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AUTOMATIC POWER FACTOR COMPENSATION (APFC) FOR INDUSTRIAL POWER USE TO MINIMIZE PENALTY

[1]Jignesh Sarkale, [2]Revannath Sontake , [3]Vinay Sadaphal , [4]Sagar Pawar,
[5]Dhananjay Pawar

[1]UG Scholar, Electrical Dept, JSPM's Bhivrabai Sawant Polytechnic,Wagholi.
[2]UG Scholar, Electrical Dept, JSPM's Bhivrabai Sawant Polytechnic,Wagholi.
[3]UG Scholar, Electrical Dept, JSPM's Bhivrabai Sawant Polytechnic,Wagholi.
[4]UG Scholar, Electrical Dept, JSPM's Bhivrabai Sawant Polytechnic,Wagholi.
[5]Asst. Prof., Electrical Dept., JSPM's Bhivrabai Sawant Polytechnic,Wagholi.

ABSTRACT

Two zero crossing detectors are employed in this suggested system to identify voltage and current zero crossi ngs.By adopting an autonomous power factor correction unit, the initiative aims to reduce penalties for indust rial units. This project's controller is a member of the Arduino family.The time lag between the zero-voltage pulse and zero-current pulse is duly generated by suitable operational amplifier circuits in comparator mode is fed to two interrupt pins of a microcontroller. The program takes over to actuate appropriate number of relays from its output to bring shunt capacitors into load circuit to get the power factor till it reaches near unity. The capacitor bank and relays are interfaced to the microcontroller using a relay driver. It displays time lag between the current and voltage on an LCD. Furthermore, the project can be enhanced by using thyristor control switches instead of relay control to avoid contact pitting often encountered by switching of capacitors due to high in rush current..

I. INTRODUCTION

We can conclude that power is extremely valuable based on the current state of technological revolution.
The power system's efficiency will decline as a result of the growing use of inductive loads in industries, which wi ll affect the system's power factor value. This causes lagging power factor that gives high penalties to consumers. The high penalty situation is tackled by the Power Factor Control. Power Factor Control is a method of reducing the disagreeable effect of loads that causes power factor to drop down to lesser than one. In A.C circuits, the power factor can be described as a proportion of the actual (Real) power that does the work and the apparent power which is provided to the circuit. Real power is well characterized as the Circuit's capacity for performing work in a specific time. This project provides continuous power factor correction without manual capacitive bank loading. The limit of engrossing the reactive power created by a heap is called Power Factor Rectification. The Reactive Power charge on your electricity bill is directly targeted against those companies who do not demonstrate clear energy efficiency use. You will find this charge itemized on electricity bill.
Reactive power charges can be made significantly smaller by the introduction of Power Factor Correction Capacitors which is a widely recognized method of reduction.

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II. SYSTEM DESCRIPTION

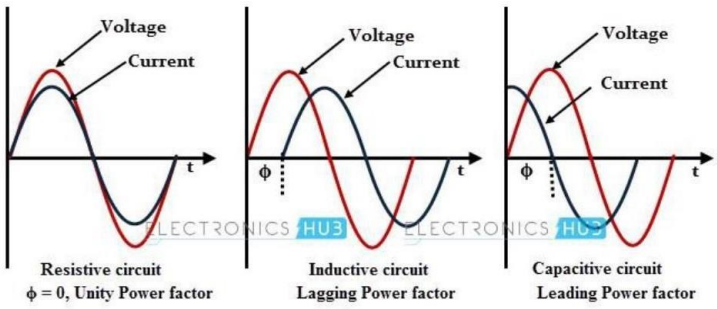
By automatically modifying the reactive power compensation, an Automatic Power Factor Compensation (APFC) system is intended to maximize the power factor in industrial environments.
This system operates on the basic tenet that inefficiencies result from a low power factor. higher energy costs, and potential penalties from utility providers. By maintaining an optimal power factor, the APFC system ensures that reactive power is properly managed, reducing the penalty charges associated with low power factor and enhancing overall system efficiency.
The core components of an APFC system operate in synergy to continuously monitor and adjust the power factor in real time, ensuring that energy consumption remains efficient and cost-effective. The primary element of the system is the **Power Factor Controller (PFC)**. This microprocessor-based controller constantly monitors the power factor and makes decisions on when to switch capacitor banks in or out of the circuit. The PFC ensures that the reactive power compensation is dynamically adjusted to match the load variations, keeping the power factor within the desired range. The **capacitor banks** are the key elements in correcting the power factor. These are used to supply reactive power, compensating for the inductive loads such as motors and transformers in the industrial facility. Capacitors are switched in or out by the PFC, providing the necessary reactive power to improve the power factor. The amount of capacitive reactance provided depends on the real-time power factor readings, which are continuously monitored.The **current transformers (CTs)** and **voltage transformers (VTs)** play a crucial role in providing the necessary data to the PFC. CTs measure the current flow in the system, while VTs provide voltage measurements. The PFC uses this information to calculate the power factor and decide whether reactive power compensation is needed. A key component of the APFC system is the **switching mechanism**, which consists of **contactors**, **circuit breakers**, or **solid-state switches** that control the connection and disconnection of the capacitor banks. These devices work based on the signals from the PFC, which ensures that the compensation is adjusted in real-time. The system also includes **bypass contactors**, which protect the capacitor banks from overload and ensure the system operates smoothly without overcompensating. An additional element often integrated into the APFC system is **harmonic filters**. Industrial loads, especially non- linear ones, can introduce harmonics into the system, which can affect the performance of the capacitor banks.
Harmonic filters mitigate these effects, maintaining the efficiency and longevity of the system.

