

Design and Implementation of an Automatic Power Factor Corrector Using a Capacitive Load Bank

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ABSTRACT

Poor power factor in inductive installations increases line current, losses, voltage drop, and utility demand. This paper presents a low-cost automatic power factor correction (APFC) system for single-phase loads. Potential- and current-transformer signals are conditioned through zero-crossing circuits and processed by an Arduino Uno to estimate the phase displacement between voltage and current. When the measured power factor falls below the programmed limit, the controller energizes relay-selected shunt-capacitor stages connected in parallel with the load. The measured value and operating status are shown on a liquid-crystal display. The implemented prototype automatically inserts compensation only when required and achieves a corrected power-factor range of approximately 0.92–0.95. The approach reduces unnecessary reactive-current flow while avoiding continuous manual switching and excessive capacitor duty.

Index Terms—Arduino Uno, automatic power factor correction, capacitor bank, inductive load, reactive power, zero-crossing detection.

INTRODUCTION

Electrical power is used most effectively when the current drawn by a load is substantially in phase with the supply voltage. Industrial and domestic installations commonly contain motors, transformers, and other inductive equipment that demand lagging reactive power. A low power factor therefore increases the apparent power and current required to deliver a given amount of useful real power. The consequences include higher copper losses, larger voltage drops, reduced loading capacity of cables and transformers, and possible reactive-power penalties.

Conventional correction connects shunt capacitors to supply leading reactive power. A fixed capacitor, however, may undercompensate a changing load or produce a leading condition when the load is removed. The proposed APFC unit continuously observes voltage and current timing, calculates the power factor, and selects capacitor stages through electromechanical relays. The design emphasizes simple hardware, economical implementation, automatic operation, and a target power factor above 0.90.

LITERATURE SURVEY

Vijay et al. [1] described an Arduino-controlled APFC system in which relays switch capacitor banks for lagging single-phase loads. Ganorkar and Patil [2] presented a low-cost strategy that combines power-factor measurement with calculated capacitor selection, ensuring that the capacitors remain disconnected when correction is unnecessary. Jasim and Alhasnawi [3] applied automatic relay-based correction to a smart-home context and emphasized real-time calibration toward unity power factor.

Related studies have examined Arduino-based automatic control [6], embedded power-factor metering [7], and complete APFC units [8]. These works establish the practicality of microcontroller-based measurement and staged compensation. The present implementation integrates isolated voltage/current sensing, zero-crossing comparison, an Arduino Uno, relay drivers, a switched capacitor bank, and local LCD indication in one experimental single-phase platform.

PROBLEM STATEMENT

Industrial and domestic inductive loads cause a lagging power factor, resulting in increased current demand, higher transmission losses, voltage drops, reduced system capacity, and possible utility penalties. Manual capacitor switching cannot respond effectively to continuous load variations, while fixed compensation may lead to undercorrection or overcorrection. Therefore, an automatic and economical system is required to monitor and improve the power factor according to changing load conditions.

OBJECTIVES

1. To continuously monitor and determine the power factor of a single-phase electrical load using voltage and current sensing.
2. To automatically improve the lagging power factor by switching suitable capacitor banks through Arduino-controlled relays, maintaining the power factor above approximately 0.9.

PROPOSED SYSTEM

The proposed system is an Arduino-based Automatic Power Factor Correction (APFC) system designed to continuously monitor the power factor of a single-phase electrical load and automatically improve it whenever it falls below the desired level. The system uses a current transformer and potential transformer to obtain current and voltage signals from the load. These signals are processed through the sensing and zero-crossing circuitry, and the Arduino determines the phase difference and corresponding power factor.

When a low or lagging power factor is detected, the Arduino sends control signals to the ULN2003 relay driver, which operates the relays connected to the capacitor bank. The required capacitors are connected in parallel with the inductive load to supply leading reactive power and compensate for the lagging reactive power. The corrected power factor and operating condition can be displayed on the LCD. The system performs this correction automatically without manual capacitor switching and is intended to maintain the power factor close to the required value while improving overall electrical-system efficiency.

BLOCK DIAGRAM

Fig. 1 shows the block diagram of the proposed Automatic Power Factor Correction system. The CT and PT sense the load current and voltage, while the ZCD and X-OR circuits provide phase information to the Arduino. Based on the measured power factor, the Arduino operates the relay to switch the required capacitor banks and improve the power factor.

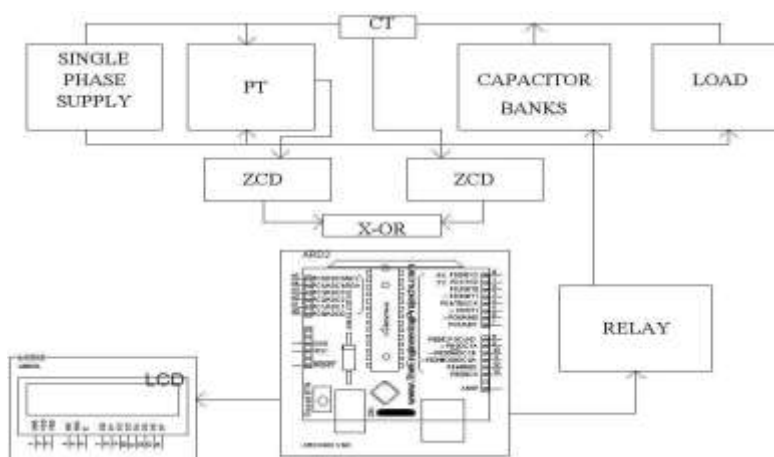


Fig. 1. Block diagram of the proposed automatic power factor corrector.

