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Automatic Power Factor Correction Using Arduino

Tashi Rapden Wangchuk[1], Nima Tenzing Lepcha[2], Bibas Limbu[3], Ganga Prasad Siwakoti[4], Ashish Chettri[5], Dimpundi Lepcha[6], Pranay Mangar[7]
Electrical and Electronics Department, Centre for Computer and Communication Technology

Abstract: In today's technological revolution, power is very valuable. Low power factor results in increased energy consumption, voltage drops, decreased power system efficiency, and shortened equipment lifespan. Identifying the causes of power loss and improving power system stability is crucial. The rise in inductive loads has decreased power system efficiency. Therefore, a simple and effective method for improving power factor is needed. An automatic power factor correction device precisely determines the delay between the line voltage and line current by measuring the time difference between the arrival of the current and voltage signals from the AC mains. This time value is then calibrated to calculate the phase angle and corresponding power factor using an internal timer. The microcontroller (Arduino) then calculates the power factor and switches on different capacitor banks accordingly. This automatic power factor correction method can be applied in industries, power systems, and even households to improve stability and system efficiency. Power factor correction plays a significant role in enhancing the efficiency and reliability of electrical power systems.
Keywords: Power factor, Arduino, Liquid Crystal Display (LCD), Relay Drives, Capacitor Bank.

I. INTRODUCTION

In modern technology, electric power plays a vital role. However, the main drawback of electrical systems is the occurrence of power losses. To minimize this problem, engineers design various techniques commonly known as power factor correction (PFC) to improve the power factor in electrical power distribution systems. Power factor indicates the efficiency with which electrical energy is utilized. APFC systems continuously monitor the system's power factor and automatically adjust the connection of capacitors to the system to maintain or improve the power factor. This helps reduce reactive power demand, minimize energy losses, and improve the overall efficiency of the electrical system. APFC systems are commonly used in industrial and commercial settings with large electrical loads, helping to optimize energy usage and reduce electricity costs.

Power factor correction (PFC) circuits typically consist of capacitors connected in parallel to the load. These capacitors provide reactive power to compensate for the lagging reactive power drawn by inductive loads, such as motors and transformers. Here's a basic description of a PFC circuit:

1) *Capacitors:* The key components in a PFC circuit, capacitors store and release electrical energy in response to changes in voltage and current. By connecting capacitors in parallel to the load, the reactive power required by inductive loads can be supplied locally, thus improving the power factor.
2) *Controller:* A controller monitors the power factor of the system in real-time. It calculates the reactive power required to achieve a desired power factor and controls the connection of capacitors accordingly. The controller may use algorithms such as proportional-integral-derivative (PID) control to adjust the capacitors' switching.
3) *Witching Mechanism:* Capacitors are switched on or off based on the requirements determined by the controller. This switching mechanism can be achieved using relays, contactors, or solid-state switches.
4) *Safety Devices:* PFC circuits may include safety devices such as overcurrent protection, overvoltage protection, and temperature monitoring to ensure safe operation and prevent damage to the capacitors and other components. Overall, the PFC circuit actively adjusts the reactive power supplied to the load, ensuring that the power factor remains close to unity (1.0), thus maximizing the efficiency of the electrical system and reducing losses in transmission and distribution.

Key contributions of the paper:

a) Design of rectifier circuit
b) Active filter
c) PCB layout

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II. RELATED WORKS

Automatic power factor correction (APFC) has become increasingly important in industrial settings due to the rise of inductive loads, which can decrease power system efficiency. The following section reviews previously published research relevant to the project:

1) Automatic Power Correction: Low-cost solution Using Arduino by Vaibhav Ganorkar et al. (2020) describes a technique to improve power factor and reduce the cost of the power correction device in industrial power systems with increasing inductive loads.
2) Arduino Based Automatic Power Factor Controller by Md Abdullah AI Rabik discusses an automatic capacitor bank that is connected whenever the power factor drops in the system. The power factor is monitored and displayed on an IoT system.
3) An Arduino – Based Automatic Power Factor Correction Device by H. A. Illias et al. (2020) presents a project where power factor correction is achieved using zero crossing detectors, ATmega328 microcontrollers, and a manually adjusted capacitor bank.
4) An Automatic Power Factor Control Using Arduino UNO by G. Soufiane et al. (2020) proposes an automatic power factor control system using reactive components, an automatic switching capacitor bank, and the ATmega328P microcontroller. The design uses an Arduino Uno board to sense the power factor efficiently and switch on enough capacitors to compensate for the reactive power, bringing the power factor closer to unity for improved efficiency and better AC output.
5) Automatic Power Factor Correction Using Arduino by CH.Vijay introduces a simple and economical design for an automatic power factor correction system for single phase loads. The switching operation of relay is controlled by Arduino and capacitor is in parallel to the connected load by relay switching.
6) Automatic Power Factor Correction using Capacitor Bank and Arduino Micro controller by A. Raghavendar, uses automatic power factor correction using capacitor bank and micro controller 8051. Using a microcontroller reduces costs.

