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Automatic Power Factor Controller

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Abstract: Automatic Power Factor Controllers (APFCs) play a crucial role in modern electrical systems by ensuring efficient electrical power and improving power quality. The paper presents a comprehensive overview of the implementation and performance analysis of an APFC system. The proposed APFC system employs advanced control techniques to regulate the power factor of the electrical load, thereby minimizing reactive power consumption and optimizing overall system efficiency. The design process encompasses the selection of suitable power electronics converters, control algorithms, and sensing techniques tailored to the requirements of an application. The results demonstrate significant improvements in power quality, energy utilization, and system stability, thereby highlighting the practical relevance and applicability of the developed APFC technology.
Keywords: Automatic Power Factor Controller (APFC), Power Factor, Current Transformer, Circuit Breaker, Sensors, Display Unit, Load Bank, Power Supply, PCB, Microcontroller.

I. INTRODUCTION

The power factor is the ratio between the Kw and the KVA drawn by an electrical load where the Kw is the actual load power, and Kva is the apparent load power. It counts how effectively the current converts into functional work output of the individual indicator of the load current on the efficiency of the supply system. In the organization, most of the load is inductive load. The result is a lagging power factor loss and wastage of energy. This results in high power bills and heavy penalties from electricity boards. If the load is uneven, it is hard to maintain the unity power factor. To overcome APFC, use a panel that has a unity power factor. So, industries require automatic power factor control systems. APFC system, used for the enhancement of power factor.

II. OBJECTIVES

The main objective of our project is to design and construct a contactor-based system that will help us find power factors automatically. A dip in the Power Factor can attract operational losses and a penalty from the electricity board responsible for the electricity supply.

1) *Design and Development:* APFC system capable of accurately measuring power factor and automatically adjusting capacitor banks to achieve near-unity power factor.
2) *Energy Efficiency Enhancement:* Improve the energy efficiency of electrical systems by reducing reactive power consumption, minimizing losses, and optimizing the utilization of electrical infrastructure.
3) *Cost Reduction:* Implement APFC to reduce electricity bills by avoiding penalties associated with poor power factors, optimizing energy consumption, and maximizing the efficiency of power distribution systems.
4) *Reliability Improvement:* Enhance the reliability and stability of electrical systems by mitigating voltage drops, improving voltage regulation, and reducing the risk of equipment failures due to excessive reactive power.

III. MOTIVATION FOR THE PRESENT RESEARCH WORK

1) *Energy Efficiency:* Improving the power factor in electrical systems enhances energy efficiency, optimizing the Power factor, and less reactive power is drawn from the grid, resulting in reduced energy consumption and lower electricity bills.
2) *Cost Reduction:* Implementing APFC can lead to significant cost savings for industries and commercial establishments by minimizing penalties associated with poor power factors and maximizing the utilization of existing electrical infrastructure.
3) *Industry Demand:* Industries and utilities increasingly demand solutions for power factor correction to improve system reliability, reduce losses, and comply with regulatory standards. Conducting research in this field addresses a real-world need.
4) *Educational & Professional Development:* Engaging research on APFC provides valuable educational and professional development opportunities, enhancing skills in electronics, programming, system optimization, and project management.
5) *Sustainability Goals:* Many organizations and governments are committed to sustainability goals, including energy efficiency improvements. Research on APFC aligns with these objectives and contributes to achieving a more sustainable energy future.

IV. LITERATURE REVIEW

The literature review serves as a critical component of this thesis, offering an extensive examination of existing knowledge, research, and developments in automatic power factor controllers (APFC).

A. Objectives of the Literature Review

1) Synthesize existing knowledge and research findings on APFC.
2) Identify key concepts, methodologies, and technologies relevant to the research.
3) Evaluate the strengths and weaknesses of current approaches.
4) Highlight areas for further investigation and development.

B. Reasons for Low Power Factor

1) Mercury vapor lamps or lamps operated with chokes
2) Power and distribution of Transformers. A completely unloaded transformer is very inductive and has a low power factor.
3) Induction motors (Load and unload condition) The inductive load equipment causing low power factor in the mines include Hoists, Shovels, Drill, Pump, Shearer, Conveyors, etc.

