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Implementation of IoT Based Energy Monitoring & Automatic Power Factor Control

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ABSTRACT: In electrical terms, power factor is basically defined as the ratio of active power to reactive power or it is the phase difference between voltage and current. Active power performs useful work while reactive power does no useful work but is used for developing the magnetic field required by the device. Most of the devices we use have power factor less than unity. Hence, there is a requirement to bring this power factor close to unity. Here we are presenting a prototype for automatic power factor correction using the Microcontroller built in ESP32 module.

KEYWORDS: Microcontroller (Arduino/ESP32), Sensors, Energy monitoring, Power factor correction.

I. INTRODUCTION

Electrical energy efficiency is of prime importance to industrial and commercial companies operating in today's competitive markets. Optimum use of plant and equipment is one of the main concerns that industries try to balance with energy efficiency for both economic and environmental reasons. As society becomes increasingly conscious of its impact on the environment, reduced energy consumption becomes more desirable, which is an achievable goal for everyone. Through the use of measures such as power factor correction, electricity consumption is optimized, which ultimately leads to reduced energy consumption and reduced CO₂ greenhouse gas emissions.

Currently, the effective use of the capacitor bank as power factor correction device has been its use as a capacitor bank for domestic use. Also known as energy stability, it will correct power factor based on the concept of employing a capacitor as a compensator of reactive current in the single phase electric circuit. However, this device proves to be less efficient because of its static operation i.e. the compensation does not vary with changes in the load.

The project titled —Automatic Power Factor Correction‖ was developed to enable operation of a single phase capacitor bank to control the power factor such that it follows the change in the load. The present single phase capacitor bank was not able to operate with an increase or reduction in the load on the power system. Because the present system could not detect load rating that changed, its operation was inefficient and power factor correction thus obtained was not optimum. Power factor is A ratio of real power and apparent power. Ideal power factor is unity. Pure resistive loads have unity power factor. But there is no such load exist. So we always try to make power factor close to unity. Reactive power is also reason of low power factor. Inductive loads absorb reactive power and capacitive loads provides reactive power. So capacitor banks are used to improve power factor in power factor correction circuit. By connecting capacitor banks parallel to load, power factor is increased. Capacitor provides reactive power locally to load instead of getting from generators or power system which in return induces burden in power system. This is main objective of automatic/intelligent power factor controller

II. FEATURES OF IMPLEMENTATION OF IOT BASED ENERGY MONITORING & AUTOMATIC POWER FACTOR CONTROL

IoT-based energy monitoring and automatic power factor control systems provide real-time visibility of energy usage, improve efficiency, and automatically correct poor power factor using capacitor banks. Real-time monitoring: Continuous measurement of voltage, current, power, and power factor using sensors like CT (Current Transformer), PT (Potential Transformer), and PZEM modules. Alerts & notifications: Automatic alerts for abnormal consumption or low power factor help prevent energy losses and equipment damage

III. CONCEPT

The concept of implementing IoT-based energy monitoring with automatic power factor control is to combine real time data acquisition, remote monitoring, and intelligent correction of power factor using capacitor banks, all managed through IoT platforms. Energy Monitoring via IoT:

Sensors such as CT (Current Transformer), PT (Potential Transformer), and Zero-Cross Detectors measure electrical parameters (voltage, current, power, and power factor). These values are processed by a microcontroller (Arduino, ESP32, or Raspberry Pi) and transmitted to an IoT platform (cloud dashboard, mobile app, or web interface). The system continuously checks the power factor of the connected load. If the power factor drops below a threshold (commonly 0.95), the controller automatically switches capacitor banks via relays to compensate for reactive power.

IV. OVERALL WORKING OF THE SYSTEM

Sensing Stage: Current Transformers (CTs) and Potential Transformers (PTs) measure current and voltage. A Zero Cross Detector identifies the phase difference between voltage and current. These inputs are fed into a microcontroller (Arduino, ESP32, Raspberry Pi, etc.).

Computation Stage: The microcontroller calculates key parameters: voltage, current, active power, reactive power, and power factor (PF). If PF is below a set threshold (e.g., 0.95), the system prepares corrective action.

IoT Communication Stage: Data is transmitted via Wi-Fi, GSM, or other IoT modules to a cloud platform. Users can access dashboards on mobile apps or web portals to monitor energy usage in real time. Historical data is logged for analysis of load behavior and efficiency.

Control Stage (Automatic PF Correction): Based on PF readings, the controller switches capacitor banks ON or OFF using relays. Capacitors supply reactive power to balance inductive loads, improving PF toward unity. This process is fully automatic, requiring no manual intervention.

Monitoring & Feedback Stage: Corrected PF and updated energy parameters are displayed on LCDs and IoT dashboards. Alerts/notifications are sent if abnormal consumption or capacitor faults occur. Continuous feedback ensures the system adapts dynamically to load changes.

V. FUTURE SCOPE OF IMPLEMENTATION OF IOT BASED ENERGY MONITORING & AUTOMATIC POWER FACTOR CONTROL

The Automatic power factor controlling system using ESP32 have several future scope possibilities for further improvement and expansion. Some potential areas for enhancement include: Integration with IoT (Internet of Things): Incorporating IoT technology can allow the Controller system to be connected to the internet, providing more advanced features such as real-time data analytics, cloud-based storage, and integration with other smart devices. Smart Sensing and Actuation: Enhance sensing capabilities by integrating advanced sensors such as temperature, humidity, and current level sensors. This can enable more precise control over controlling and better monitoring of environmental conditions. Machine Learning Algorithms: Implementing machine learning algorithms can optimize controlling schedules based on historical data, weather forecasts, and specific plant requirements. This can lead to more adaptive and efficient controlling strategies over time.

VI. CONCLUSION

The system enables continuous monitoring of electrical parameters such as voltage, current, power, and power factor using IoT-enabled sensors. Through cloud dashboards and mobile apps, users gain remote visibility and can analyze consumption trends, detect inefficiencies, and receive alerts. The automatic power factor control (APFC) mechanism dynamically switches capacitor banks to maintain the power factor close to unity, reducing reactive power and transmission losses. This integration ensures energy efficiency, cost savings, and compliance with utility regulations by avoiding penalties for low power factor. The IoT framework makes the system scalable and adaptable, suitable for industries, commercial buildings, and even smart homes.

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