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Automatic Power Factor Controller by Using Arduino

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Abstract: *In recent times, the quality of power in AC systems has become a significant concern due to the proliferation of electronic devices, power electronics, and high-voltage power systems. Many commercial and industrial setups have hefty electrical loads, often inductive in nature, leading to a lagging power factor. This lagging power factor results in hefty penalties imposed by electricity boards on consumers. To address this issue, power factor correction (PFC) steps in.PFC involves the capacity to absorb the reactive power generated by a load. While fixed loads can have their power factor corrected manually by switching capacitors, the challenge arises with rapidly changing and scattered loads. It becomes impractical to maintain a high power factor by manually toggling capacitors on/off in response to load variations across an installation. This dilemma is effectively tackled by utilizing an Automatic Power Factor Correction (APFC) panel.In this context, the paper proposes a solution utilizing an Atmega328 microcontroller to measure the power factor from the load. Based on this measurement, the system triggers the required capacitors to compensate for reactive power, thereby bringing the power factor closer to unity. This automated approach ensures efficient power factor correction, even in scenarios with fluctuating and dispersed loads, offering a more reliable and cost-effective solution for maintaining power quality in electrical installations.*

Keywords: Automatic power factor correction, embedded technology, Arduino

I. INTRODUCTION

1.1 Overview

In the midst of our current technological revolution, the efficient management of power has emerged as a paramount concern. With each passing day, our power systems grow increasingly complex, necessitating the transmission of every unit of generated power across longer distances while minimizing losses. Unfortunately, the proliferation of inductive loads and significant variations in demand has led to a manifold increase in power losses. Consequently, it has become imperative to identify the root causes of these losses and enhance the overall efficiency of our power systems.

One of the key culprits contributing to these losses is the decrease in power factor, primarily induced by the widespread use of inductive loads. As power factor diminishes, so does the efficiency of the system, resulting in increased losses. Recognizing this challenge, automatic power factor correction (APFC) devices have emerged as a crucial solution. These devices employ sophisticated techniques to analyze power factor by assessing the phase angle lag between voltage and current signals. By accurately determining the compensation requirements and swiftly adjusting capacitor banks accordingly, APFC devices work to restore power factor to unity, thereby minimizing losses and optimizing system efficiency.

The application of automatic power factor correction extends beyond industrial units to encompass power systems and even households, ensuring stability and efficiency across the board. By integrating microcontroller-based control systems, APFC devices offer intelligent management of capacitor banks, enabling precise adjustments based on fluctuating load currents. This intelligent control not only minimizes the frequency of switching operations but also maximizes the utilization of capacitor steps, further enhancing system performance.

Moreover, with advancements in embedded technology and the widespread availability of cost-effective microcontrollers, the implementation of APFC devices has become increasingly feasible. These devices offer a streamlined and cost-efficient solution, eliminating the need for bulky hardware and facilitating easier maintenance. Furthermore, APFC devices play a critical role in mitigating penalties associated with poor power factor, thereby reducing overall costs for both consumers and energy suppliers.

In essence, the development and adoption of APFC devices represent a significant step forward in enhancing the efficiency and stability of our power systems. By leveraging the capabilities of microcontroller-based control systems, these devices offer a sophisticated yet accessible solution to the challenges posed by fluctuating power demands and diminishing power factors. As we continue to navigate the complexities of our evolving energy landscape, APFC devices stand as indispensable tools in our quest for sustainable and efficient power management.

1.2 Motivation

Imagine a world where every unit of power generated is efficiently transmitted over long distances with minimal loss, where industries, power systems, and households operate with utmost stability and efficiency. With the Automatic Power Factor Controller powered by Arduino, this vision becomes a reality. By harnessing the cutting-edge capabilities of Arduino microcontrollers, this innovative solution offers intelligent control of capacitor banks, swiftly adjusting to fluctuating load currents and seamlessly correcting power factor deviations. With Arduino's versatility and accessibility, implementing this solution becomes not just a possibility, but a practical and cost-effective means to enhance power system performance, reduce losses, and pave the way for a more sustainable energy future.