III. SYSTEM MODEL/METHODOLOGY/DESIGN

A. *Simulation*

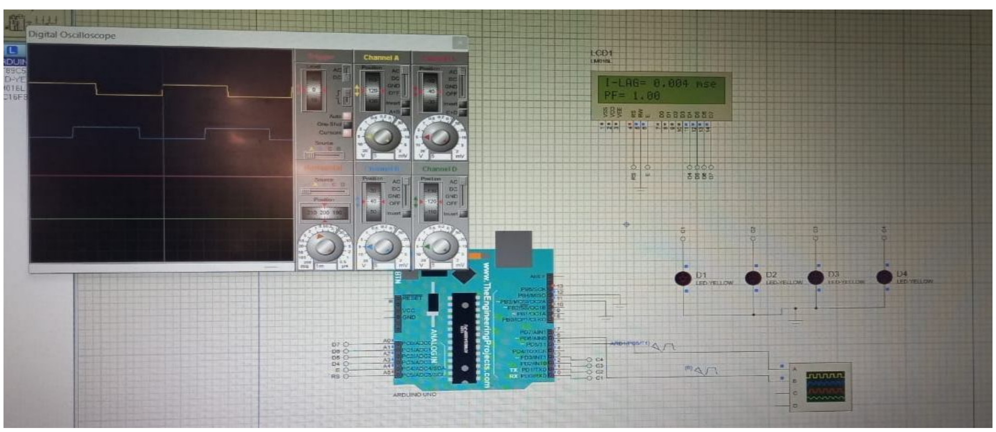

Fig.1. Improved Power factor

In the fig.1 we can see the improved power factor. And the phase difference between current and voltage is also shown.

B. *Block Diagram*

The supply signal voltage and current are given by the mains and stepped down by the current transformer and potential transformer and fed to the rectifier unit, which convert the alternating current signal to direct current signal. Then this direct current supply is given to the regulator as it can be seen in block diagram. The regulator used 7805. +eve supply is given to zero crossing detector(V), zero crossing detector(I), Liquid Crystal Display (LCD), and Arduino. Two operational amplifier acts as comparators with their output fed into two separate optocouplers, which generate dual pulse that are then fed into an X-OR gate. The output of the X-OR gate. The output of the X-OR gate is connected to a digital pin (i.e. pin 10) of the Arduino. The Arduino has an internal timer circuit that calculate time in (mS), which than convert into phase angle, and the power factor will display on LCD. If the power factor is low, then the Arduino actuates relay, and the shunt capacitor will come in contact with a device that provides leading current. Thus, power factor will be improved and shown on LCD.

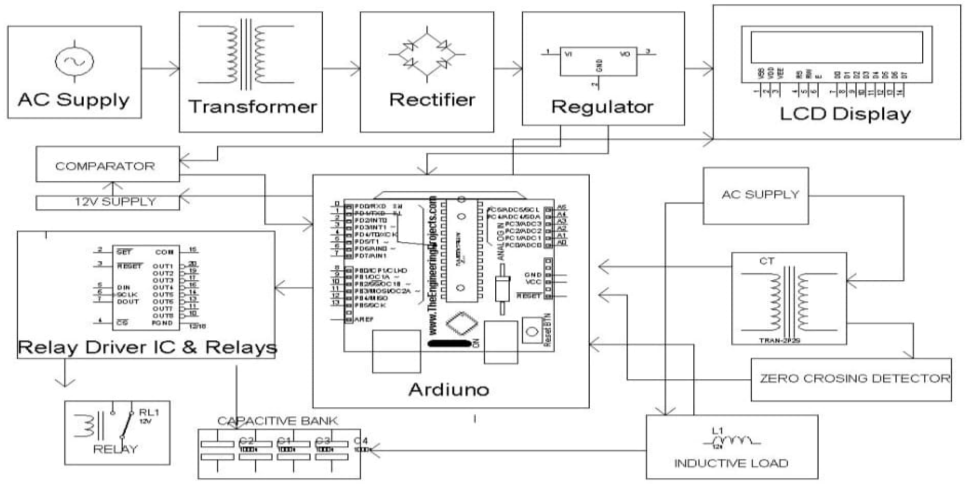

Fig.2. Block Diagram

IV. EXPERIMENTAL CONDUCTION

The main components required for this project has been listed below:

