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Automatic Power Factor Corrector using Capacitor Bank

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***Abstract*—The rapidly growing number of electronic devices, power electronics, and high voltage power systems have made the power quality of the ac system a major concern in recent years. Large electrical loads that are multiple-inductive in nature, present in the majority of commercial and industrial installations across the nation, result in lagging power factors, which are penalized heavily by the electricity board for the consumers. PFC is handling this matter. The ability of a load to absorb reactive power is known as power factor correction. It is possible to manually switch the capacitors on and off in response to the variation in the load within an installation when dealing with constant loads. However, when dealing with rapidly variable and scattered loads, this becomes more challenging to maintain a high power factor. The APFC panel is used to get around this problem. The Atmega328 microcontroller is used in this article to measure power factor from load and to trigger the necessary capacitors to adjust reactive power and approach unity in power factor.**

***Index Terms*—Automatic power factor correction, embedded technology, Efficiency of the system increases, Improve the power system performance.**

I. INTRODUCTION

Power is extremely precious in the current technology revolution, and the power system is growing more complicated every day. Each unit of power created must therefore be transmitted across a greater distance with the least amount of power loss possible. Yet, losses have also multiplied in tandem with the rise of inductive loads and significant load fluctuations. Investigating the reasons behind power outages and enhancing the power system are therefore wise moves. Growing usage of inductive loads results in a significant drop in the load power factor, increasing system losses and ultimately reducing the efficiency of the power system.

By employing an internal timer to measure the delay in the arrival of the current signal relative to the voltage signal from the source, an automatic power factor correction device can accurately determine the power factor from line voltage and line current. It calculates the corresponding power factor (cos ø) by first determining the phase angle lag (ø) between the voltage and current signals. After that, the microcontroller determines how much compensation is needed and turns on the necessary number of capacitors from the capacitor bank in
order to achieve a power factor normalization of roughly unity.

To stabilize industrial units, power systems, and households, automatic power factor correction procedures can be used. The system stabilizes as a result, and both the apparatus's and the system's efficiency rise. As a result, both electrical energy suppliers and customers incur lower overall costs when using microcontroller-based power factor correctors.

Using capacitor banks for power factor correction lowers reactive power consumption, which minimizes losses and simultaneously boosts the electrical system's efficiency. Single phase capacitor banks for residential and commercial applications have been developed in response to concerns about power conservation and reactive power control. The goal of this project is to create a microprocessor-based control system that will improve and modernize the way single phase capacitor banks operate.

Based on the fluctuating load current, the control unit will be able to regulate the working stages of the capacitor bank. For sampling purposes, the load current is measured using a current transformer. By utilizing this microprocessor control unit for intelligent control, power factor correction is optimized, the number of switching operations is reduced, and capacitor steps are used evenly. The Compact Fluorescent Lamp (CFL) choke will function as an inductive load.

II. LITERATURE REVIEW

The article "Power factor correction unit using 89C52" published in 2014 contains the use of the 89C52 to measure and correct the power factor. The advantage of this research was that it showed the best method to measure the power factor of the systems but the disadvantage was the increase in the response time of the microcontroller [1].

The article "Power factor correction unit using an active series of filters" contains the use of active filters for the purpose of power factor correction, which is a unique method of power factor correction. The advantage of this method was the use of active filters to improve the power factor, but the disadvantage was the use of active filters because the filters do not have sharp cutoff frequencies and there were no either using controller, the circuit was not automatic [2].

The article "Automatic Induction Motor Power Factor Correction Using Arduino" contains the practical realization and power factor correction through the induction motor. The advantage of this article was that it solved the problem of low power factor practically at the level of the induction motor by using it as an inductive load. The downside was that using the Arduino UNO board increased the cost of the circuit because it had to be more connected to the controller [3].

The article "Automatic power factor correction unit" published in 2016 contains the use of a precision rectifier, an EXOR gate and the use of an Arduino board as well as inductive and capacitive loads for the improvement and power factor correction. The advantage of this item is that it measures the voltage and current value and solves the power factor problem and displays the corrected value, but its disadvantage is the measurement of voltage and current value using a rectified sine wave and also the use of a precision rectifier which increases the size and complexity of the circuit [4].

III. PROBLEM STATEMENT

Large electrical loads that are multiple-inductive in nature, present in the majority of commercial and industrial installations across the nation, result in lagging power factors, which are penalized heavily by the electricity board for the consumers. PFC is handling this matter. The ability of a load to absorb reactive power is known as power factor correction. It is possible to manually switch the capacitors on and off in response to the variation in the load within an installation when dealing with constant loads. However, when dealing with rapidly variable and scattered loads, this becomes more challenging to maintain a high power factor. The APFC panel is used to get around this problem.

The Atmega328 microcontroller is used in this article to measure power factor from load and to trigger the necessary capacitors to adjust reactive power and approach unity in power factor.

