Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 5, April 2026
Paper Id: – IJ2026V6I5 -1 A-F
ISSN 2582-6026

DESIGN AND IMPLEMENTATION OF APFC UNIT FOR REDUCING POWER FACTOR PENALTIES IN INDUSTRIES

[1]Bhavar Nikita Janardhan, [2]Shinde Sanskruti Balnath, [3]Shinde Rutuja kailas, [4]Shinde Rohini Dattatray, [5]Prof.S. S. Yeole, [6]Dr.Sanjay Kumar

[1]UG Scholar, Electrical Dept. SND College of Engineering and Research Center, Yeola, Nashik.
[2]UG Scholar, Electrical Dept. SND College of Engineering and Research Center, Yeola, Nashik,
[3]UG Scholar, Electrical Dept. SND College of Engineering and Research Center, Yeola, Nashik,
[4]UG Scholar, Electrical Dept. SND College of Engineering and Research Center, Yeola, Nashik,
[5]Asst. Prof. Electrical Dept. SND College of Engineering and Research Center, Yeola, Nashik
[6]Asst. Prof. Electrical Dept. SND College of Engineering and Research Center, Yeola, Nashik

ABSTRACT - The power factor of an alternating current (AC) power system directly affects how well electrical energy is used. limited power factor, which is typically caused by inductive loads like motors, transformers, and lighting ballasts, results in a high demand for current. This leads to high transmission and distribution line losses, voltage dips, limited system capacity, and higher electricity costs. The current study addresses the design, development, and verification of an automated power factor correction (APFC) system using a stepwise capacitor bank and a microcontroller-based controller unit in order to address these issues. The system uses sensor circuits to identify voltage and current waveforms in real time and determines the phase angle.

difference to decide the power factor. According to the measured power factor, the microcontroller dynamically switches on or off capacitors to provide the necessary leading reactive power, thus compensating the lagging component caused by inductive loads. The system is implemented using low-cost, easily available components such as a current transformer (CT), potential transformer (PT), zero-crossing detectors, a relay module, and a bank of shunt capacitors. Simulation and experimental confirmation were carried out under different loading conditions to test system performance. The findings exhibit a notable increase in power factor-from levels as low as 0.72 to as high as 0.97-along with line current reduction and improved power quality. Economic assessment also shows substantial annual savings and a brief payback period on investment. The ease, scalability, and efficiency of the system render it appropriate for residential, commercial, and small-scale industrial applications, leading to more sustainable energy consumption habits.
Keywords: Power Factor Correction, Capacitor Bank, Re active Power, Microcontroller, Power Quality, Energy Efficiency, Inductive Load Compensation, Automated Control

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 5, April 2026
Paper Id: – IJ2026V6I5 -1 A-F
ISSN 2582-6026

I. INTRODUCTION

These days, industry is growing daily. Numerous motors in the sector are constantly in operation to produce an inductive load. The system's power factor decreases as a result of the inductive reactive power. The standard limit for the power factor value is set by the electrical board. Therefore, the electrical board charges the customers a penalty if the power factor value exceeds the rated value. The system's power factor drops as a result of the inductive loads, which lowers the system's efficiency. To get beyond these problems the architectures are introduced in the system to minimization the losses which are programmable device. When we think about programmable devices then the pictorial representation of technologies are comes into forefront. The most popular technology against the reduction of penalty is microcontroller based embedded technology.

For improving efficient transmission of active power the automatic power factor correction device is very important device. The automatic power factor correction device is used in the improvement of power factor also it helps to maintain the good efficient transmission of active power. The APFC device collects the value of power factor from line voltage and line current.

1.1 Power Factor Theory:

There are three types of power in the system.

a) Active Power: The power which is useful for the load or dissipated in the network is called the true power or useful power. The active power is measured in watts it is symbolically represented by capital letter P. the resistance (R) is dissipative element of circuit which is a function of active power.

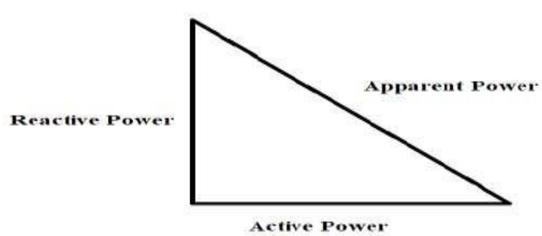

Fig. 1.1 Power Triangle

II. METHODOLOGY

The suggested power factor correction system utilizes a microcontroller-controlled capacitor bank to monitor and correct the power factor in real time. Sensing the electrical parameters, determining the power factor, and dynamic switching of capacitor banks to supply the necessary reactive power are steps involved in this methodology. This entir

2.1 System Overview The system is composed of the following key components:

• Voltage and Current Sensing: A potential transformer (PT) steps down the line voltage, while a current transformer (CT) samples the line current.

• Zero-Crossing Detection: Voltage and current signals are passed through zero-crossing detectors to determine the phase angle difference.

• Microcontroller Unit: An Arduino Uno is used to compute the power factor by analyzing the time delay between voltage and current zero crossings.

• Capacitor Bank: A multi-stage bank of shunt capacitors (e.g., 10 µF, 20 µF, 40 µF, 80 µF) is used to supply leading reactive power.

• Relay Module: A 4-channel relay driver enables or disables specific capacitor combinations based on real time PF measurements. • Display Unit: A 20×4 I2C LCD displays the calculated power factor and status of the capacitor bank.

2.2 Operating Algorithm Control algorithm of the system is as below:

1) Measure voltage and current waveforms with PT and CT.