III. DESIGN ARCHITECTURE

A. Working:

The voltage or current waveform has a sinusoidal waveform with a wave cycle of 360 degrees which when converted into time seconds it is 20 milliseconds (Frequency = 50Hz, T=1/F = 1/50). When the load is applied the current waveforms changes its every zero-crossing position depending on the characteristics of the load. Irrespective of load the time period is similar but the every zero crossing of the current waveform changes whereas the voltage waveform remains in the same position. So the voltage is used as the reference waveform to determine the time variation or time at which current waveform starts. The difference in the every zero crossing of the voltage and current waveforms is known as

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As mentioned above one cycle of the waveform is 20 milliseconds. The sinusoidal waveform contains a positive and negative half cycle. The wavefrom touches zero mark and enters negative cycle or positive cycle for every half cycle i.e. at 180 degrees which when converted into seconds it is 10 milliseconds, this process is known as zero crossing. But the zero crossing remains the same at 10milliseconds. So when load is applied there is a difference between the zero crossing of voltage and current waveforms. The difference in their time of zero crossing is noted and converted into degrees. This value is known as phase angle difference .The power factor is the cosine of the phase angle difference of the voltage and current waveforms. So, the obtained phase angle difference gives us the value of power factor. The power for the Arduino and other components is supplied by a 5V DC supply. The two Op-Amps converts the sinusoidal signal into square signal. The square waves from the output of the Op-Amps is fed to the Exclusive OR(X-OR) gate. The output of X-OR gate is phase angle difference which is given to Arduino. The cosine of the phase angle difference gives the power factor value. If the power factor is less than 0.9 then the capacitor is switched on

B. Methodology

The methodology for designing, constructing, and operating an Automatic Power Factor Compensation (APFC) system involves several key steps that encompass the selection of components, system design, and the operational process to optimize power factor and minimize penalties. This section outlines the processes involved in creating and operating an APFC system, from the selection of key components to the continuous monitoring and control of the system..

1. Selection of Key Components

The first step in the methodology is the selection of the key components that make up the APFC system. These components include:

- **Power Factor Controller (PFC):** This microprocessor-based controller is the central unit responsible for continuously monitoring the power factor and making decisions on when to switch the capacitor banks on or off. It is the brain of the APFC system and directly impacts the system's efficiency and penalty reduction.
- **Capacitor Banks (Energy Compensation Medium):** Capacitors are the key components used to correct the power factor. These banks supply reactive power to compensate for inductive loads. The capacity and number of capacitors are selected based on the load and required power factor correction.
- **Current Transformers (CTs) and Voltage Transformers (VTs):** CTs and VTs are used to measure the current and voltage in the system. The data from these transformers is sent to the PFC, allowing it to calculate the power factor and determine if compensation is needed.
- **Switching Devices (Contactor or Circuit Breakers):** These devices control the connection and disconnection of the capacitor banks. Based on the PFC's signals, these switches enable or disable the capacitors as needed to maintain the desired power factor.
- **Bypass Contactors:** These are used to prevent overload on capacitor banks by bypassing them in the

event of failure or when excess reactive power is injected.

Harmonic Filters (Optional): In industrial settings with non-linear loads, harmonic filters may be added to prevent harmonic distortion and ensure that the capacitors function efficiently without causing damage

2. System Design and Construction

Once the key components are selected, the system design and construction phase begins. This includes:

- **System Layout:** The system layout involves designing the physical placement of the capacitor banks, PFC, transformers, and switching devices. The layout must ensure that all components are optimally placed for efficient operation and easy maintenance.
- **Energy Compensation Calculation:** The required reactive power compensation is determined by calculating the power factor correction needed. The capacitor banks' capacity is calculated based on the current power factor and the target power factor. This ensures that the system is designed to provide adequate compensation without overcompensating.
- **PFC Optimization:** The PFC should be designed with advanced algorithms to adjust the capacitor banks' switching in real time based on the measured power factor. The efficiency of the PFC is critical to minimize energy losses and ensure quick responses to fluctuations in the load.
- **Capacitor Bank Selection:** The capacitor banks need to be selected based on the reactive power requirement. Capacitors should be able to handle both the expected load and potential variations. Proper sizing is crucial to prevent both under and over- compensation, as this could lead to penalties.

3. Operation and Power Factor Compensation Cycle

The operation of an APFC system revolves around two primary phases: **power factor monitoring** and **compensation**.