1) Arduino UNO
2) Capacitor Bank
3) Relay Module
4) LCD Display
5) Passive components (resistors, capacitors, wires, bread board etc.)
6) Transformer (CT and PT)

The model setup is arranged as depicted in the block diagram. When load is connected, current starts to flow, by help of current and voltage sensors the V and I is measured, after that a program has been written using the energy monitoring library to calculate the phase angle between V and I. In these by giving the calibrating value of V&I phase angle and PF is calculated. If the PF is below the set value that is 0.95 the microcontroller is set to given a turn on signal to the relay units which connects the capacitor to the load which can improve the lagging power factor near to the unity. If the PF is above the 0.95 then the microcontroller will not send any signal to the relay unit. And simultaneously the PF value is been printed in the LCD in order get track of the PF value for the user and to check the improved PF.

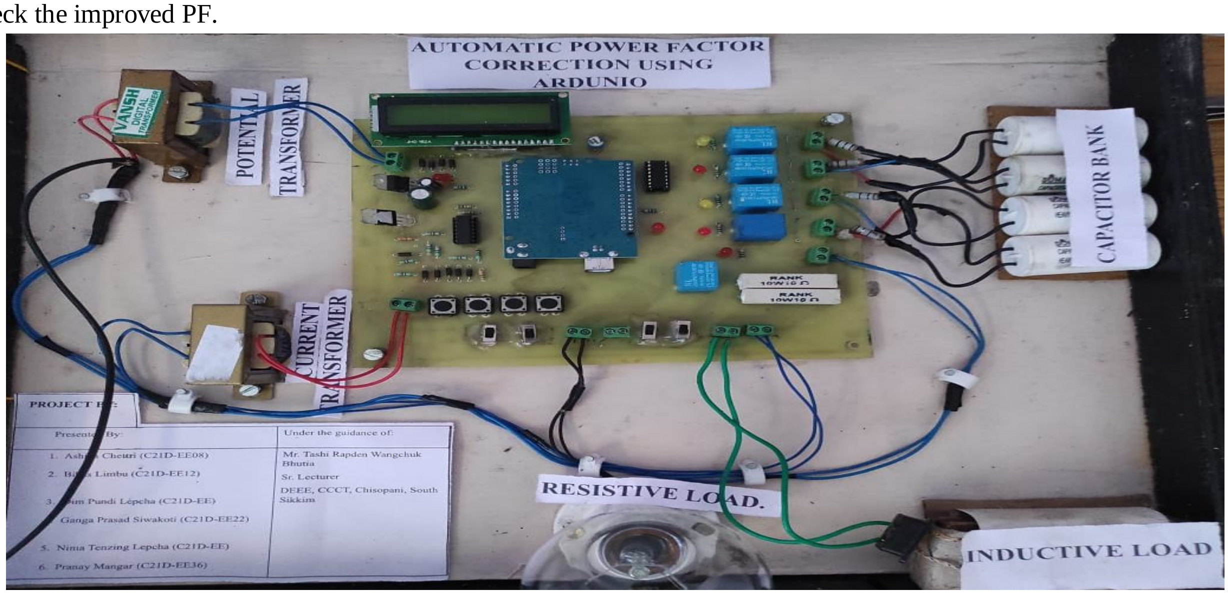

Fig.4. Automatic Power Factor Correction Using Arduino

V. RESULTS AND DISCUSSIONS

S/No.	Condition	Current(I) Lag	Power Factor (PF)	Improved Power Factor (PF)
1	Automatic	2.996mse	0.59	0.41
2	1 Capacitor connected in load	1.164mse	0.93	0.34
3	2 Capacitor connected in load	0.004mse	1	0.41

1) 1st condition.

When we connect the chock as inductive load then the current will lag. (I lag) by 2.996mse power factor (PF) is 0.59 and the improved power is 0.41

2) 2nd condition.

When we connect 1 capacitor in parallel to load the current will lag. by 1.164mse where the power factor is 0.93 and the improved power factor is 0.34.

3) 3rd condition

Similar to the 2nd condition the capacitor is connected in parallel to load but the quantity of capacitor is 2. So, that we can observe the difference in improved output. Where we get current lag 0.004mse, Power factor 1 and final improved power factor 0.41.