IV. PROPOSED SYSTEM

The conventional method for achieving power factor correction (PFC) in a power system is to provide a capacitive load to counterbalance the inductive load. Every motor can have a single capacitor linked in parallel. In order to offer power factor adjustment while the motor is in use, the capacitor bank is also powered while the motor is.

This method's advantage is that it regulates the capacitive load in proportion to the inductive load. To increase the induction motor's power factor, we use delta connection capacitors. Due to the fact that the necessary capacitor for a delta connection is less than that of a star connection capacitor by a factor of three. By adding capacitive kilo VAR, the system load is decreased from KVA1 to KVA2 following the installation of capacitors in tandem with an induction motor.

Through this project, we were able to understand that the introduction of a low-rated capacitor bank and its automatic adjustment via microcontroller can result in a more precise and flawless power factor improvement.

The study we conducted focused on enhancing the power factor, and in order to get optimal results, we would like to suggest four capacitor banks with ratings of 300, 500, 800, and 1600 KVAR. With this configuration, power factor variations can be adjusted over a narrow range using the best ratings. By selecting the necessary capacitor bank, it can give any rating with a minimum capacitance of 300 KVAR (now 500 KVAR). Capacitor banks with ratings ranging from 300 KVAR to 3100 KVAR can accommodate the majority of intermediate values. As an illustration, 300 KVAR and 400 KVAR banks can be turned on to introduce 700 KVAR.

The atmega328p microcontroller is the main component of the circuit. With the aid of potential and current transformers, the current and voltage single are obtained from the main AC line. Following acquisition, these signals are sent through zero crossing detectors. An analog signal is converted to a digital signal using a bridge rectifier for both voltage and current signals. In order to choose the value of the in-demand capacitor for the load and fix the power factor, the microcontroller reads the RMS value for voltage and current. It then uses this information to monitor the behavior of the enduring load based on the current that the load depletes. When the power factor is low, the microcontroller signals the switching unit to turn on the capacitor's in-demand value. The LCD displays the actions that the microcontroller performs to fix the low power factor by choosing the capacitor's in-demand value and keeping track of the load.

V. SYSTEM DESIGN

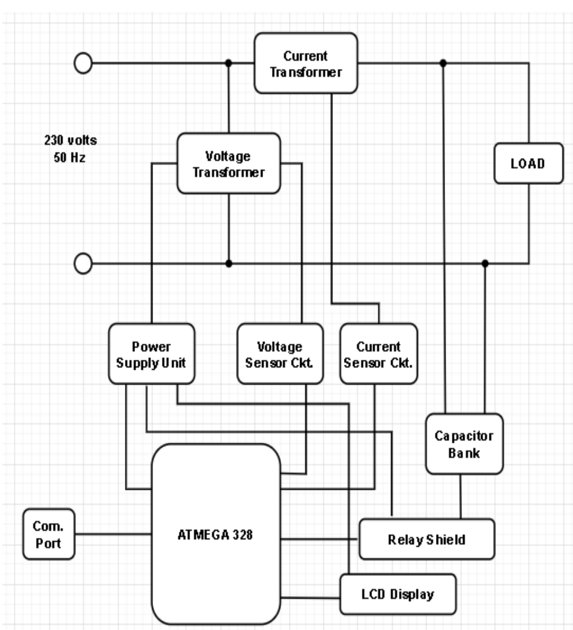

Figure 1: Block Diagram

The above block diagram for automatic power factor detection and correction works on the basis of continuously observing the system's power factor and triggering the necessary correction if it falls below the predetermined value. Instrument transformers connected within the circuit are utilized for the purpose of sampling the voltage and current signals. The magnitude of the current and voltage values that the instrument transformers provide is precisely proportional to the circuit current and voltage, but they are stepped down. At each zero crossing of the voltage and current signals, the zero crossing detectors, which alter their state, convert the sampled analog signals into appropriate digital signals. After that, the ZCD signals are combined to provide pulses that show how long it takes for the voltage and current signals to zero cross.

The AT328's internal timer circuit measures the duration of these pulses using the function pulseIn(), which provides the duration in microseconds. The circuit's power factor is computed using the obtained time period. The microcontroller will now turn on the necessary amount of capacitors until the power factor is greater than or equal to the set value if the computed power factor is less than the minimum power factor limit, which is set at roughly 0.96-0.98.

VI. ALGORITHM/FLOWCHART

Within the algorithmic system, the program created using software development approach is positioned as follows. The linked judgment may change as a result of an agreement or as a result of the circumstances represented in the study. Once a database is constructed, it is kept duplicated using suitable simulators that have been utilized for all possible scenarios that have been run through the system before.

