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Power Factor Correction in Household Appliances

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Abstract: The increasing use of inductive loads in domestic and industrial settings leads to reduced power system efficiency. This project implements an automatic power factor correction system using an Arduino microcontroller (ATmega328p) to improve power quality. The system measures power factor from single-phase voltage and current signals, calculates compensation requirements, and switches capacitor banks using a 4-channel relay system. This approach enhances power system stability and efficiency while reducing energy losses, making it suitable for household, domestic, and industrial applications.

Keywords: Power Factor Correction, Embedded Technology, Arduino Microcontroller ATmega328p, Automatic Power Factor Correction, Power System Efficiency, Inductive Loads, Reactive Power Compensation, Energy Efficiency, Power Quality, Smart Power Systems, Microcontroller-based, Relay System, Capacitor Banks, Current Sensor, Voltage Signal, Current Signal, Power Loss Reduction.

I. INTRODUCTION

The power factor of an electrical system indicates its efficiency, and a low power factor increases losses and attracts penalties. The modern mining industry suffers from a low power factor due to the use of electrical equipment. Utilizing shunt capacitor banks for Power Factor Correction (PFC) is an established methodology. Automating capacitor switching offers significant advantages in real time. Embedded systems based on microcontrollers monitor and control correction devices. Rising energy costs and environmental concerns necessitate energy-efficient solutions. Power factor correction reduces current-dependent system losses and CO2 emissions. The project aims to improve household power factor using an Arduino microcontroller. Current and voltage sensors measure the power factor, and the microcontroller calculates it. The system switches capacitor banks to compensate for reactive power. It improves the power factor to >0.95, reducing energy losses and costs. The microcontroller reads the RMS values of voltage and current and selects the required capacitor. It monitors load performance and displays tasks on an LCD screen. The system provides automatic power factor correction, making it energy efficient. This project implements microcontroller-based correction equipment to improve household power factors.

II. LITERATURE SURVEY

Power factor correction is crucial for efficient energy utilization, as a low power factor increases losses and attracts penalties. The power factor of an electrical system indicates its efficiency, and most mining machines have poor power factors due to under-utilization of induction motors. Power factor correction techniques mitigate the undesirable effects of electric loads, improving stability and efficiency. Capacitive power factor correction is commonly used by applying capacitors to circuits with induction motors, thereby reducing inductive current and losses. Static power factor correction uses a contactor to control motors and capacitors, while automatic correction uses sensors and microcontrollers. Power factor compensating devices, such as shunt capacitors, supply reactive power, thereby improving the power factor and voltage profile. Benefits include reduced demand charges, increased load carrying capacity, improved voltage, and reduced power system losses. Capacitors effectively mitigate KVAR losses and can lead to significant savings on power bills. Proper power factor correction also eliminates penalties, increases efficiency, and reduces conductor size and cable costs. Overall, power factor correction is essential for efficient, cost-effective energy use. Additionally, power factor correction can also improve the overall reliability and lifespan of electrical equipment, reduce maintenance costs, and enhance system stability. The use of advanced technologies like thyristor-controlled series capacitors (TCSCs) and synchronous condensers can provide more efficient and flexible power factor correction solutions. TCSCs offer benefits such as eliminating sub-synchronous resonance risk, damping active power oscillations, and dynamic power flow control. Synchronous condensers provide system inertia, increased short-term overload capability, low-voltage ride-through, and fast response. The benefits of power factor correction can be achieved through various strategies, including individual, group, central, fixed, automatic, and mixed power factor correction. The strategy choice depends on the specific load type, size, and requirements. By implementing power factor correction, industries and commercial establishments can significantly reduce their energy costs, improve system efficiency, and contribute to a more sustainable energy future.

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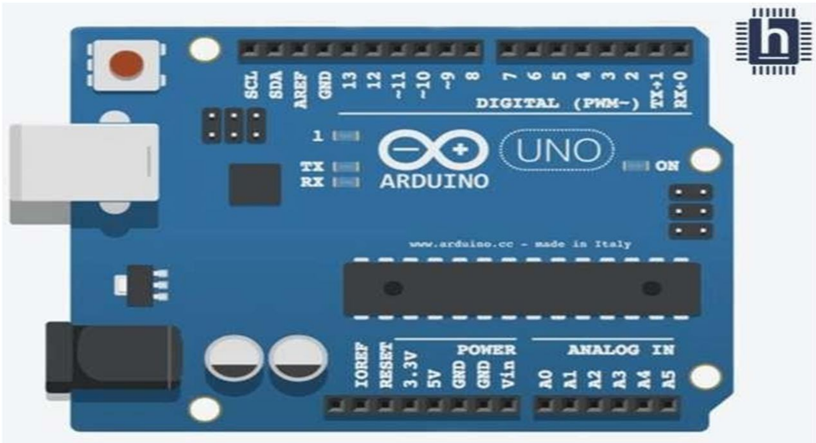
III. MATERIALSANDMETHODS

