INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 05, Issue 03, March 2025, pp : 2254-2259
www.ijprems.com
editor@ijprems.com
e-ISSN : 2583-1062
Impact Factor : 7.001

RASPBERRY PI PICO BASED UPFC/APFC SYSTEM

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DOI: https://www.doi.org/10.58257/IJPREMS39424

ABSTRACT

The Unified Power Flow Controller and automatic power factor correction systems are vital elements of present-day electrical grids. Here, I aim to develop the integration of these functionalities Enhancement of the electricity quality and reduction of losses while also offering a robust solution for controlling power in real time is the major target of the work. The research is constructed on consideration of the problem, its objectives, design, implementation and results of the project, including its strengths and weaknesses.

Power efficiency and quality are paramount issues in contemporary electrical grids, especially with the escalating penetration of renewable energy resources and nonlinear loads. This project outlines the construction of a Raspberry Pi Pico-based Unified Power Flow Controller (UPFC) and Automatic Power Factor Correction (APFC) system, intended to enhance the power quality, reduce transmission loss, and provide improved system stability.

The UPFC is a high-technology power electronics-based controller used for regulating voltage, phase

angle, and impedance of transmission lines to achieve maximum power flow and minimize grid instability. The APFC system continuously tracks power factor fluctuation and dynamically compensates it through capacitor banks, thus minimizing reactive power requirement and enhancing energy efficiency.

Low-cost yet high-performance microcontroller Raspberry Pi Pico, based on RP2040 dual-core architecture, acts as the central controller. It is Micro Python/C++ programmed to execute real-time monitoring and control algorithms. The system uses current and voltage sensors to measure electrical parameters in real time, thyristor-controlled switching circuits to activate capacitor banks, and communication modules to support remote monitoring and control

1. INTRODUCTION

The contemporary power grid is increasingly challenged to be efficient, stable, and reliable, particularly with the demand for integrating renewable energy and more nonlinear loads. To meet these challenges, high-end power management technologies like the Unified Power Flow Controller (UPFC) and Automatic Power Factor Correction (APFC) are now indispensable. These technologies enhance power flow optimization, correct power factor imbalances, and optimize overall grid performance.

This project introduces a Raspberry Pi Pico-based UPFC and APFC system, providing a scalable, cost-effective, and real-time power management system. The system provides real-time control over voltage levels, impedance, and phase angles, while also enhancing power quality by minimizing reactive power losses. Relying on the features of Raspberry Pi Pico, this project is designed to create a smart, efficient, and affordable power control system for electrical grids.

2. LITERATURE SURVEY

[1] Kumar, S. et al. The work investigates the use of Raspberry Pi Pico in the design of an adaptive automatic power factor correction (APFC) system tailored for renewable energy systems. The system adapts reactive power compensation dynamically based on real-time changes in loads, offering a great boost to energy efficiency as well as system reliability. It emphasizes the utilization of smart algorithms with Pico for maximum performance.

[2] Patel, R. et al. The article addresses the integration of Raspberry Pi Pico-based unified power flow controllers (UPFC) in contemporary smart grids. The research focuses on the controller's capability to stabilize voltage and control power flow in urban electricity distribution networks. Its real-time monitoring capabilities and effective control mechanisms are especially emphasized for improving grid stability and reducing transmission losses.

[3] Ahmed, H. et al. This study offers a comparative analysis of conventional UPFC implementations and Raspberry Pi Pico solutions. It exhibits the latter's advantage in controlling power flow in low-voltage networks by minimizing transmission inefficiencies. The system also provides enhanced voltage stability and reduced operational costs under dynamic load conditions.

[4] Sharma, T. et al. The authors explore the potential of Raspberry Pi Pico in alleviating harmonic distortions in power systems in industries using sophisticated APFC systems. Through dynamically compensating the reactive power, the system is given a marked enhancement in power quality in general. Case studies from industrial installations are featured

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in the study, highlighting practical gains in terms of downtime.

[5] Zhang, L. et al. This work presents novel control schemes for UPFC systems on Raspberry Pi Pico, with emphasison dynamic compensation of active and reactive power. The research unveils that the compact design and processing capabilities of Pico make it perfectly suited to applications demanding quick reaction to variations in load. It also touches on the economic benefits of such an approach. Automated Control and Protection System in Induction Motor

[6] Singh, A. et al. The research identifies the use of IoT technologies along with Raspberry Pi Pico for remote monitoring and APFC system control. Through the use of IoT-based features, the system ensures proper energy management and appreciable cost reduction in practical applications. It also highlights the scalability of the design for industry and commercial applications.

[7] Lee, J. et al. This study discusses applying Raspberry Pi Pico in creating affordable APFC systems for small and medium industries. The paper points out its efficiency and affordability when compared to conventional approaches. It also illustrates how the system responds to changing power loads, providing constant power factor correction.

