

Automatic Power Factor Improvement using PWM Board

Gopinath K^{1*}, Neha B M², P A Apoorva³, Preethi kumari Yadav E S⁴

¹Department of Electronic & Communication Engineering, R R Institute Of Technology,(VTU) Bangalore, Karnataka, India.

²Department of Electronic & Communication Engineering, R R Institute Of Technology,(VTU) Bangalore, Karnataka, India.

³Department of Electronic & Communication Engineering, R R Institute Of Technology,(VTU) Bangalore, Karnataka, India.

*Corresponding Author: appidarshu555@gmail.com

Abstract

This work designs an automatic power factor improvement system to address the low power factor caused by inductive loads, which increases energy loss and voltage drop. The system uses a microcontroller to continuously monitor the power factor and automatically switches in PMW Board to compensate for reactive power, improving the power factor towards unity. The main objectives are to reduce power system losses, lower electricity costs, and improve overall system efficiency by keeping the power factor near its optimal value.

Keywords- Automatic Power factor Improvement, power efficiency, equations, methodology, experimental evaluation.

1. Introduction (Size 10)

Power factor is an important parameter that indicates how electric power is effectively utilized. In some cases like Induction loads, fans, motors causes power factor decreasing. When Power factor decreases it leads to high current consumption, efficiency will reduce and it increases system losses. In our work design we will help to improve power factor and avoid unnecessary losses. In our design we used PMW Board for improving power factor with microcontrollers like Arduino, current and voltage sensors, relay. The process of our work is to monitor the power factor, if power factor decrease then with the help PWM Board and Ardino we will improve the power factor. Capacitor are not used in our design because we use PWM Board which is updated version. By monitoring and improving power factor losses we can extended the life of a inductive load.

2. Related Work

The article "Power factor correction unit using 89C52" published in 2014 contains the use of the 89C52 to measure and correct the power factor. The advantage of this research was that it showed the best method to measure the power factor of the systems but the disadvantage was the increase in the response time of the microcontroller [1].

The article "Power factor correction unit using an active series of filters" contains the use of active filters for the purpose of power factor correction, which is a unique method of power factor correction. The advantage of this method was the use of active filters to improve the power factor, but the disadvantage was the use of active filters because the filters do not have sharp cutoff frequencies and there were no either using controller, the circuit was not automatic [2].

The article "Automatic Induction Motor Power Factor Correction Using Arduino" contains the practical realization and power factor correction through the induction motor. The advantage of this article was

that it solved the problem of low power factor practically at the level of the induction motor by using it as an inductive load. The downside was that using the Arduino UNO board increased the cost of the circuit because it had to be more connected to the controller [3].

The article "Automatic power factor correction unit" published in 2016 contains the use of a precision rectifier, an EXOR gate and the use of an Arduino board as well as inductive and capacitive loads for d improvement and power factor correction. The advantage of this item is that it measures the voltage and current value and solves the power factor problem and displays the corrected value, but its disadvantage is the measurement of voltage and current value using a rectified sine wave and also the use of a precision rectifier which increases the size and complexity of the circuit [4].

Tiwari, A. K. (2014), "Power factor correction unit using 89C52":The article contains the use of the 89C52 to measure and correct the power factor. The advantage of this research was that it showed the best method to measure the power factor of the systems but the disadvantage was the increase in the response time of the microcontroller.[5]

Barsoum, N. (2007), "Programming of PIC Micro-Controller for Power Factor Correction":

This research focuses on the programming and algorithm development for PIC-based boards to monitor and correct power factor. The advantage is the precise mathematical calibration of phase angles, but the disadvantage is that it is primarily a passive switching method that may not handle high-speed current distortions as effectively as active PWM.[6]

Garcia, O., et al. (2003), "Single Phase Power Factor Correction":The authors present a method for active power factor correction (APFC) using high-frequency PWM switching. The advantage of this research is providing a framework for near-unity power factor and minimal harmonic distortion; the disadvantage is that high switching frequencies introduce electromagnetic interference (EMI) that requires complex filtering.[7]

Saha, S., et al. (2014), "ARM® Microcontroller based Automatic Power Factor Monitoring and Control System":This paper implements an ARM-based microcontroller board to monitor phase differences

and automate switching. The advantage is the significant improvement in processing speed and monitoring precision compared to 8-bit controllers; the disadvantage is the higher cost and increased complexity in board design.[8]

Jadhav, S., et al. (2014), "PWM Based Passive Power Factor Correction":The study uses PWM signals to control the timing of capacitor engagement via a microcontroller. The advantage is that it combines the simplicity of passive correction with the precision of PWM-driven timing; the disadvantage is that the mechanical relays used for switching are prone to wear and tear.[9]

