lost. This means more capital investments in generation, transmission, distribution and control. The costs are passed on to the consumer in addition to contributing to global warming. Power factor correction tries to push the power factor of the electrical system such as the power supply towards 1, and even though it doesn't reach this it gets to as close as 0.95 which is acceptable for most applications.

### 1.1 METHODS OF POWER FACTOR CORRECTION

i) Static compensation
ii) Synchronous condenser
iii) Phase advancer

#### i. Static capacitor

We know that most of the industries and power system loads are inductive that take lagging current which decrease the system power factor. For Power factor improvement purpose, Static capacitors are connected in parallel with those devices which work on low power factor. These static capacitors provide leading current which neutralize (totally or approximately) the lagging inductive component of load current (i.e. leading component neutralize or eliminate the lagging component of load current) thus power factor of the load circuit is improved. These capacitors are installed in Vicinity of large inductive load e.g Induction motors and transformers etc, and improve the load circuit power factor to improve the system or devises efficiency.

#### ii. Synchronous condenser:

When a Synchronous motor operates at No-Load and over-exited then it's called a synchronous Condenser. Whenever a Synchronous motor is over-exited then it provides leading current and works like a capacitor. When a synchronous condenser is connected across supply voltage (in parallel) then it draws leading current and partially eliminates the re-active component and this way, power factor is improved. Generally, synchronous condenser is used to improve the power factor in large industries.

iii. Phase advancer:

Phase advancer is a simple AC exciter which is connected on the main shaft of the motor and operates with the motor's rotor circuit for power factor improvement. Phase advancer is used to improve the power factor of induction motor in industries. The phase advancer can be easily used where the use of synchronous motors is Unacceptable. As the stator windings of induction motor takes lagging current 90° out of phase with Voltage, therefore the power factor of induction motor is low. If the exciting ampere-turns are excited by external AC source, then there would be no effect of exciting current on stator windings. Therefore the power factor of induction motor will be improved. This process is done by Phase advancer

## II. PROPOSED SYSTEM

In electrical plants, the loads draw from the network electric power (active) as power supply source (e.g. personal computers, printers, diagnostic equipment, etc.) or convert it into other form of energy (e.g. electrical lamps or stoves) or into mechanical output (e.g. electrical motors). To get this, it is often necessary that the load exchanges with the network (with net null consumption) and the reactive energy is produced mainly from inductive type. This energy, even if not immediately converted into other forms, contributes to increase the total power flowing through in the electrical network, from the generators, all along the conductors, to the users. To smooth such negative effect, the power factor correction of the electrical plants is carried out. The power factor correction obtained by using capacitor banks to generate locally the reactive energy necessary for the transfer of electrical useful power, allows a better and more rational technical-economical management of the plants. Most of the industrial plants are using the inductive loads in infrastructure such as transformers and motors. Among them, the large industrial motors are essentially used in the industrial plants. Induction motors receive the grate reactive power from network for their proper function. Reactive power consumption causes the reduction of voltage of feeder in the plants and on the other hand, it causes the reduction of power factor of the whole plants. Therefore to improve the power factor is very important for all of the plants and even in the domestic industries and home appliances The functional block diagram of the complete project is shown in the following figure.

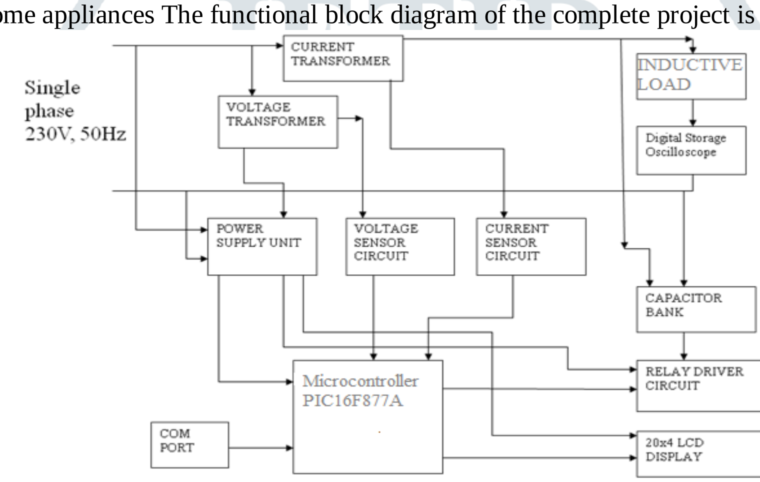


Figure 1 Block diagram of the APFC and Energy Monitoring system

The whole APFC unit consists of eight modules. They collectively work together to gain a power factor correction. These modules are given as follows:

A. Power supply:

It's is a component that supplies power to at least one electric load. Typically, it converts one type of electrical power to another, but it may also convert a different form of energy – such as solar, mechanical, or chemical - into electrical energy. A Transformer is a static apparatus, with no moving parts, which transforms electrical power from one circuit to another with changes in voltage and current and no change in frequency.