3. PROTECTION AND CONTROL MECHANISM

It appears you're seeking details on protection and control scheme for a Raspberry Pi Pico-based UPFC (Unified Power Flow Controller) or APFC (Automatic Power Factor Correction) system. This is a fascinating subject, combining power electronics and microcontroller-based control.

1. Introduction to UPFC/APFC with Raspberry Pi Pico:

-UPFC (Unified Power Flow Controller): It is a controllable device in power systems utilized for voltage control, impedance, and power flow, which facilitates better grid stability.

- APFC (Automatic Power Factor Correction): It increases the power factor of a system, minimizing loss of energy and efficiency improvement.

The Raspberry Pi Pico, which is powered by a dual-core ARM Cortex-M0+ microcontroller, provides an economical way of deploying control algorithms with its GPIO pins, ADCs, and PWM features.

2. Major Protection Mechanisms:

a. Overvoltage and Under voltage Protection:

- Deployment: Utilize voltage sensors to track the system voltage. In case the voltage goes beyond a threshold, the Raspberry Pi Pico can trigger relays or MOSFETs to disconnect the load.

- Example: Voltage comparators or Zener diodes can operate in conjunction with the Pico for fast action.

b. Overcurrent Protection:

- Current Sensors: Employ Hall-effect sensors or current transformers to sense current flow.

- Control Logic: The Pico can determine current in real-time and initiate protective action (such as disconnecting the load or engaging circuit breakers).

c. Short-Circuit Protection:

- Detection: High-response algorithms identify short circuits by sensing abrupt current spikes.

- Response: The system can isolate the faulted area instantaneously through solid-state relays.

d. Thermal Protection:

- Temperature Sensors:DS18B20 or LM35 can be used to sense the temperature of vital components.

- Control: In case of overheating, the Pico reduces the load or initiates cooling procedures.

e. Ground Fault Protection:

- Ground Fault Sensors: Identify leakage currents to ground.

- Response: Initiate alarms or disconnect the system to avoid damage.

3. Control Mechanisms:

a. Power Flow Control (for UPFC):

- Phase-Locked Loop (PLL): To synchronize with the grid frequency.

- PWM Generation: Regulation of power electronics such as IGBTs or MOSFETs to modify power flow.

- Feedback System: Utilize ADCs to feed back voltage and current continuously, modifying the control signal accordingly.

b. Power Factor Correction (for APFC):

- Real-Time Monitoring: Ongoing computation of power factor with real-time data.

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- Capacitor Bank Control: The Pico can turn capacitors in/out of the circuit through relays or SSRs depending on the measured power factor.

c. Data Logging and Communication:

- I2C/SPI/UART: To communicate with external devices or SCADA systems.
- Display Module (optional): For real-time monitoring through an OLED or LCD display.

4. Hardware Setup:

- Raspberry Pi Pico (Microcontroller)
- Current Sensors: ACS712, CT sensors
- Voltage Sensors: ZMPT101B
- Power Electronics: MOSFETs/IGBTs, relays, SSRs
- Protective Devices: Fuses, surge protectors
- Communication Modules: RS485, Wi-Fi (for Internet of Things integration)

5. Software Implementation:

- Programming Language Micro Python or C/C++ for the Pico
- Control Algorithms: PID controllers, fuzzy logic (for complex systems)
- Protection Logic: Implement using interrupts and real-time monitoring loops

COMPONENTS(TOOLS)

Copper Clad PCB

A Copper Clad PCB (Printed Circuit Board) is a type of PCB made using a copper-clad laminate (CCL) as the base Material

Fig.1 Copper Clad PCB

Transformer:

Step-down transformer is an electrical machine that steps down a higher voltage to a lower voltage based on the theory of mutual induction In a 230V to 12V, 1A transformer, input (main) side runs at 230V AC, and the output (secondary) side provides 12V AC with a maximum of 1A current.

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Fig.2.

7805 Voltage regulator IC

The 7805-voltage regulator is a linear voltage regulator

Fig.3. 7805 Voltage regulator IC

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Raspberry Pi Pico:

The Raspberry Pi Pico is a low-cost, high-performance microcontroller board based on the RP2040 chip.

Fig.4. Raspberry Pi Pico

Single Phase Induction Motor:

An induction motor or asynchronous motor.