CIRCUIT DIAGRAM

Fig. 2 shows the integrated circuit diagram of the Automatic Power Factor Correction system using an Arduino Uno. The sensing circuit determines the phase relationship between voltage and current, while the Arduino controls the relay driver to switch the required capacitor banks for improving the load power factor.

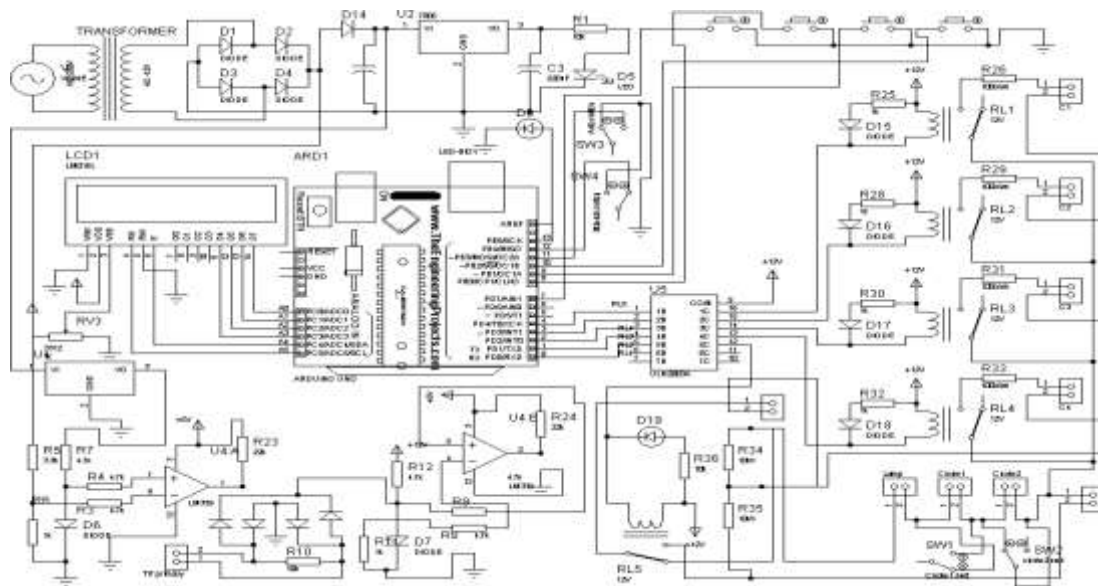


Fig. 2. Integrated circuit diagram of the APFC system.

METHODOLOGY

The proposed **Automatic Power Factor Correction (APFC)** system continuously monitors the voltage and current of the connected inductive load using a **Potential Transformer (PT)** and **Current Transformer (CT)**. The sensed voltage and current signals are supplied to the zero-crossing detector circuits, which convert them into suitable signals for determining the phase difference between voltage and current. The Arduino Uno processes these signals to determine the operating power factor of the load.

When the measured power factor falls below the predetermined value, the Arduino generates a control signal for the **ULN2003 relay driver**, which operates the appropriate relays and connects the required capacitor banks in parallel with the inductive load. The leading reactive current supplied by the capacitors compensates for the lagging reactive current of the load, thereby improving the power factor. The system continuously repeats the sensing and correction process, automatically connecting or disconnecting capacitor banks according to load conditions and displaying the system status through the LCD.

RESULTS AND DISCUSSION

The **Fig. 3** developed Automatic Power Factor Correction (APFC) system demonstrates the automatic improvement of power factor under inductive load conditions. The Arduino Uno continuously processes the sensed voltage and current signals and controls the relay-based capacitor bank to compensate for the required reactive power. Experimental results show that the system successfully improves and maintains the power factor within the range of 0.92 to 0.95, thereby enhancing the overall efficiency of the electrical system.

The results demonstrate that automatic capacitor switching reduces the need for manual power factor correction and allows the compensation to respond to load conditions. Improving the power factor reduces reactive power demand, line losses and voltage drop while improving the utilization of the electrical system. The developed system therefore

provides a simple and economical approach for automatic power factor correction using an Arduino-controlled capacitive load bank.



Fig. 3. Experimental operation and displayed system response.

CONCLUSION

The developed Automatic Power Factor Correction (APFC) system using a capacitive load bank provides an effective and economical method for improving the power factor of inductive loads. The Arduino-based controller automatically detects variations in power factor and switches the required capacitor banks through relays, reducing the need for manual correction. The system improves electrical efficiency, reduces reactive power demand and associated losses, and maintains the power factor near the desired level. The use of automatic capacitor switching also avoids unnecessary continuous connection of capacitors, thereby improving their operational life and making the proposed system suitable for industrial and distribution applications.

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