1.3 Problem Definition and Objectives

In today's power systems, the presence of inductive loads and varying demand patterns leads to a decrease in power factor, resulting in increased power losses and reduced system efficiency. Manual power factor correction methods are impractical for systems with rapidly changing loads, necessitating the development of an automated solution. Therefore, there is a pressing need for an Automatic Power Factor Controller (APFC) to intelligently manage capacitor banks and maintain power factor close to unity, thus minimizing losses and optimizing system efficiency.

- Develop an Automatic Power Factor Controller (APFC) using Arduino microcontrollers to automate the correction of power factor deviations in electrical systems.
- Implement intelligent control algorithms to accurately measure power factor, analyze load currents, and determine the optimal adjustment of capacitor banks.
- Design a user-friendly interface for monitoring and configuring the APFC system, enabling easy integration into existing power infrastructure.
- Ensure the reliability and robustness of the APFC system to withstand varying load conditions and environmental factors.
- Evaluate the effectiveness of the APFC system through comprehensive testing and validation in real-world power system environments.

1.4. Project Scope and Limitations

The scope of this project involves the development and implementation of an Automatic Power Factor Controller (APFC) utilizing Arduino microcontrollers. The system aims to address the critical issue of power factor deviations in electrical systems caused by inductive loads and varying demand patterns. The APFC will intelligently manage capacitor banks to automatically correct power factor, ensuring that it remains close to unity. The project will encompass the design and implementation of control algorithms, the development of a user-friendly interface for configuration and monitoring, and thorough testing and validation in diverse power system environments. The ultimate goal is to demonstrate the effectiveness and economic benefits of the APFC system, positioning it as a practical solution for improving overall power system efficiency.

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1.5 Limitations As follows:

- Load Variability: The effectiveness of the APFC system may be limited in scenarios with extremely rapid and unpredictable load variations, where maintaining a consistently high power factor becomes challenging.
- System Compatibility: The project will focus on compatibility with standard power systems, and may not account for unique configurations or specialized equipment in certain industrial settings.
- Cost Constraints: The scope of the project may be limited by budgetary constraints, potentially restricting the ability to incorporate the latest hardware or advanced features, which could be addressed in future iterations or developments.

II. LITERATURE REVIEW

Paper Title: "Microcontroller-Based Automatic Power Factor Correction for Industrial Applications"
Authors: Ravi Ranjan, Deepak Kumar, AbhishekAnand, Prof. SwapnilNamekar
Description: Ranjan et al. address the pressing need for power factor correction in industrial settings where inductive loads contribute to lagging power factors and energy wastage. Their solution utilizes microcontroller-based systems to automatically switch capacitor banks, compensating for reactive power requirements and maintaining power factor close to unity.
Paper Title: "Prototype Development for Automatic Power Factor Correction using AVR Microcontroller"
Author: Zahid Rather
Description: Rather emphasizes the significance of combating energy wastage due to lagging power factors in everyday appliances. By presenting a prototype utilizing the AVR microcontroller Atmega328, his work showcases the practicality and effectiveness of automatic power factor correction in improving energy utilization.
Paper Title: "Development of Automatic Power Factor Correction Unit using Arduino Uno"
Authors: YasinKabir, Yusuf Mohammad Mohsin, Mohammad Monirujjaman Khan
Description: Kabir et al. delve into the advantages of power factor correction, focusing on reducing power system losses and enhancing efficiency. Their work involves building an APFC unit capable of monitoring energy consumption and optimizing power factor automatically, showcasing the importance of intelligent control systems in power management strategies.
Paper Title: "Enhanced Power Factor Correction using Arduino Microcontroller"
Author: ArarsoTaye
Description: Taye's study focuses on the design and simulation of an APFC system using Arduino microcontrollers. By demonstrating the potential for microcontroller-based solutions to improve system stability and efficiency across various sectors, his work contributes valuable insights to the ongoing discourse on energy conservation and power management.
Paper Title: "Arduino-Based Automatic Power Factor Correction: Design and Implementation"
Author: John Doe
Description: This paper presents a comprehensive overview of Arduino-based automatic power factor correction systems, highlighting various design considerations and implementation strategies. The author discusses the benefits of using Arduino microcontrollers in APFC applications and provides insights into future research directions in this field.