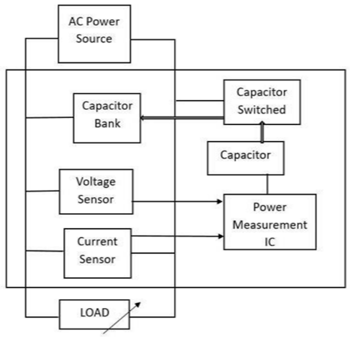
V. OVERVIEW OF PREVIOUS RESEARCH WORK

1) Standard Publication International Journal of Innovations in Engineering Research and Technology, the topic of Automatic Power Factor Correction published by Gopal Reddy K. This paper presents the control to correct the power factor automatically without any human presence.
2) The International Journal of Engineering Trends and Technology (IJETT) on the topic of “Power Factor Improvement using dual Boost Converter” The author published by Prof. D. D. Ahire. The paper involves the simulation of power electronics analysis of the current and voltage waveforms.
3) The International Journal of Advance Research and Innovative Ideas in Education on the topic of "Automatic Power Factor control using Arduino UNO" was published by Prof. Kunal Shah. This paper presents a Contactor-based APFC system that can sustain up to the rating of 20-25 KVA of the industrial load.
4) In the International Journal of Advance Research(IJAR). The topic of" Automatic power factor correction and monitoring by using microcontrollers" was published by Aparna Sarkar and Umesh Hi wase. The topic of this paper is an advanced method of power factor correction that utilizes a microcontroller.

VI. METHODOLOGY

The voltage and current signal from the system is sampled and taken as input where the difference between the arrivals of waveforms indicates the phase angle difference. The system power factor is compared with the desired level and the difference is measured for switching of required number of capacitors from the bank.

1) The controller acts as the brain of the circuit; it performs all the mathematical operations.
2) When the difference is detected, the controller closes the contactors, which act as a switch between the capacitor and the supply.
3) Required capacitors are added to the system to improve the power factor of the load.
4) Added capacitors result in an increase in the power factor to the desired value.
5) The controller panel display shows the improved Power factor.



Circuit

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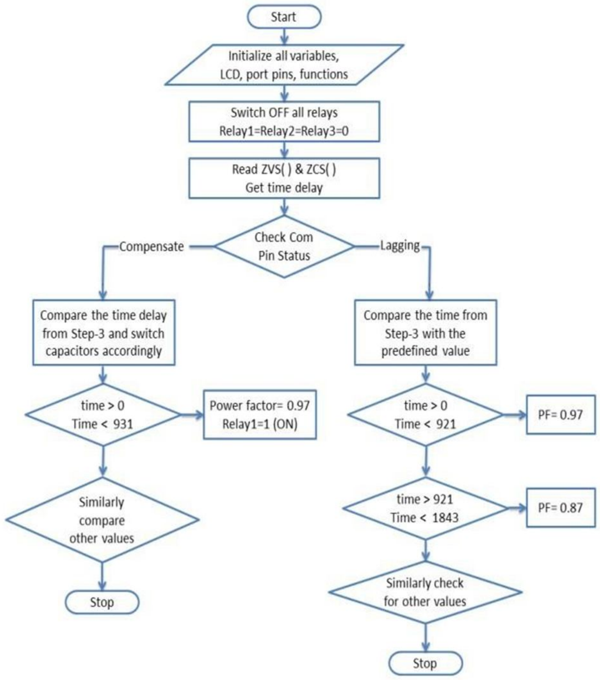
A. Algorithm

1) Step 1: Take input for voltage and current in the circuit.
2) Step 2: Measure the phase lag and calculate the power factor.
3) Step 3: Differentiate from the targeted power factor and calculate the reactive power requirement. Step-4: Switch ON or OFF the appropriate number of capacitors from the capacitor bank depending on the reactive power supplied by each step.
4) Step-5: After comparing the power factor with the targeted PF continue from step-1.



VII. DESIGN & IMPLEMENTATION

This chapter describes the detailed design of each block of the proposed power factor correction equipment along with the working of each part. Each block consists of several components connected in the required way to give the desired output. The complete circuit diagram is provided at the end based on which the fabrication was completed.