Fig.5. Single Phase Induction Motor

BLOCK DIAGRAM

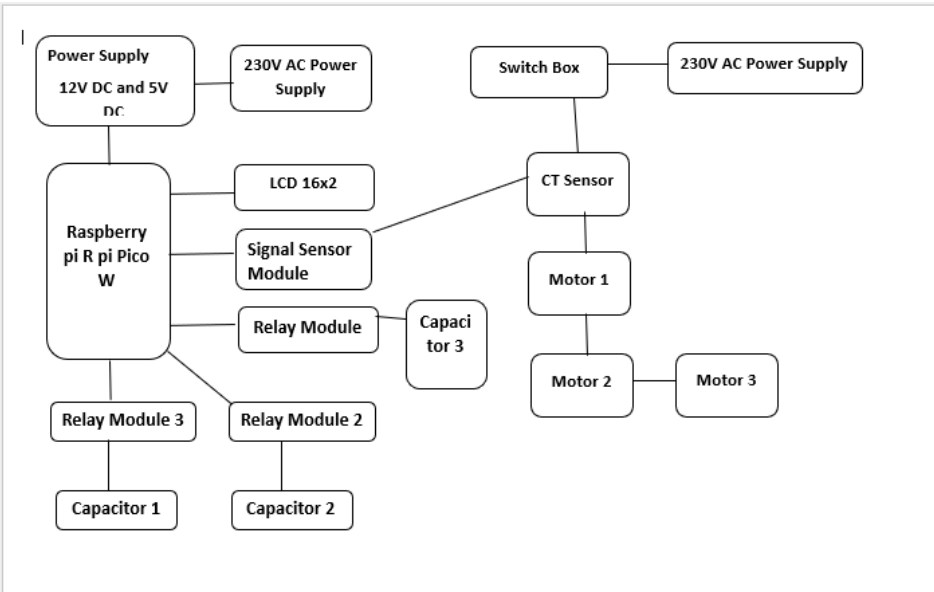

Fig.6. Block Diagram

4. RESULT

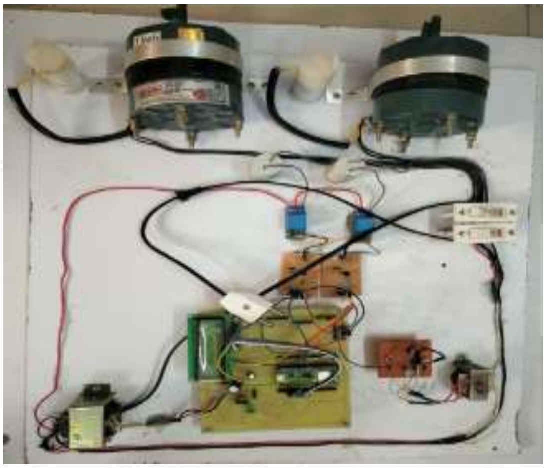

Fig.7 Result

5. CONCLUSION

The Raspberry Pi Pico APFC/UPFC System is a new technical approach to mitigating the power quality issue by merging the ideas of the Automatic Power Factor Correction (APFC) and the Unified Power Flow Control (UPFC). The approach is to analyze the electrical parameters in real-time to resolve a power factor problem through the senses of reactive power in imbalance and whenever needed, use the existing functionalities provided with components like the ACS712 current sensors, relays, voltage regulators, microcontroller and capacitors banks to incorporate ultimately to resolve the power factor.

This approach can decrease energy consumption, lower the electricity bill, and enhance efficiency in the electrical network.One of the main advantages of the system is the compactness and cost efficiency. The system is entirely automatic with real-time response considering the possibility of integrating sectors to wirelessly communicate power management platform to be advantageous in monitoring and controlling.From extensive testing and analysis this system improves all stability by mitigating losses, voltage stability, and longevity of electrical components. The system dynamic reactive power compensation uses the electrical grid conditions adaptable throughout different load regimes, for it to be extremely dependable for any industrial application. Furthermore, it can be used while there are loading fluctuations on the grid.

6. FUTURE SCOPE

There is a significant future opportunity for the Raspberry Pi Pico Based APFC/UPFC System with several opportunities for improvement to boost the system's effectiveness, flexibility, and practical application. Some notable future opportunities include:

1. Integration with IoT and Cloud Computing

i. Implementing a real-time cloud-based date logging system for remote monitoring and data analytics.

ii. Incorporating IoT sensors for alerts on power fluctuations and insights into recommended predictive automated control and protection system in induction motors.

2. Artificial Intelligence (AI) and Machine Learning (ML) Algorithms

i. Utilize Adaptive control systems for predictive power factor correction.

ii. Use ML models to switch capacitors and improve overall efficiency one the system is enhancing control and monitoring capabilities.

3. Advanced Communication Technologies

i. Upgrading from Bluetooth to WI-Fi, Zigbee, or LoRa for long range monitoring and control with multiple devices.

ii. Utilize a mobile app or web dashboard for user-friendly interface and ability to monitor and control the system in real-time.

4. Integration with Renewable Energy Systems

i. The system can be modified for use with solar and wind energy since striving to address unstable power supply variations

ii. In conjunction with battery storage.

5. Scalability on the industrial side and smart grid projects i. Enhancing the system for three-phase power correction in larger industrial applications.

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