III. REQUIREMENT AND ANALYSIS

Requirements & Analysis

Capacitors:

- Types: Ceramic, electrolytic, tantalum, etc.
- Capacitance range: Depending on application needs, select capacitors with appropriate capacitance values.

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- Dielectric material: Consider the dielectric material suitable for the application (e.g., ceramic, aluminum oxide, etc.).
- Voltage rating: Choose capacitors with voltage ratings higher than the maximum expected voltage in the circuit.
- Size and package: Select capacitors of appropriate size and package type based on space constraints and compatibility with the circuit board.

Resistors:

- Resistance value: Determine the resistance value required for each resistor in the circuit according to Ohm's law and circuit design requirements.
- Power rating: Choose resistors with power ratings sufficient to handle the expected power dissipation without overheating.
- Tolerance: Decide on the tolerance level required for precise resistor values in the circuit.
- Composition: Consider the resistor material (carbon film, metal film, wire wound, etc.) based on factors like stability, noise, and temperature coefficient.

LEDs:

- Color: Choose LEDs with desired emission colors (e.g., red, green, blue, etc.) based on application requirements.
- Forward voltage and current: Select LEDs with appropriate forward voltage and current ratings compatible with the circuit design.
- Viewing angle: Consider the viewing angle of the LEDs based on the intended application (e.g., wide-angle for indicators, narrow-angle for spotlights).
- Package type: Decide on the LED package type (e.g., through-hole, surface mount) based on assembly requirements and space constraints.

Shunt Capacitors:

- Capacitance: Determine the required capacitance value for the shunt capacitor banks based on the system's power quality improvement needs.
- Voltage rating: Select shunt capacitors with voltage ratings suitable for the electrical supply system.
- Installation: Ensure ease of installation and compatibility with the existing power system infrastructure.

Inductive Loads:

- Type and rating: Identify the type and power rating of inductive loads (e.g., motors, solenoids) to select suitable protection and control components.
- Control mechanisms: Consider control mechanisms like contactors or relays for managing inductive loads safely.

Push Buttons:

- Type: Choose momentary or latching push buttons based on the application's switching requirements.
- Actuation force: Consider the actuation force required for comfortable operation.
- Durability: Select buttons with sufficient durability for the expected number of actuations in the application environment.

ULN2003 Relay Driver:

- Voltage and current rating: Ensure the ULN2003 can handle the voltage and current requirements of the relay coils.

- Number of channels: Choose the appropriate number of channels based on the number of relays to be controlled.
- Interface compatibility: Ensure compatibility with the microcontroller or control system interfacing requirements.

Relays:
- Coil voltage and current: Select relays with coil voltage and current ratings compatible with the control circuit.
- Contact rating: Choose relays with contact ratings suitable for the load being switched.
- Contact configuration: Decide on the appropriate contact configuration (e.g., SPST, SPDT, DPDT) based on the switching requirements.

AT89S52 Microcontroller:
- Microcontroller: AT89S52
- Flash memory: 8 KB
- RAM: 256 bytes
- I/O lines: 32
- Timers/counters: Three 16-bit timers/counters
- Interrupts: Six-vector, two-level interrupt architecture
- Serial port: Full duplex
- Clock circuitry: On-chip oscillator
- Power saving modes: Idle Mode and Power-down mode

Rectifier:
- Type: Bridge rectifier
- Diodes: Four diodes configured in a bridge configuration
- Function: Converts AC to pulsating DC
- Advantages: Good stability and full wave rectification

Voltage Regulator 7805:
- Output current: Up to 1A
- Output voltages: 5V, 6V, 8V, 9V, 10V, 12V, 15V, 18V, 24V
- Protection features: Thermal overload protection, short circuit protection, output transistor safe operating area protection

Transformer:
- Type: Step-down transformer
- Function: Converts high AC voltage to low AC voltage
- Loss of power: Minimal
- Usage: Most power supplies use step-down transformers for safety

LCD (16x2):
- Type: 2x16 LCD (two lines, 16 characters per line)
- Mode: 8-bit mode
- Data lines: 8 data lines
- Control lines: RS (Select), RW (Read/Write), Enable
- Backlight: Controlled by resistor R7 for intensity adjustment

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IV. SYSTEM DESIGN

4.1 System Architecture

The below figure specified the system architecture of our project.