A. System Development

1) Requirement Analysis

a) Understand the power consumption patterns and requirements of the electrical system.
b) Determine the target power factor and reactive power compensation needed to improve power efficiency.

2) System Design

a) Consider voltage levels, load types, and system capacity when designing the APFC system architecture.
b) Choose suitable components, like capacitors, reactors, contactors, and controllers, according to system requirements.

3) Controller Selection

a) Choose a suitable controller that can monitor the power factor in real time and control the switching of capacitors accordingly.
b) Consider controllers with features like digital signal processing, communication interfaces, and protection mechanisms.

4) Sensor Integration

a) Integrate sensors such as voltage and current transformers or transducers to measure parameters like voltage, current, and power factor.
b) Effective control requires accurate and reliable sensor readings.

5) *Capacitor Bank Design*
a) Design the capacitor bank to provide the required reactive power compensation.
b) Determine the number of capacitor stages and their ratings based on load variations and power factor correction needs.

6) *Control Strategy Development*
a) Develop control algorithms to continuously monitor the power factor and activate/deactivate capacitor stages accordingly.

B. Hardware Implementation

Hardware Components of APFC

1) *Power Factor Correction Controller:* This is the core component that controls the overall PFC operation. It uses feedback from the load to adjust the current waveform to improve the power factor.
2) *Switching Devices:* MOSFETs or IGBTs can be used as the switching elements. These devices rapidly switch on and off to shape the input current waveform.
3) *Inductor (Choke):* An inductor can store energy and smooth the current waveform. It helps in reducing the harmonic content in the current.
4) *Capacitors:* Capacitors can used for filtering and energy storage. They help in maintaining a steady DC bus voltage.
5) *Diodes:* Diodes are used in rectification and freewheeling to allow current to bypass the switching element when it is off.
6) *Resistors:* Uses for current sensing, voltage division, and protection.

VIII. RESULT & CONCLUSION

Implementing Active Power Factor Correction (APFC) yields several significant benefits and improvements in electrical systems.

A. Increased Efficiency

APFC improves the power factor, often bringing it to 1 (unity). This means that the electrical power supplied can be used more effectively, reducing wasted energy and improving the overall efficiency of that system.

B. Reduced Reactive Power

By minimizing the reactive power component, APFC reduces the burden on the power supply and the distribution system. This leads to more efficient transmission of electrical energy.

Lower Energy Costs: Improved power factor leads to reduced energy losses, translating to lower electricity bills. In many cases, utilities charge penalties for poor power factor; by improving it, those penalties can avoided.

C. Example of Results

Here’s a hypothetical example to illustrate the results of implementing APFC:

1) *Before APFC*

Apparent Power (S): 1000 VA True Power (P): 700 W
Reactive Power (Q): 700 VAR
Power Factor (PF): 0.7

2) *After APFC*

Apparent Power (S): 707 VA
True Power (P): 700 W
Reactive Power (Q): 0 VAR Power Factor (PF): 1.0

In this example, the implementation of APFC has improved the power factor from 0.7 to 1.0, reduced the reactive power to zero, and decreased the apparent power from 1000 VA to 707 VA. This load demonstrates a significant improvement in the efficiency and performance of the electrical system.

D. Practical Considerations

1) While APFC offers numerous benefits, there are practical considerations to keep in mind:
2) The installation of APFC circuits can be relatively costly. However, this is often by the savings in energy costs and avoided penalties for poor power factor.
3) Designing and implementing APFC circuits can be complex and may require specialized knowledge. Proper design, implementation, and maintenance are crucial to achieving the desired benefits.

IX. CONCLUSION

From our project, we observed that this APFC Panel will help us in finding

1) Raising the power factor has been proven to help utilities and end users use electricity more efficiently.
2) It reduces the consumer's electricity bills.
3) It also helps to reduce the cable size and circuit breaker size.
4) It can concluded that the power factor correction technique can be applied to industries, power systems, and households to ensure their stability, resulting in the system becoming stable and the efficiency of the systems and apparatus increasing. If the compensator rating is less than the load observed by the detected power, it will improve the power given by the AC supply and reduce the power consumption. Good power quality is achieved by reducing the apparent power drawn from the AC supply and minimizing the power transmission losses. Hence, the efficiency of both the systems and apparatus increases.

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