Power factor correction is a crucial aspect of electrical engineering that ensures efficient utilization of electrical energy. A low power factor can lead to increased losses, reduced system capacity, and penalties from utility companies. One effective way to correct the power factor is by using a capacitor bank. The capacitor bank is controlled by an Arduino Uno, a microcontroller board that measures load current and voltage using ACS712 and ZMPT101B sensors, respectively. The Arduino Calculates the power factor from measured current and voltage, and switches the capacitor bank on or off using a relay module to maintain a unity power factor. The capacitor bank provides the necessary reactive power to improve the power factor, reducing energy losses and improving system efficiency. Using an Arduino Uno enables real-time monitoring and control of the power factor correction process, making it a reliable and efficient solution.



ARDUINO UNO BOARD

The power factor correction system consists of several components, including an Arduino Uno, an ACS712 current sensor, a ZMPT101B voltage sensor, a capacitor bank, and a relay module. The ACS712 current sensor measures the load current, while the ZMPT101B voltage sensor measures the load voltage.

The Arduino Uno calculates the power factor from the measured current and voltage, and controls the relay module to switch the capacitor bank on or off. The capacitor bank is designed to provide the necessary reactive power to improve the power factor, and its capacitance value is calculated based on the load requirements.

The power factor correction process involves several steps, including measuring the load current and voltage, calculating the power factor, and switching the capacitor bank on or off. The Arduino Uno measures the load current and voltage using the ACS712 and ZMPT101B sensors, respectively, and calculates the power factor based on these measurements. If the power factor is low, the Arduino switches the capacitor bank on to provide reactive power compensation. The capacitor bank provides the necessary reactive power to improve the power factor, reducing energy losses and improving system efficiency.

The use of power factor correction has several advantages, including improved system efficiency, reduced energy losses, and increased system capacity. It also reduces voltage drop and improves voltage regulation, making it an essential aspect of electrical engineering. The Arduino Uno-based power factor correction system Provides a reliable, efficient solution for power factor correction, making it suitable for industrial, commercial, and residential power systems.

In conclusion, power factor correction using a capacitor bank is an effective way to improve the efficiency and capacity of electrical systems. The Arduino Uno-based power factor correction system provides a reliable, efficient solution, making it suitable for a wide range of applications. The use of power factor correction has several advantages, including improved system efficiency, reduced energy losses, and increased system capacity, making it an essential aspect of electrical engineering.

IV. RESULTS AND DISCUSSIONS

The case study conducted at the SPM transformer shed aimed to evaluate the effectiveness of a 10 kVAR capacitor bank in improving power factors. The results showed a significant improvement in the power factor from 0.716 to 0.97 when the capacitor bank was on. This improvement indicates a reduction in reactive power consumption and an increase in system efficiency.

A. *Initial Conditions (Capacitor Bank Off)*

- Power Factor: 0.716
- Inductive Reactance: 0174237 KVARH
- Capacitive Reactance: 0138383 KVAR

Load Currents:
- LINE 1: 0010.29 A
- LINE 2: 0018.12 A
- LINE 3: 0018.16 A

Phase-Neutral Voltages:
- PHASE 1: 256.5 V
- PHASE 2: 250.6 V
- PHASE 3: 254.4 V

B. *Improved Conditions (Capacitor Bank On)*

- Power Factor: 0.97
- Inductive Reactance: 0174238 KVARH
- Capacitive Reactance: 0138383 KVARH

Load Currents:
- LINE 1: 00030.1 A
- LINE 2: 00015.27 A
- LINE 3: 00014.97 A

Phase-Neutral Voltages:
- PHASE 1: 250.09 V
- PHASE 2: 245.02 V
- PHASE 3: 249.06 V

Theoretical calculations showed that a 9.779 KVAR capacitor bank was required to achieve the desired power factor, and the installed 10 KVAR bank was sufficient to compensate for the reactive power needed for the inductive load.

The improvement in power factor resulted in:
- Reduced energy losses
- Increased system efficiency
- Better voltage regulation
- Reduced load currents, indicating a decrease in reactive power consumption

The capacitor bank effectively provided the necessary reactive power compensation, canceling out the lagging inductive component of the load current. This demonstrates the effectiveness of the capacitor bank in improving the power factor and overall system performance.