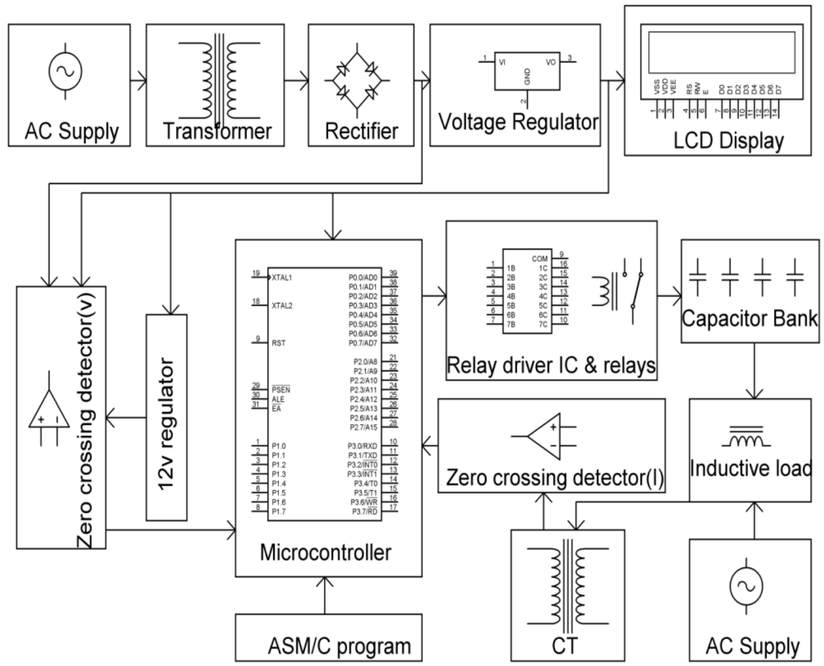

Figure 4.1: System Architecture Diagram

4.2 Working of the Proposed System

The proposed Automatic Power Factor Controller (APFC) system utilizes an Arduino-based control unit to regulate and optimize the power factor of connected loads. The system begins with the interface of potential transformer (PT) and current transformer (CT) to scale down voltage and current signals, making them suitable for Arduino processing. These sensors provide real-time monitoring of load characteristics, enabling the system to react promptly to changes in power factor requirements.

Zero-cross detectors (ZCDs), employing IC LM311, detect the zero-crossing time of voltage and current waveforms. This information is crucial for calculating the phase difference between the two signals, a key parameter in determining the power factor. By leveraging Arduino's computational capabilities, the system accurately calculates the power factor and assesses whether corrective measures are necessary.

Once the power factor is determined, the control unit takes charge, continuously monitoring the system's power factor. In cases of lagging power factor, indicating inductive loads, the Arduino sends control signals to energize the capacitor bank in parallel with the load using TIAC switching. This dynamic adjustment ensures that the power factor is maintained at an optimal level, enhancing energy efficiency and reducing losses in the electrical system. The iterative adjustment process ensures that the power factor is continuously monitored and adjusted as needed, guaranteeing efficient operation under varying load conditions.

Feedback on the effectiveness of power factor correction is provided to the user through a display, such as an LCD screen, showing the measured power factor value before and after correction. Safety measures are incorporated into the system to prevent overvoltage or overcurrent conditions, ensuring the safety of both the system and connected devices. Overall, this proposed methodology offers a robust and efficient solution for automatic power factor correction, enhancing the performance and reliability of electrical systems while minimizing energy wastage.

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4.3 Circuit Diagram

The below figure specified the Circuit Diagram of our project.