There are two types of transformers classified by their function: Step up Transformer and Step down Transformer. A Step down Transformer steps down the input voltage i.e. the secondary voltage is less than the primary voltage.An electrical device which converts an alternating current into a direct one by allowing a current to flow through it in one direction only. In signal processing, a filter is a device or process that removes some unwanted components or features from a signal. Filtering is a class of signal processing, the defining feature of filters being the complete or partial suppression of some aspect of the signal.

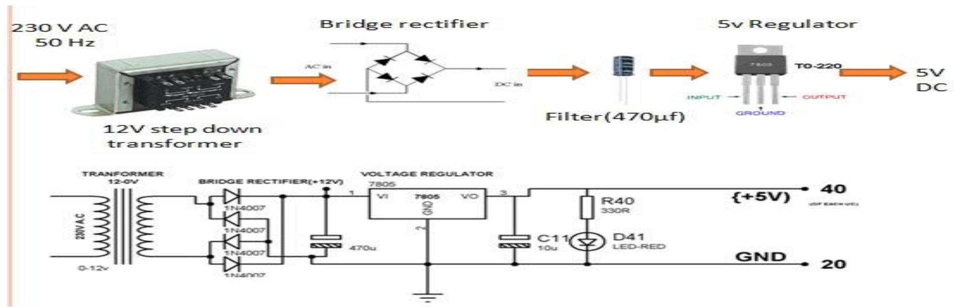


Figure 2: Connection diagram of Power supply unit

B. Voltage sensor:

The primary function of voltage sensors is to detect and measure AC and/or DC voltage levels. When the presence of voltage is detected, the sensors provide an output in the form of analogue voltage signals, current levels, frequency and modulated frequency outputs or audible sounds. There are various applications associated with voltage sensors. The common areas of use include power demand control areas, power failure detection, safety switching, revenue metering, load control especially in motors, power quality monitoring especially near VAR compensators and energy management control systems.


Figure 3: Voltage Sensor

Voltage Sensor Module:

- Divider ratio : 5:1
- Resistor Tolerance : 1:1A
- Maximum input voltage : 25V
- Resistor value: 30K/7.5KΩ

C. Current sensor: (acs712):

A current sensor is a device that detects and converts current to an easily measured output voltage, which is proportional to the current through the measured path. When a current flows through a wire or in a circuit, voltage drop occurs. Also, a magnetic field is generated surrounding the current carrying conductor. Both of these phenomena are made use of in the design of current sensors. Thus, there are two types of current sensing: direct and indirect. Direct sensing is based on Ohm’s law, while indirect sensing is based on Faraday’s and Ampere’s law.

Direct Sensing involves measuring the voltage drop associated with the current passing through passive electrical components. Indirect Sensing involves measurement of the magnetic field surrounding a conductor through which current passes

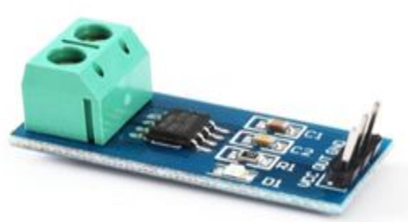

Figure 4 Current sensor

ACS712 Current Sensor Module – 5A can sense up to 5A of current flow. Sensing and controlling the current flow is a fundamental requirement in wide variety of applications, which includes over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, etc.

ACS712 Current Sensor Module – 5A Specification:

- Supply Voltage: 4.5V ~ 5.5V DC
- Measure Current Range: 20A
- Sensitivity: 100mV/A
- Low noise analog signal path.
- 5µs output rise time in response to step input current

D. Microcontroller:

PIC 16F877A MICROCONTROLLER is used as a controlling unit **PIC 16F877A:** In my work, I am using PIC 16F877A for producing switching pulses. The PIC 877A features 256 bytes of EEPROM data memory and it is ideal for more advanced applications in automotive, industrial, appliances and consumer applications. A microcontroller is a small computer on a single integrated circuit containing processor core, memory, and programmable input/output peripherals. Mains voltage, mains current, real power, apparent power and power factor of the network are calculated through the developed program.

E. Inductive load network:

The inductive load network is a combination of loads having inductive characteristics and consuming huge electrical power due to lagging power factor. The network collectively simulates a highly inductive load operating at a very poor power factor.

F. Relay driver circuit: (ULN2803):

The loads and capacitors are connected to a high voltage circuit. In order to incorporate these high voltage components with microcontroller relay is used for switching operation on capacitors in high voltage circuit through the control signal from microcontroller keeping the microcontroller safe and electrically isolated from high voltage. The ULN2803 is a high-voltage, high-current Darlington transistor array. The device consists of eight NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of each Darlington pair is 50v/500 mA. The Darlington pairs may be connected in parallel for higher current capability.