2) Determine zero-crossing points of voltage and current signals.

3) Find phase angle ϕ between the signals.

4) Calculate power factor using PF = cos(ϕ).

5) Measure the power factor and compare with the reference threshold (usually 0.95).

6) Calculate the required reactive power by: $Qc = P.(\tan(\phi 1) - \tan(\phi 2))$ (5)

7) Operate the needed set of capacitor banks by means of relays. 8) Repeat the process continuously for dynamic compensation.

III. BLOCK DIAGRAM

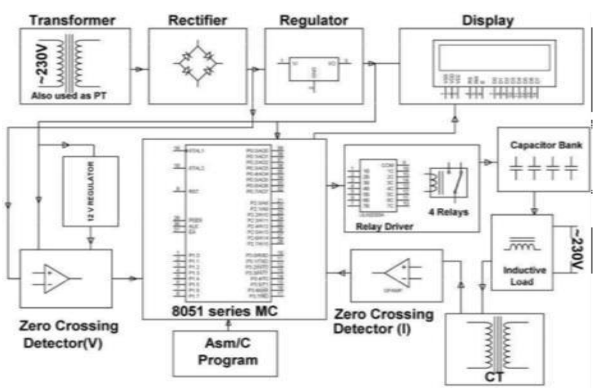

Fig 1.- Block diag.

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 5, April 2026
Paper Id: – IJ2026V6I5 -1 A-F
ISSN 2582-6026

IV. PROPOSED SYSTEM

The automated power factor correction unit's primary component is the microcontroller. It uses the user-defined algorithm to maintain power quality and guarantee that the power factor varies within the set limit. The voltage and current signals are obtained using the voltage and current transformers, which are input to the microcontroller. The automatic power factor correction unit detects the phase lag between the voltage and current waveform by using zero crossing detector to determine the existing power factor as shown in the fig.1.1. To bring it to unity, it is required to connect capacitor bank in parallel with the system. The number of capacitors that is to be

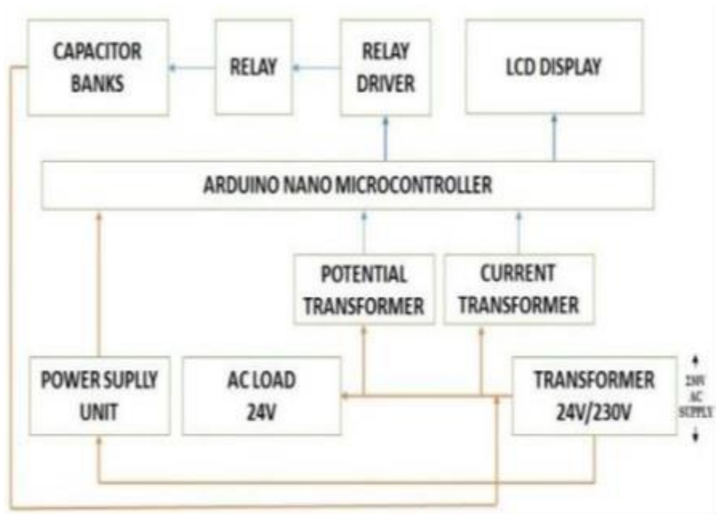

Fig 2 – Proposed system

V. ADVANTAGES AND DISADVANTAGES

Advantages:

- It improves system and device effectiveness minimises voltage drop
- shrinking a conductor's and cable's size to save money
- It assists in getting rid of the negative effects of low power factor on the electric supply.
- It lowers the cost of the power bill.
- It increases the efficiency of system and devices
- Reduces the voltage drop
- Reduction in size of a conductor and cable which reduces the cost
- It helps in eliminating the penalty of low power factor from the electric supply
- It provides saving in the electric bill.

Disadvantages:

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 5, April 2026
Paper Id: – IJ2026V6I5 -1 A-F
ISSN 2582-6026

- Power systems becomes unstable
- Resonant frequency is below the line frequency
- Current ant voltage increases

VI. CONCLUSION

The following conclusions were drawn from the measuring and monitoring of the simulated electrical demand using power factor correction equipment built on microcontrollers and capacitor banks: Under test load circumstances, the power factor was improved from 0.76 to 0.97 using the power factor correction device. For both the intended load and various load patterns, the average energy consumption reduction was around 1.7%. The system capacity is freed when the appropriate amount of reactive power compensation is applied because the current drawn decreases. According to the economic study, there would be substantial energy cost reductions and a payback period of around nine months.

FUTURE WORK

- The designed equipment was studied in the laboratory scale; it can be implemented in the mine substations with proper protection to verify the operation in a real time environment.
- In case of automatic PF correction, if the load is changing frequently, the numerous switching of capacitor bank may cause harmonic problem. Suitable filter design as well as an optimum algorithm design can be done based on the frequent load change pattern to avoid regular switching of capacitor bank.
- A comparative study on the location of correction equipment may be employed in the field to find out the optimum location referring to maximum utilization and savings.

REFERENCES

[1] McGill, T., Power Factor Correction, Eaton Corporation, 2007, pp. 24-26.

[2] Institute of Electrical and Electronics Engineers. The authoritative dictionary of IEEE standards terms. Standards Information Network, Std. 100, IEEE Press, 2000.

[3] Power Factor Correction Explained, Available at http://www.lexelectrix.com/index.php, Accessed on: April 27, 2015.

[4] Saied, M. M., Optimal Power Factor Correction, IEEE Transaction on Power Systems, 1988, pp. 844-851.