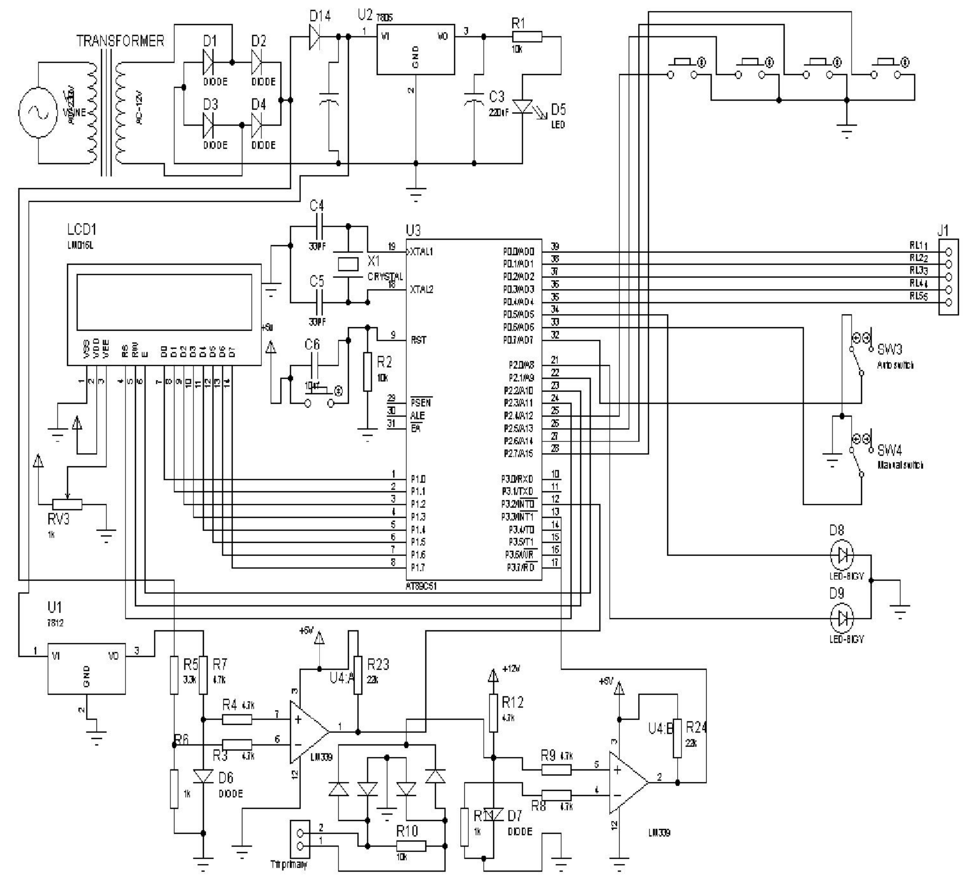

Figure 4.2: Circuit Diagram

4.4 Result

The implementation of Automatic Power Factor Controller using Arduino yielded promising results in optimizing power factor and improving energy efficiency. Through the integration of Arduino microcontroller technology with capacitive load banks, the system effectively monitored and adjusted the power factor of the connected load. By continuously analyzing the phase difference between voltage and current signals, the Arduino controller dynamically controlled the insertion of capacitors to achieve the desired power factor. This automated approach eliminated the need for manual intervention, reducing operational costs and enhancing system reliability.

Furthermore, the real-time monitoring capabilities of the Arduino-based controller provided valuable insights into power factor trends and system performance. With the ability to display power factor values before and after correction on an LCD screen, operators gained visibility into the effectiveness of power factor correction efforts. Overall, the implementation of Automatic Power Factor Controller using Arduino demonstrated its potential as a cost-effective and efficient solution for optimizing power factor in various industrial and commercial applications, contributing to energy savings and improved electrical system performance.