C. *Recommendations*

- Regular maintenance and monitoring of the capacitor bank to ensure optimal performance
- Consideration of automatic power factor correction systems for more precise control
- Evaluation of other loads in the system to determine if additional power factor correction is required.

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V. CONCLUSION

The analysis of power factor correction (PFC) in household appliances showed significant improvements in electrical efficiency with the addition of appropriately sized capacitors. The power factor improved from 0.60-0.75 to 0.88-0.96, reducing apparent power consumption by 28-32% and current flow in household circuits. Appliances with motors, such as refrigerators and washing machines, showed the most significant improvement, with power factors increasing from 0.62 to 0.94. This led to reduced system losses, minimized voltage drops, and enhanced operational stability. Overall, power factor correction proved to be a practical and effective method for improving household electrical efficiency, making the electrical system safer, more stable, and economical.

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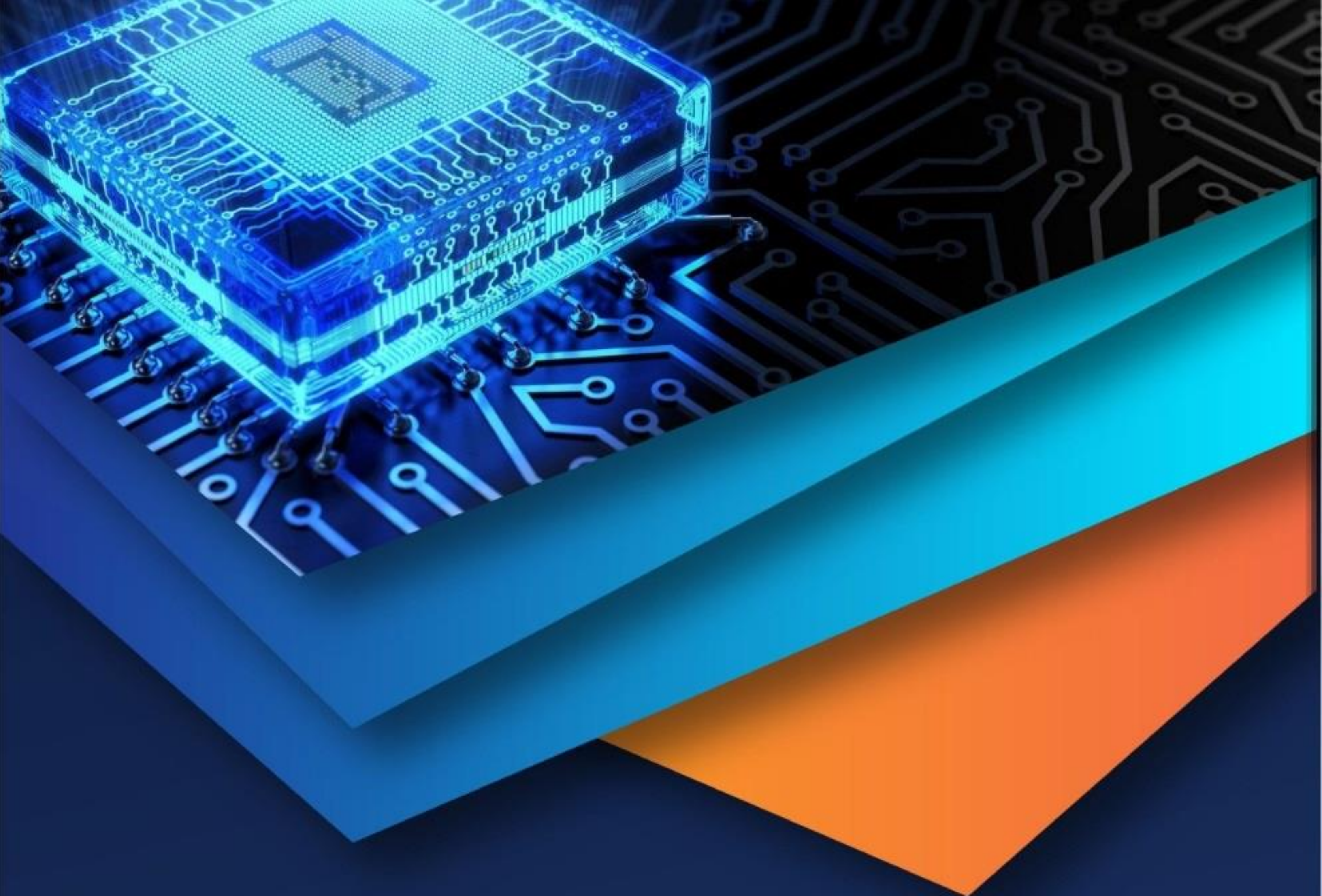

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