- **Power Factor Monitoring:**
  - Continuous monitoring of the real-time power factor is performed using CTs and VTs. The PFC constantly calculates the power factor by measuring current and voltage data.
  - If the power factor deviates from the set optimal value (typically around 0.95 or above), the PFC determines whether to inject or remove reactive power.
- **Compensation Process:**
  - **Capacitor Bank Switching:** Based on the decision of the PFC, capacitor banks are switched on or off. Capacitors are switched in to inject reactive power when the power factor is low (lagging), or switched out when the power factor is high (leading).
  - **Dynamic Compensation:** The system continuously adjusts the compensation throughout the day to account for variations in the load, ensuring that the power factor remains close to the optimal value.
- **Energy Loss Reduction:** By minimizing the need for reactive power from the utility grid, the APFC system reduces line losses and optimizes energy consumption within the facility.

4. System Monitoring and Control

The control system is central to the operation of the APFC system. It involves several key functions:

- **Real-Time Monitoring:** Sensors and measurement devices (CTs and VTs) provide continuous data about the system's voltage, current, and power factor. This data is fed to the PFC for decision-making.
- **Automated Control:** The PFC automatically adjusts the compensation by switching capacitor banks on and off. The system can be integrated with SCADA (Supervisory Control and Data Acquisition) systems to ensure automated operation with minimal human intervention.
- **Efficiency Optimization:** The control system optimizes the switching operation to minimize energy losses

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and maintain a stable

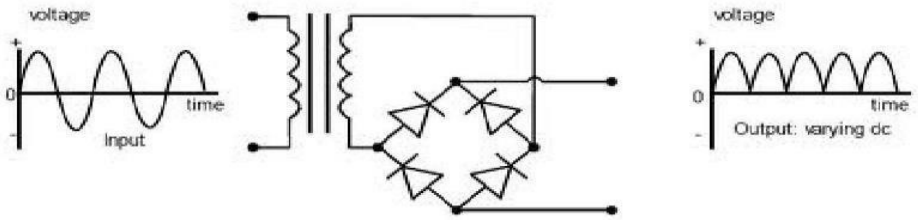
C. Hardware Required

1. TRANSFORMER

Transformers convert AC electricity from one voltage to another with a little loss of power. Step-up transformers increase voltage, step-down transformers reduce voltage. Most power supplies use a step-down transformer to reduce the dangerously high voltage to a safer low voltage.

2. RECTIFIER

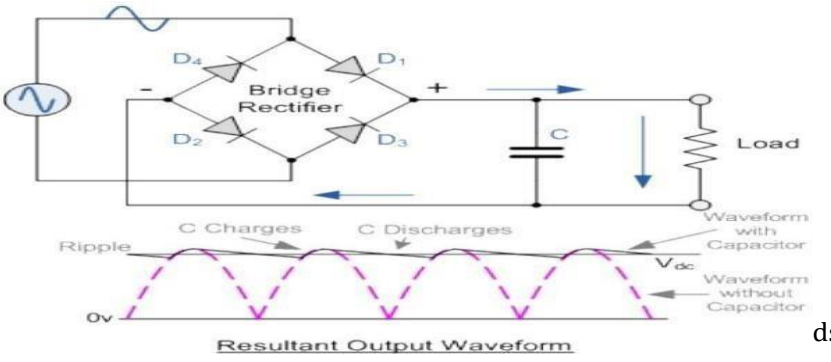
A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), current that flows in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid statediodes, vacuum tube diodes, mercury arc valves, and other components. The output from the transformer is fed to the rectifier. It converts A.C. into pulsating D.C. The rectifier may be a half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification. In positive half cycleonly two diodes (1 set of parallel diodes) will conduct, in negative half cycle remaining two diodes will conduct and they will conduct only in forward bias only.



3. FILTER

Capacitive filter is used in this project. It removes the ripples from the output of rectifier and smoothens the D.C. Output received from this filter is constant until the mains voltage and load is maintained constant. However, if either of the two is varied, D.C. voltage received at this point changes. Therefore a regulator is applied at the output stage. The simple capacitor filter is the most basic type of power supply filter. The use of this filter is very limited. It is sometimes used on extremely high-voltage, low-current power supplies for cathode-ray and similar electron tubes that require very little load current from the supply. This filter is also used in circuits where the

power-supply ripple frequency is not critical and can be relatively high. Below figure can show how the capacitor A gear motor in a gravity battery system is typically used to control the movement of the weight, which is essential for storing and releasing energy. Gravity batteries work by lifting a heavy object (such as a weight) to a



dst.com/

higher position to store potential energy. The gear motor helps in this process by either lifting the weight or, in some cases, controlling the release of the weight in a controlled manner to generate electricity.

IV.CONCLUSION

It can be concluded that power factor correction techniques can be applied to the industries, power systems and It can be concluded that power factor correction techniques can be applied to the industries, power systems and also households to make them stable and due to that the system becomes stable and efficiency of the system as well as the apparatus increases. The use of microcontroller reduces the costs. Due to use of microcontroller multiple parameters can be controlled and the use of extra hard wares such as timer, RAM, ROM and input output ports reduces. Care should be taken for overcorrection otherwise the voltage and current becomes more due to which the power system or machine becomes unstable and the life of capacitor banks reduces.

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