

Automatic Power Factor Correction (APFC) System Using Arduino

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ABSTRACT

Power factor is very important for the AC electrical system to work well. The usage of inductors like electronic ballasts, chokes, and motors causes a lagging power factor thus, increasing losses, making voltage regulation poor, and energy costs going up. This paper describes the design and implementation of a Smart Automatic Power Factor Compensation (APFC) system that uses Arduino, PZEM-004T V4.0 energy measurement module, and an automatic capacitor bank.

The system continuously measures voltage, current, and power factor through a current transformer (CT) and voltage sensing terminals of the PZEM-004T module. According to the power factor, the Arduino controller activates the proper capacitor steps through relays thus, making the power factor better. If the power factor goes below a set limit, a buzzer alert is activated. The experimental data indicates that the system is capable of enhancing the power factor from 0.90 to nearly 0.97, which means the system is efficient, low-cost and reliable enough for both industrial and educational use.

Keywords:- Power Factor, APFC, Arduino, PZEM-004T, Capacitor Bank, Energy Efficiency.

1. INTRODUCTION

Power factor compensation through a Smart Automatic Power Factor Compensation (APFC) system is an eco-friendly approach that makes a single-phase AC load power factor automatically correct. Electronic ballasts and chokes are among the inductive loads that create a lagging power factor, which in turn results in higher current, energy losses, and lower overall system efficiency. So the chosen set for this project is a 40 W electronic ballast (choke) for inductive load and a 60 W incandescent lamp for resistive load. Continuous electrical parameters measurement of voltage, current, and power factor is done through the PZEM-004T V4.0 energy measurement module together with a current transformer (CT). An Arduino microcontroller is the one to process this information and give the power factor monitoring real-time.

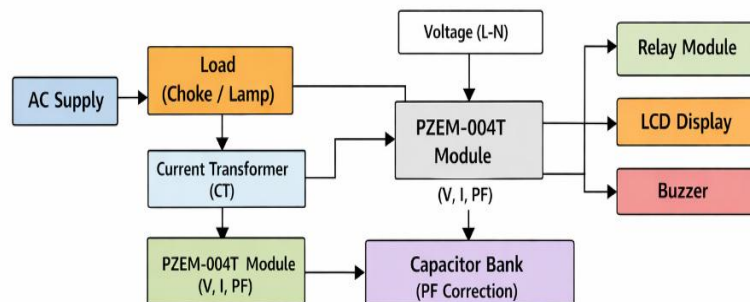
The preset value is set so that the measured power factor does not fall below it, and the Arduino takes automatic action then by switching a relay-controlled capacitor bank consisting of 2.5 μ F AC capacitors that compensates for the power loss due to lagging current flow. With the improvement of the power factor, it will be the unnecessary capacitor steps that will be disconnected to prevent overcompensation. Each capacitor has a bleeder resistor across it for safe discharge. A buzzer alert tells the system when the power factor is low, and a 16 $\times$ 2 LCD display keeps showing real-time values of voltage, current, and power factor. The whole system is fully automatic and does not require controller resetting when there is a load change, thus it is an efficient and low-cost power factor improvement solution.

2. SYSTEM ARCHITECTURE

The automatic smart power factor correction system (APFC) is a system that works through the continuous measurement, intelligent control, and automatic compensation process. The load is supplied with a single-phase alternating current (AC), which is manually operated and can be either an inductive load, such as a 40 W electronic choke, or a resistive load like a 60 W incandescent lamp. The energy measurement module PZEM-004T V4.0 directly measures the supply voltage from the phase and neutral lines, while the load current is measured through a current transformer (CT) which is clamped on the phase wire. These parameters (voltage, current, and power factor) are sent to the Arduino microcontroller acting as the main control unit. Following the power factor analysis, the Arduino automatically activates a relay to switch capacitor steps (2.5 μ F capacitors) of the capacitor bank on or off for feeding reactive power and correcting the power factor. To ensure the safe discharge of capacitors that are switched off, there is a bleeder resistor across each capacitor. There is also an LCD display that is part of the system for monitoring in real-time and a buzzer to give an alert when the power factor falls below the predetermined limit. The entire system is set up to run uninterruptedly and automatically without the need for resetting the controller, even when there are changes in the load.

3. PROBLEM IDENTIFICATION

In numerous electric circuits, particularly those containing inductive loads like electronic ballasts, chokes, motors, and transformers, the power factor is observed to be low and lagging. The occurrence of low power factor leads to the line current increase, which subsequently causes power losses, poor voltage regulation, and decrease in the overall efficiency of the electrical equipment as its consequences. Moreover, in small-scale industries and laboratories, power factor correction often remains manually done or not done at all, leading to energy wastage and thus, high electricity bills.



The conventional methods of power factor correction are based on fixed capacitor banks installation and manual switching, which are not flexible enough to cope with frequent changes in the load. Consequently, when the load fluctuates, these approaches either provide reactive power that is insufficient or excessive thus making them inefficient and unreliable. What is required is a power factor correction system that is intelligent, automatic, and economical and can for the entire time watch electrical parameters and modify the capacitor values instantly without human involvement or system reset.

4. RESULTS

The Smart Automatic Power Factor Compensation (APFC) system was tested and implemented successfully with a 40 W electronic ballast and a 60 W incandescent lamp as an inductive and resistive load respectively. Initially, when the inductive load was switched ON without any compensation, the power factor measured was around 0.88–0.90 (lagging). When the automatic capacitor bank controlled by Arduino was turned ON, the system dynamically switched through relays to connect the needed 2.5 μ F capacitor steps. Consequently, the power factor enhancement was about 0.96–0.98 which was an indication of excellent reactive power compensation.

5. CONCLUSION

A Smart Automatic Power Factor Compensation (APFC) system utilizing Arduino, PZEM-004T V4.0, a current transformer, and a relay-controlled capacitor bank was successfully designed and implemented. The system performs continuous monitoring of voltage, current, and power factor in real time and automatically compensates for the lagging power factor that is caused by the inductive loads like electronic choke. The experimental results revealed that the power factor is able to get significantly improved from a low value (approximately 0.88–0.90) to almost unity (0.96–0.98) after compensation. The system works dependably and without the need of a reset as load varies and gives clear visual and audible indications by means of an LCD display and buzzer. This project proves to be a low-cost, effective, and smart solution for power factor enhancement and reactive power loss reduction.

6. FUTURE SCOPE

- Extension of the system to a three-phase APFC configuration for industrial applications
- Use of industrial-grade contactors and protection devices for higher power ratings
- Implementation of adaptive control algorithms for faster and more accurate compensation
- Addition of harmonic analysis and filtering for non-linear loads
- Development of a compact commercial APFC panel based on the proposed design

7. REFERENCES

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