G. Display:

The calculated power parameters current power factor, mains voltage, mains current, real and apparent power are continuously displayed on a 16x2 Liquid Crystal Display monitor. LCD technology is used for displaying the image in notebook or some other electronic devices like mini computers. Light is projected from a lens on a layer of liquid crystal. This combination of colored light with the grayscale image of the crystal (formed as electric current flows through the crystal) forms the colored image. This image is then displayed on the screen.

H. Capacitor bank:

A capacitor bank is group of several capacitors of the same rating that are connected in series or parallel with each other to store electrical energy. The resulting bank is then used to counteract or correct a power factor lag or phase shift in an alternating current (AC) power supply. They can also be used in a direct current (DC) power supply to increase the ripple current capacity of the power supply or to increase the overall amount of stored energy. The most common use of a capacitor bank for AC power supply error correction is in industrial environments which use a large number of transformers and electric motors

## III. RESULTS AND ANALYSIS:

An experimental automated power factor correction panel is built to confirm the increase in the power factor of the proposed system. The developed hardware is built and tested in power electronics laboratory. The test is carried out on a inductive load to absorb the corrected power factor before and after correction. To demonstrate the working process of the APFC and Energy Monitoring system some inductive load is installed to create a load network. A decreasing power factor was thus created in the system.

The load network is of inductive having inductance value in series with resistance. As the resistance level is decreased keeping the inductance constant, the proportion of inductance compared to resistive component increased, and the power factor falls down. A decreasing power factor was thus created in the system. The system can detect and measure the exact power factor of a load network. The pre-programmed microcontroller can determine the required VAR demand for raising the power factor up to 0.81. It then switches on capacitors from the capacitor bank based on the VAR demand.

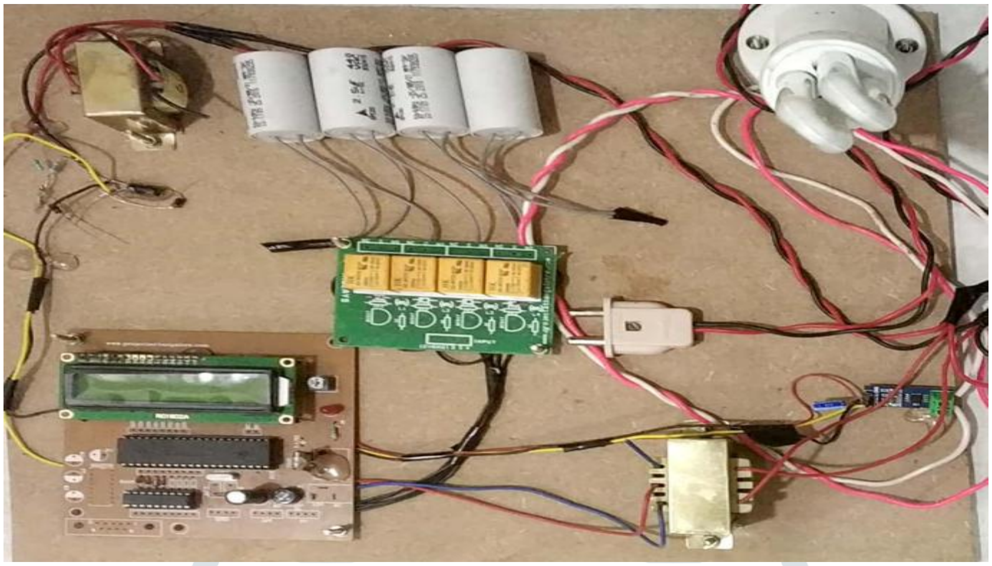

Figure 5 Complete APFC and Energy Monitoring system

The load network is of inductive having inductance value in series with resistance. As the resistance level is decreased keeping the inductance constant, the proportion of inductance compared to resistive component increased, and the power factor falls down. A decreasing power factor was thus created in the system. The system can detect and measure the exact power factor of a load network. The pre-programmed microcontroller can determine the required VAR demand for raising the power factor up to 0.81. It then switches on capacitors from the capacitor bank based on the VAR demand.


Figure 6 Load condition before power factor correction

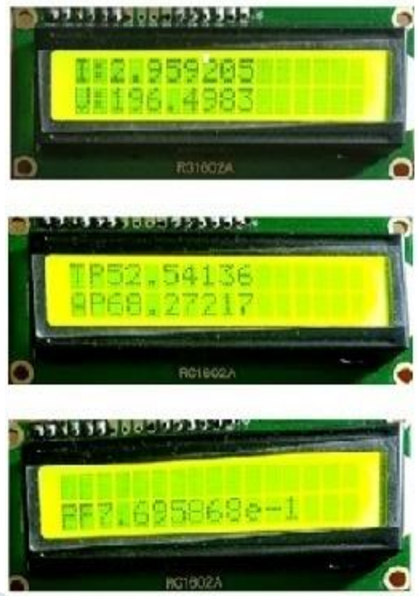


Figure 7. Load condition after power factor correction

The following table illustrates the data recorded from the system.

