International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 03 | March – 2026 DOI:10.55041/ISJEM05726
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Intelligent Power Factor Controller for Single Phase Induction Motor

Prof. Pratibha Patil, HOD, SSWP, Solapur , Naj .H. Attar, Shrushti .S. Bokade, Yashaswi .B. Chougule, Anushka .B. Meragu, Nirmiti .K. Phutane

Electrical Engineering, Shri Siddheshwar Women's Polytechnic Solapur

---***---

Abstract - Single-phase induction motors are widely used in domestic and small industrial applications, but they often operate with a low power factor due to their inductive nature. A low power factor increases current consumption, causing higher energy losses and reduced efficiency in electrical systems. An intelligent power factor correction system can improve this condition by automatically providing reactive power compensation. The system monitors voltage and current in the motor circuit and determines the operating power factor. When the power factor drops below a desired level, capacitor banks are connected through relay switching. This process improves the power factor, reduces power losses, and enhances the efficiency and reliability of motor-driven electrical systems.

Key Words: power factor correction, single-phase induction motor, reactive power compensation, capacitor bank switching, intelligent controller.

I. PROBLEM STATEMENT

Single-phase induction motors are widely used in residential and small industrial applications, but they often operate with a low power factor due to their inductive characteristics. A low power factor increases the current drawn from the power supply, resulting in higher energy losses and reduced efficiency of the electrical system. Conventional power factor correction methods using fixed capacitors cannot effectively respond to changing load conditions. Therefore, an intelligent power factor correction system is required to automatically monitor the motor operation and provide appropriate reactive power compensation to maintain an improved power factor.

I. OBJECTIVE

The objective of this research is to design and study an intelligent power factor correction system for a single-phase induction motor. The system aims to continuously monitor electrical parameters such as voltage and current in order to determine the operating power factor of the motor. Based on the measured values, the system provides suitable reactive power compensation using capacitor banks to improve the power factor. The proposed approach is intended to reduce power losses, improve energy utilization, and enhance the overall performance of single-phase motor driven systems.

I. INTRODUCTION

Single-phase induction motors are widely used in electrical systems that require low-power motor drives. These motors are commonly found in water pumps, fans, compressors, refrigerators, air conditioners, and household appliances. Their popularity is mainly due to their low cost, simple structure, and reliable operation.

Despite these advantages, single-phase induction motors generally operate with a low power factor. The reason for this is the inductive nature of the motor windings. Inductive loads require reactive power in order to establish the magnetic field necessary for motor operation. This reactive power causes a phase difference between supply voltage and current, resulting in a lagging power factor.

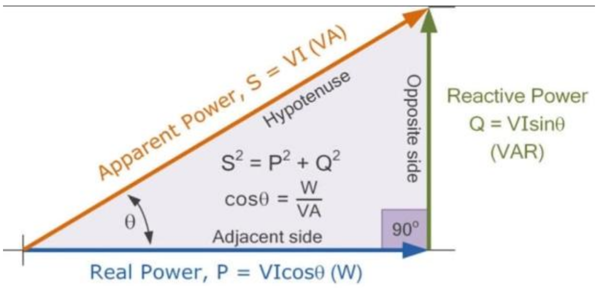
Low power factor leads to several problems in electrical systems. It increases the current drawn from the supply, which causes higher transmission losses and reduces the efficiency of the power system. In addition, low power factor can cause voltage drops in distribution lines and increase the required rating of electrical equipment such as transformers and cables.

Power factor correction is therefore essential for improving the performance and efficiency of electrical systems that use inductive loads. Conventional power factor correction methods involve the use of fixed capacitors connected in parallel with the load. However, fixed capacitors cannot respond effectively to changing load conditions. As a result, the system may experience insufficient or excessive compensation.

An intelligent power factor correction system provides a more flexible solution by automatically adjusting reactive power compensation according to load variations. This paper presents the design and analysis of an intelligent power factor corrector specifically developed for a single-phase induction motor.

International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 03 | March – 2026 DOI:10.55041/ISJEM05726
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

I. POWER FACTOR CONCEPT



Power factor is an important parameter in AC power systems that indicates how effectively electrical power is being used. It is defined as the ratio between real power and apparent power in the electrical circuit.

Real power represents the useful power that performs actual work, such as rotating a motor shaft or producing mechanical output. Apparent power represents the total power supplied by the electrical source.

Power factor can be expressed mathematically as:

PF = Real Power / Apparent Power

Another way to express power factor is through the phase angle between voltage and current. In AC circuits, voltage and current waveforms may not always be in phase with each other. The cosine of the phase angle between these two quantities represents the power factor.

When voltage and current are perfectly in phase, the power factor is equal to one. This condition indicates that electrical power is being used efficiently. However, when the current waveform lags behind the voltage waveform, the power factor becomes less than one. This situation commonly occurs in circuits containing inductive loads such as motors and transformers.