Ahmed, M., et al. (2017), "Automatic Power Factor Correction and Monitoring By Using PIC Microcontroller". This paper describes the use of Zero Crossing Detection and PWM logic within a PIC board to trigger capacitor banks. The advantage is the real-time LCD monitoring of current, voltage, and power factor; the disadvantage is the high dependency on precise sensor calibration, where any drift leads to inaccurate correction.[10]

3. Materials and Methods

This focuses on the development of our design to improve the power factor Fig1 shows the block diagram and Fig2 is Flow chart of our design. Block diagram components are listed below:

- AC supply: The AC supply produce electrical power to the entire system, which is necessary to turn ON the devices which are connected together, some times this power causes the lagging power factor in a load so that power factor should be $\uparrow$ to work load effectively.
- Voltage sensor: In this project we have used ZMPT101B voltage sensor, which is responsible for measuring the voltage supplying to load. It continuously measures the voltage and sent that values to the arduino, it will calculate the phase difference of voltage & current that lead to power factor value.
- Current sensor: In this project we have used a ACS713 current sensor, which is responsible for measuring the instanious current supplying to load. It continuously

measures the current and sends that value to the Arduino, it will calculate the phase difference of voltage & current that leads to the power factor value.

- **Arduino uno:** (ATmega 328P microcontroller) Acts as a brain of the whole system. It is the controller of the operation of the project. It will collect the voltage and current values from the voltage sensor and current sensor respectively, with the help of code dumped to it, it will calculate the phase difference b/w the current voltage and by then it will calculate the power factor of the load. If it is below 0.9, the understand there is lagging power factor so it turns ON relay and PWM board.
- **Relay module:** when the relay module gets a message from arduino uno to turn on. It will turn on and increase the voltage value and act like a switch and turn ON PWM board.
- **APFC (Automatic power factor correction or PWM board):** It help in correcting the power factor in a load. It generate variable duty cycle signal. Using this signal it will correct the power factor.
- **Inductive load:** In electrical circuits generally lagging current produces when causes the reduction in power factor. In this project we have used DC motor as a inductive load.

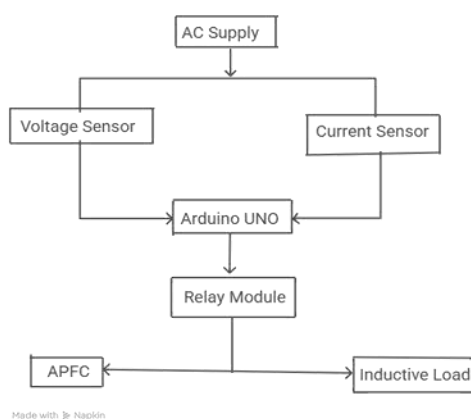


Fig1. Block diagram of Automatic Power factor Improvement.

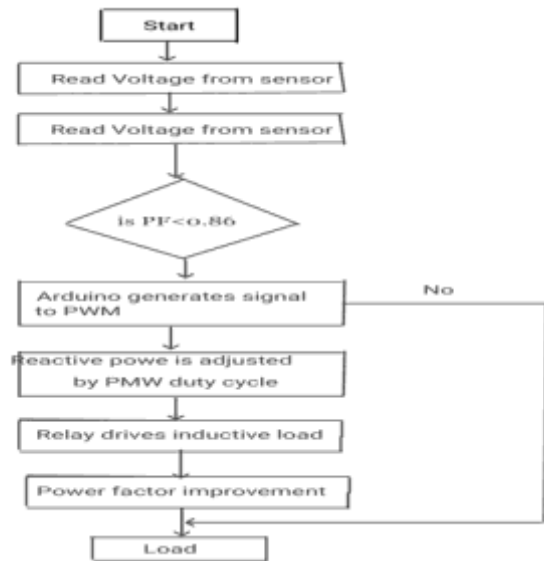


Fig2. Flow Chart of Automatic Power factor Improvement.

- **Start:** The system is powered ON. Arduino and all equipment begin initialisation.
- **Read Voltage from Sensor:** The voltage sensor (ZMPT101B) continuously measures the instantaneous AC voltage waveform. And it send this voltage value to Arduino for phase difference calculation.
- **Read Current from Sensor:** The Current sensor (ACS712) reads the instantaneous AC current waveform flowing through the load. Both voltage and current waveforms are now available to the microcontroller.
- **Check Power Factor:** The Arduino calculates the power factor by measuring the phase difference between voltage and current. If the current lags the voltage then Load power factor becomes less than 1. If PF drops below the preset limit (0.9), correction is needed.
- **Arduino Generates PWM Signal:** When power factor is low, Arduino sends a PWM signal to control. The PWM duty cycle determines how much reactive power must be compensated: Higher duty cycle is More reactive compensation, Lower duty cycle is Less compensation, This replaces traditional switching of capacitor banks.