VI. CONCLUSION

It can be concluded that power factor correction techniques can be applied to industries, power systems, and households to enhance their stability. Consequently, the system becomes more stable, and the efficiency of both the system and the apparatus increases. Using a microcontroller allows multiple parameters to be controlled, reducing the need for additional hardware such as timers, RAM, ROM, and input/output ports.

VII. FUTURE SCOPE

The future scope of automatic power factor correction using Arduino is vast and multi-faceted. As technology continues to advance, Arduino-based APFC systems will likely become more sophisticated, integrated, and widespread, contributing significantly to energy efficiency and power quality improvements across various sectors.

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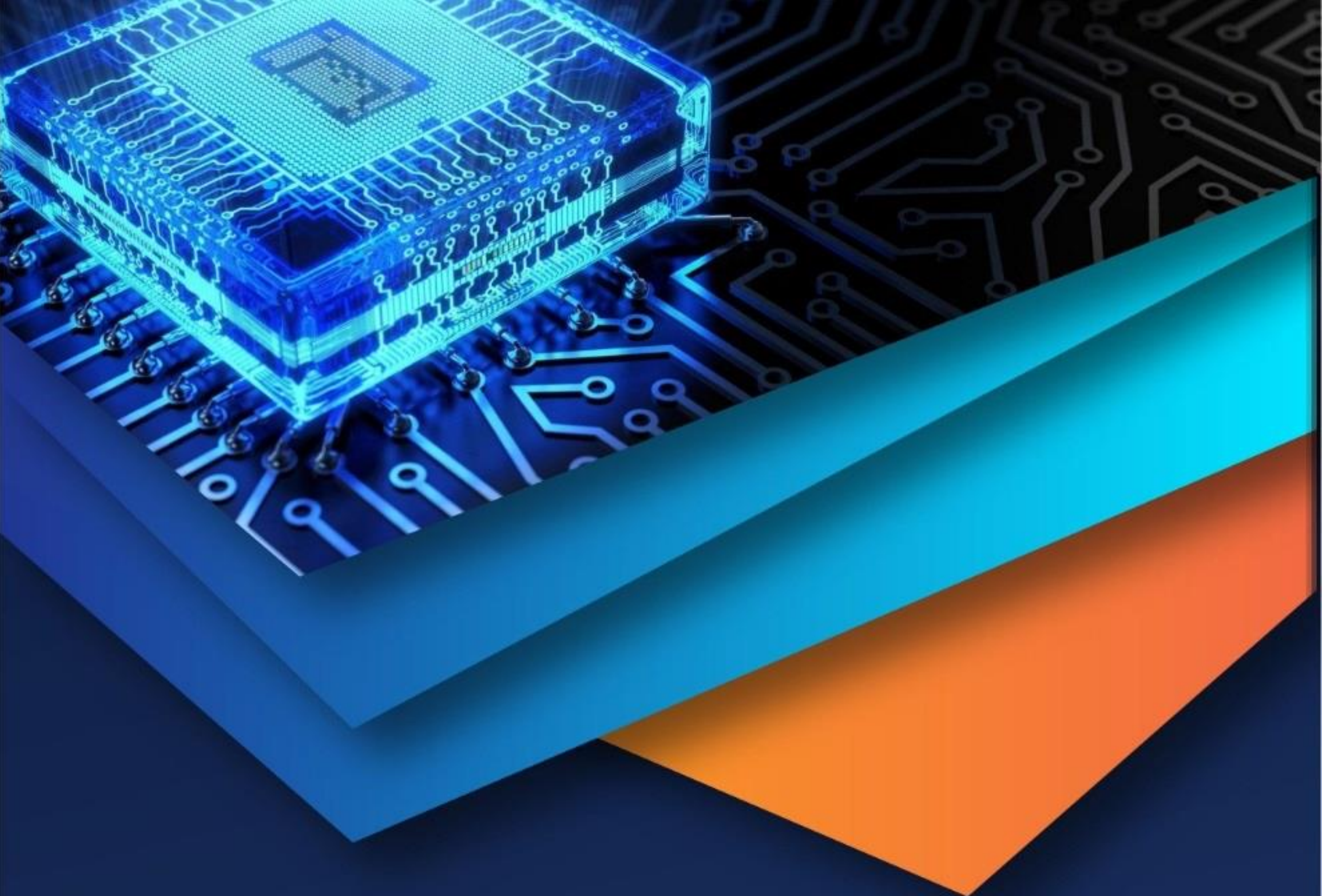

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