II. EFFECTS OF LOW POWER FACTOR

Low power factor can create several technical and economic problems in electrical power systems.

One of the most significant effects is the increase in current required to deliver a given amount of useful power. As current increases, the losses in electrical conductors also increase. These losses are usually in the form of heat and can reduce the efficiency of the system.

Another effect is the reduction in the capacity of electrical equipment. Generators, transformers, and cables must carry higher currents when the power factor is low, even though the useful power delivered remains the same.

Low power factor can also lead to voltage drops in transmission and distribution lines. These voltage drops may affect the proper operation of electrical equipment connected to the system.

In many cases, electrical utility companies impose additional charges on consumers who operate with low power factor. Therefore, maintaining an improved power factor is important for both technical and economic reasons.

III. INTELLIGENT POWER FACTOR CORRECTOR

An intelligent power factor corrector is an automatic system designed to improve the power factor of an electrical load by providing appropriate reactive power compensation. The system monitors the electrical parameters of the load and determines whether power factor correction is required.

When the measured power factor falls below a predetermined value, the system connects capacitor banks to the circuit. These capacitors supply reactive power locally, which reduces the reactive power drawn from the electrical supply.

Unlike traditional fixed capacitor systems, an intelligent correction system continuously monitors the operating conditions of the load. This allows the system to adjust the level of reactive power compensation according to the actual requirement of the motor.

As a result, the intelligent system maintains an improved power factor while preventing overcompensation.

IV. COMPONENTS OF THE PROPOSED SYSTEM

The intelligent power factor correction system consists of several electrical and electronic components that work together to monitor the power factor and provide the necessary reactive power compensation.

1. AC Power Supply

The system operates using a **230 V AC mains supply**, which provides electrical power to the single-phase induction motor and the correction system.

2. MCB / Fuse

A Miniature Circuit Breaker (MCB) or fuse is used as a protection device. It protects the circuit from overcurrent and short-circuit conditions.

3. Current Sensor

The current sensor measures the current drawn by the motor. The measured signal is sent to the controller so that it can determine the load condition and calculate the power factor.

4. Voltage Sensor

The voltage sensor monitors the supply voltage of the system. This information is required to determine the phase difference between voltage and current.

Step-Down Transformer

A step-down transformer converts the main supply voltage (230 V AC) to a lower voltage level suitable for the control circuit.

6. Rectifier and Voltage Regulator

The rectifier converts AC voltage into DC voltage, and the voltage regulator maintains a stable DC supply required for the microcontroller and electronic components.

7. Microcontroller / Controller

The controller acts as the central processing unit of the system. It receives signals from the voltage and current sensors, calculates the power factor, and determines whether correction is required.

8. Relay Driver

The relay driver amplifies the control signal from the controller so that it can operate the relay module effectively.

9. Relay Module

The relay module acts as a switching device that connects or disconnects the capacitor banks depending on the controller's command.

10. Capacitor Bank

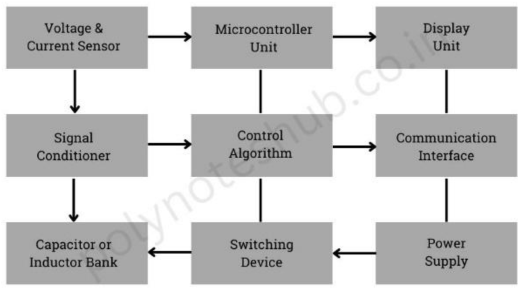
The capacitor bank provides reactive power to the system. In the proposed system, multiple capacitors such as **5 µF, 10 µF, and 15 µF** are used to achieve step-wise power factor correction.

11. Single-Phase Induction Motor

The single-phase induction motor acts as the load in the system. Due to its inductive nature, it operates with a lagging power factor that requires correction.

12. Power Factor Display

A display unit is used to show the real-time power factor value calculated by the controller.



Block Diagram of Intelligent Power Factor Controller

I. WORKING PRINCIPLE

The intelligent power factor correction system operates on the principle of reactive power compensation. Inductive loads such as single-phase induction motors draw reactive power from the supply, which causes the current to lag behind the voltage and reduces the power factor.

To improve the power factor, capacitors are connected in parallel with the motor load. Capacitors generate leading reactive power that offsets the lagging reactive power of the motor. As a result, the phase difference between voltage and current decreases, and the power factor improves.

The controller continuously monitors voltage and current signals to determine the operating power factor. When the measured power factor drops below the desired level, the controller activates the relay module to connect appropriate capacitor banks. This process supplies the required reactive power and improves the system power factor.

II. WORKING

The operation of the intelligent power factor correction system can be explained in the following steps.

The 230 V AC supply is provided to the system through the protection device such as an MCB or fuse.

Voltage and current sensors continuously monitor the electrical parameters of the motor circuit.

The measured signals are sent to the controller, where the power factor is calculated based on the phase relationship between voltage and current.