- **APFC Adjusts Reactive Power Using PWM:** The APFC circuit uses the PWM to control: A reactive compensation module (inductive or capacitive). Typically a reactor/inductor or active compensation circuitry. PWM controls how much reactive current is injected back to balance the load PF.
- **This is the key innovation: No capacitor banks, PWM-controlled APFC instead.**
- **Relay Drives Inductive Load:** A relay activates the inductive compensation module based on PWM instructions. It helps counter the lagging current by injecting controlled reactive power.
- **Power Factor Improved:** With proper compensation: Phase difference between voltage and current reduces, using variable duty cycle signal produced by PWM, power factor increases toward unity, System becomes more efficient, Line losses reduce, Load receives better voltage profile, This block indicates the correction output is achieved.
- **Loop Back to Re-Read Sensors:** After compensation, the system continuously: Re-measures voltage & current, Recalculates PF, Checks if further correction is needed, This ensures real-time automatic PF control.

Equations:

A. Real Power (P): The power that does useful work. For a single-phase system: $P = V \times I \times \cos \phi$ For a three-phase system: $P = \sqrt{3} \times V \times I \times \cos \phi$.

B. Apparent Power (S): The total power supplied, calculated by multiplying voltage and current. $S = V \times I$ (for singlephase) $S = \sqrt{3} \times V \times I$ (for three-phase).

C. Reactive Power (Q): The power that creates and sustains the magnetic fields in inductive or capacitive loads. $\sqrt{Q} = S^2 - P^2$.

D. Power Factor (P F): The ratio of real power to apparent power, or the cosine of the phase angle (ϕ) between voltage and current. $P F = P / S$ $P F = \cos \phi$.

E. **Experimental Procedure** The experimental procedure for an automatic power factor improvement mini-project involves setting up the hardware, applying varying loads, monitoring the power factor, and observing the system's automatic response in connecting/disconnecting capacitor banks.

Table 1: Advantages and Disadvantages

Advantages	Disadvantages
Savings	Cost
Efficiency	High maintenance
Automated	Risk Harmonics
Better voltage	Limited life span
Reduced Losses	Complexity

4. Results and Discussion



Fig3. Project

The above Fig3 is our project design. In this project Components we used are Arduino Uno(ATmega 328P), Current sensor(ACS712), Voltage sensors(ZMTT101B), Relay, PWM Board, 16x2 LCD, Inductive load (DC-Motor), Breadboard and some Connecting wires. The system detects low power factor and improves using PWM control (phase shifting / active compensation technique) to improve the overall power factor. Results show improvement from 0.62 (uncompensated) to 0.93 (compensated) under the tested load profile, with reduced reactive power and modest changes in harmonic profile.



Fig4. Power factor of a load before power factor improvement

Above Figure shows power factor is decreased when the inductive load was switched ON, the voltage sensor showed a stable supply voltage, while the current sensor displayed a higher current due to the reactive component drawn by the load. The power factor calculated by the Arduino was noticeably low. This confirmed that the load was highly inductive and required reactive power compensation. The LCD display accurately showed low PF values and higher apparent power, validating the sensor measurements. Now by using our design we will improve the power factor.



Fig5. Power factor of a load after power factor improvement.

When the power factor dropped below, the Arduino activated the relay module, which switched ON the PWM Board in the APFC unit. Immediately after PWM Board connection, the sensor readings changed the current drawn by the load reduced, the reactive power decreased, and the power factor values began to rise. This is shown above Fig5. The improvement in power factor also led to a noticeable reduction in apparent power, confirming that the compensation was effective. The system automatically turned OFF the PWM Board once the power factor reached a stable and acceptable value, preventing over compensation.

5. Conclusion

This mini-project is a successful illustration of the use of Pulse Width Modulation (PWM), in conjunction with a microcontroller or similar programmable device, to accomplish Automatic Power Factor Improvement (APFI) without the need for conventional bulky capacitor banks. The system monitors the power factor of a load in real-time by measuring the phase angle difference between voltage and current waveforms.

This project will reduce the amount of wasted reactive power in a load, while also optimizing and frequently improving the power factor to a desired level (typically above 0.9 or near unity). By achieving near-phase voltage and current signals, overall power system efficiency is increased, line losses are decreased, and voltage regulation is improved.

Using a PWM Board and Power Electronics provides benefits over the mechanical switching of the capacitors, including being faster responding, more precise, and being designed much more compact than mechanical switching. Removing chemical power factor banks and the associated manual operation lowers hardware and space requirements, making this project a viable option for many different applications, including homes and small businesses.

The PWM based system can be updated with Wi-Fi or other communication devices (e.g., ESP8266) allowing remote monitoring and controlling of the various power systems parameters (voltage, current, power factor, energy consumption) via the internet on a web page or mobile device.

This project was created to tackle issues with the power factor associated with reactive loads. In future phases, an additional feature of the project will be adding Active Power Filters (APF) to actively reduce harmonics created by non-linear loads and enhance the overall quality of the electrical system.

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