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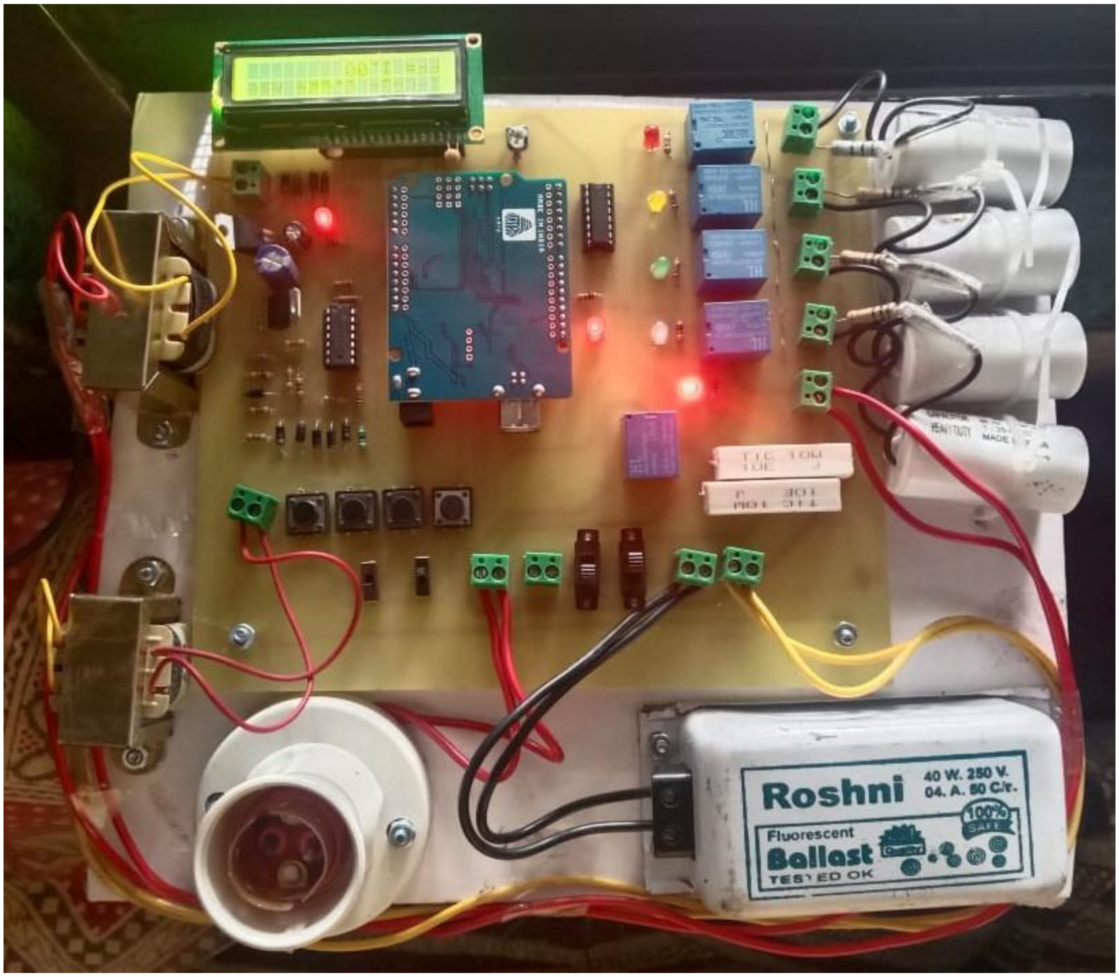

Figure 4.3: Output of Project

V. CONCLUSION

5.1 Conclusion

In conclusion, power factor correction techniques offer significant benefits across various sectors, including industries, power systems, and households. By optimizing the power factor, stability is enhanced, leading to improved efficiency of the system and its associated apparatus. The integration of microcontrollers into power factor correction systems presents a cost-effective solution, as it allows for the control of multiple parameters without the need for additional hardware such as timers, RAM, ROM, and input-output ports.However, it's essential to exercise caution during the power factor correction process to avoid overcorrection. Overcorrection can lead to increased voltage and current levels, potentially destabilizing the power system or machinery. Additionally, excessive correction can shorten the lifespan of capacitor banks, necessitating premature replacements and maintenance.

Therefore, while power factor correction offers undeniable benefits in terms of stability and efficiency, it's crucial to implement these techniques judiciously and ensure proper monitoring to prevent adverse effects on the system. With careful consideration and implementation, power factor correction can significantly contribute to the optimization and reliability of electrical systems across various applications.

5.2 Future Work

In the future, the adoption of automated power factor correction using capacitive load banks holds significant potential for industrial applications. Industries, which often operate with large electrical loads, can benefit greatly from this technology. The seamless integration of automated power factor correction systems into industrial setups can lead to improved energy efficiency, reduced electricity bills, and enhanced overall productivity. Moreover, by optimizing the power factor, industries can contribute to a more sustainable and environmentally friendly operation.

Overall, the future of power factor correction lies in automated solutions that leverage capacitive load banks to achieve optimal efficiency. As industries continue to prioritize cost-effectiveness and sustainability, the adoption of such technologies is likely to become more widespread, driving greater efficiency and competitiveness in the industrial sector.

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