ISSN: 2583-6129
DOI:10.55041/ISJEM05726

The calculated power factor value is displayed on the power factor display unit.

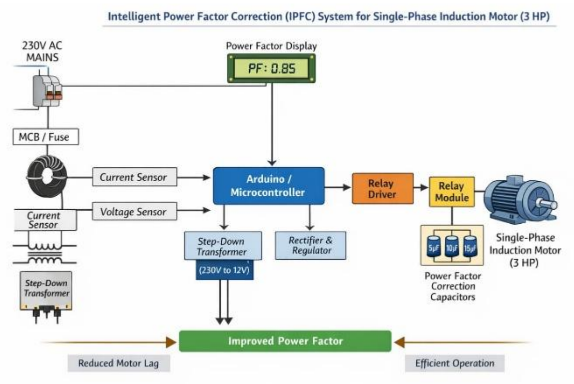
If the power factor falls below the preset value, the controller sends a signal to the relay driver.

The relay driver activates the relay module, which connects one or more capacitors from the capacitor bank to the circuit.

The capacitors supply reactive power to the motor and reduce the phase difference between voltage and current.

As a result, the power factor improves and the motor operates more efficiently.

The controller continuously monitors the system and adjusts capacitor switching depending on the load condition.



II. ADVANTAGES OF THE PROPOSED SYSTEM

The intelligent power factor correction system provides several important benefits.

It automatically improves the power factor without requiring manual intervention.
It reduces the current drawn from the power supply.
It decreases energy losses in electrical conductors.
It improves voltage regulation in the power system.
It increases the efficiency of motor-driven systems.
It helps reduce electricity costs by avoiding power factor penalties.

III. APPLICATIONS

- Industrial motor systems
- Pumps and compressors
- HVAC systems
- Small and medium industries
- Agricultural motor pumps
- Commercial buildings
- Power distribution systems
- Workshops using induction motors

IV. FUTURE SCOPE

The intelligent power factor correction system can be further improved by incorporating advanced monitoring and control techniques. Future developments may include the use of more precise sensing methods to improve the accuracy of power factor measurement. The system can also be integrated with digital display or monitoring systems to observe electrical parameters more effectively.

In addition, the design can be expanded for higher power loads and industrial motor applications. Improvements in switching devices and control circuits may increase the reliability and response speed of the system. The system may also be combined with smart energy management techniques to enhance overall power quality and efficiency in modern electrical networks.

V. CONCLUSION

Single-phase induction motors are commonly used in domestic and small industrial applications, but they often operate with a low power factor due to their inductive characteristics. A low power factor increases the current drawn from the supply and leads to higher power losses in the electrical system. An intelligent power factor correction system improves the power factor by automatically connecting capacitor banks to provide reactive power compensation. This helps reduce energy losses, improve efficiency, and enhance the overall performance and reliability of motor-driven electrical systems.

VI. ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the faculty members of the Electrical Engineering Department for their valuable guidance and support during the completion of this work. Their suggestions and encouragement greatly helped in the successful development of this study.

The authors also thank the institution for providing the necessary facilities and resources required to complete this work. Finally, appreciation is extended to all those who contributed directly or indirectly to the successful completion of this research.

VII. REFERENCES

1. 1 B. L. Theraja and A. K. Theraja, A Textbook of Electrical Technology, S. Chand Publishing.
2. J. Nagrath and D. P. Kothari, Electric Machines, McGraw Hill Education.
3. P. S. Bimbhra, Electrical Machinery, Khanna Publishers.
4. S. J. Chapman, Electric Machinery Fundamentals, McGraw Hill.
5. S. E. Haque, **"**Power Factor Improvement of Induction Motor Using FC-TCR Compensator**,"** *Proceedings of the IEEE Symposium on Electric Power Systems in Fast Developing Countries*, Riyadh, Saudi Arabia, pp. 371–374, Mar. 1987.
6. S. E. Haque, **"**Microprocessor Based Power Factor Improvement
7. J. Nagrath and D. P. Kothari, Electric Machines, McGraw Hill Education.
8. P. S. Bimbhra, Electrical Machinery, Khanna Publishers.
9. S. J. Chapman, Electric Machinery Fundamentals, McGraw Hill.
10. S. E. Haque, "Power Factor Improvement of Induction Motor Using FC-TCR Compensator**,"** *Proceedings of the IEEE Symposium on Electric Power Systems in Fast Developing Countries*, Riyadh, Saudi Arabia, pp. 371–374, Mar. 1987.
11. S. E. Haque, "Microprocessor Based Power Factor Improvement of Induction Motor," *Journal of King Saud University – Engineering Sciences*, vol. 2, no. 2, pp. 245–257, 1990. \
12. Z. Azazi, E. E. El-Kholy, S. A. Mahmoud and S. S. Shokralla, "Power Factor Correction for Three-Phase Induction Motor Drive System," *Proceedings of the International Conference on Electrical Engineering (ICEENG)*, pp. 1–25, 2014.