Table 1: Power factor correction

| Before correction | | | | | After correction | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Power Factor (PF) | Current (Amp) | Voltage (Volts) | Apparent Power (VA) | True Power (P) | Power Factor (PF) | Current (Amp) | Voltage (Volts) | Apparent Power (VA) | True Power (P) |
| 0.71 | 2.85 | 196.19 | 68.06 | 48.84 | 0.769 | 2.95 | 196.14 | 68.2 | 52.5 |

**IV. ADVANTAGES AND APPLICATIONS:**

i. Advantages of power factor correction:

1.Due to reduced power consumption there will be Less greenhouse gases
2. Reduction of electricity bills. .
3. Better usage of power system, lines and generators etc
4. Eliminate the penalty of power factor from the Electric Supply Company.

ii. Application of power factor correction:

Industries: Power factor correction brings the power factor of an AC power circuit closer to 1 by supplying reactive power of opposite sign, adding capacitors or inductors that act to cancel the inductive or capacitive effects of the load, respectively.

Home appliances: Power Factor Correction (PFC) devices that would connect to the mains and improve power factor measured by your electricity meter. However it is important to note that utilities bill a residential user based on real power that does not factor in Power factor and thus none of these devices would really reduce your monthly bill.

Commercial lines and power distribution system to increase stability and efficiency of the system.

## V.CONCLUSIONS:

The low PF experienced by many industrial electrical distribution systems can usually be improved at a reasonable capital expenditure. Savings in the utility bill normally provide the main economic justification for investing in the improvement of PF. Among other advantages, capacitors have a reasonable cost and they are manufactured in a variety of ratings that permits a substantial number of different combinations to meet the specific requirements of most industrial electrical distribution systems. My work is carried out to design and implement the automatic power factor controlling system using PIC Microcontroller (16F877A). PIC Microcontroller senses the power factor by continuously monitoring the load of the system, and then according to the lagging behavior of power factor due to load it performs the control action through a proper algorithm by switching capacitor bank through different relays and improves the power factor of the load. My work gives more reliable and user friendly power factor controlling system by continuously monitoring the load of the system. Measuring of power factor from load is achieved by using PIC Microcontroller 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 desired level.

## VI. REFERENCES


1) Yasin Kabir, Yusuf Mohammad Mohsin1,and Mohammad Monirujjaman Khan1 “Automated Power Factor Correction and Energy Monitoring System” 978-1-5090-3239-6/17/$31.00©2017IEEE
2) ArarsoTaye “Design and simulation of automatic power factor correction for industry application” Vol.5 (Iss.2): February, 2018. ISSN: 2454-1907 DOI: 10.5281/zenodo.1173999
3) Muhammad Bilal Khan, Muhammad Owais “Automatic Power Factor Correction Unit” Hamdard Institute of Engineering & Technology, Hamdard University Karachi, Pakistan DOI:978-1-5090-1252-7/16/$31.00 ©2016 IEEE
4) Ms.Sivasankari.J.Thirukkumaran.J,NaveenKumar.C,Sindhu.S,Suparnna.R "Voltage monitoring and power factor correction using GSM” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 p-ISSN: 2395-0072 ISO 9001:2008 Certified Journal
5) Aparna Sarkar UmeshHiwase “Automatic Power Factor Correction by Continuous Monitoring” ISSN: 2277-3754 ISO 9001:2008 Certified International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 10, April 2015
6) MyintMyint Than “Implementation of Power Factor Correction Using Solid State Switched Capacitors” IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 4 Ver. II (Jul. – Aug. 2016), PP 70-79
7) Praveen V.A, Sumaya Fathima, Sumalata I. A, Badiger K. D, Kandagal S. S “Automatic power factor correction using capacitor banks and 8051 microcontroller” International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, Volume-3, Issue-6, June 2015
8) Murad Ali “Design and Implementation of Microcontroller-Based Controlling of Power Factor Using Capacitor Banks with Load Monitoring”Global Journal of Researches in Engineering Electrical and Electronics Engineering. Volume 13 Issue 2 Version1.0 Year 2013.
9) Sapna Khanchi, Vijay Kumar Garg “Power Factor Improvement of Induction Motor by Using Capacitors” International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 7- July 2013
10) Ms. Jadhav Tejas S., Ms. Kamble Namita. Y., Ms. Shinde Sneha N., Ms. Jathar Amruta A., Prof. Kanase Digvijay B. “Power Factor Improvement of Single Phase Induction Motor” Vol-3 Issue-2 2017 IJARIIE-ISSN(O)-2395-4396