Step 1: Measures the voltage and current input into the circuit.
Step 2: Measure the phase lag to get the power factor.
Step 3: Determine the needed reactive power by deviating from the desired power factor.
Step 4: Relying on the reactive power supplied by each step, turn on or off the necessary number of capacitors from the capacitor bank.
Step 5: Continue from step 1 and equate the power factor through directed PF once more.

Figure 2 displays the algorithm flowchart with the various steps for the various PFC control operations.

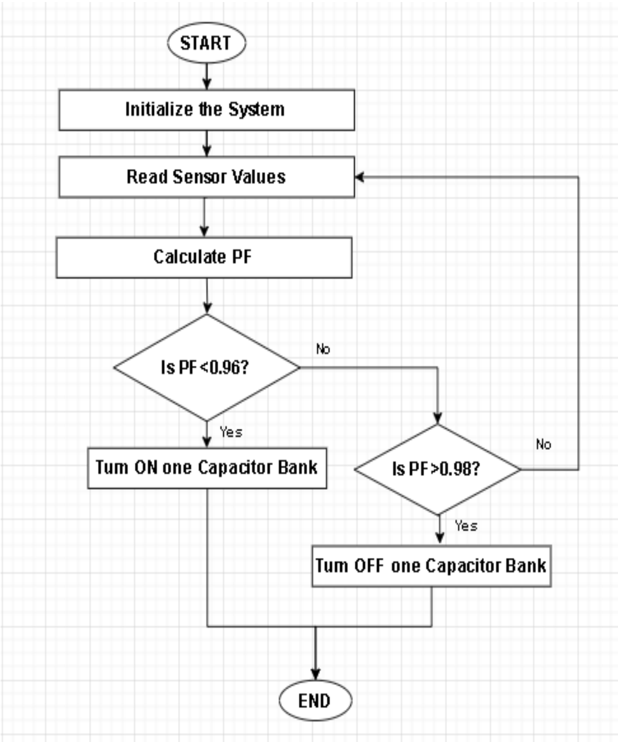

Figure 2: Flowchart

VII. CALCULATIONS

The following formula was used to determine power factor. After adding the RKVAh Lead component to this tariff order, the POWER FACTOR computation looks like this.

$$PF = \frac{KWH}{\sqrt{(KWH^2) + RKVAh \quad lag^2}}$$
(1)

MERC had changed the incentives and disincentives related to power factor in the aforementioned cited order. When the average percentage of fit is greater than 0.95 lag and up to 1, an incentive is granted. Similarly, penalties are applied anywhere the average percentage of profit (lag or lead) is less than 0.9. Consequently, PF is determined using the formula below:

$$PF = \frac{KWH}{\sqrt{(KWH^2) + (RKVAh \quad lag + RKVAh \quad lead)^2}}$$
(2)

If RKVAh lead exceeds RKVAh lag, PF incentive is not granted since Lead PF is not liable for incentive.

As the energy meter reads the PF using the above formula, we have utilized the second formula to create the ladder logic in the controller in order to achieve ideal outcomes for the power factor adjustment.

Step.1: Calculation of actual load (KW)

$$Load(KW) = Volts(V) \times \sqrt{3} \times Current(I) \times PF(Cos\theta)$$
(3)

Nominal voltage in Volts = 415V
Non Corrected Current in Amp = 1000 Amp
Non Corrected Power Factor = 0.600
Non Corrected load KVA = 718.8 KVA
Actual Load = 431.3 KW

Step.2: Calculation of Power Factor correction (KVAr) Required.

$$PowerFactorCoreection(KVAr) = PowerKW\ (Tan\phi i - Tan\phi d)$$

$$Tan\phi i = \cos^{-1}(\text{Re}\ quiredPowerFactor)$$

$$Tan\phi d = \cos^{-1}(InitialPowerFactorPF)$$

Actual Load = 431.3 KW
Non corrected PF *cosØ* = 0.600
Required PF *cosØ* = 0.950
Correction Required KVAr = 400 KVAr
Total Capacitor Bank connected to the system is of 433 KVAr.

Step.3: Calculation of Actual Power factor correction KVAr

From (2)

$$PF = \frac{KWH}{\sqrt{(KWH^2) + (RKVAh \quad lag + RKVAh \quad lead)^2}}$$

Correction Applied KVAr = 400 KVAr
Original Load = 431.3 KW
Non Corrected Power Factor = 0.600
From (2) corrected PF obtained

Corrected Power Factor cosØ = 0.927

VIII. RESULT AND DISCUSSIONS

Figure 3 shows the whole hardware of Automatic Power Factor Correction using Capacitor Bank used for improving power factor. One of the results is discussed below. When inductive load was applied i.e. Choke is used in this case the measured P.F was found to be 0.85 Lagging, the P F is increased to 0.99 by adding capacitor in parallel.

The result shows the working and idea of Automatic Power Factor Correction using Capacitor Bank.

Figure 3: Hardware Setup

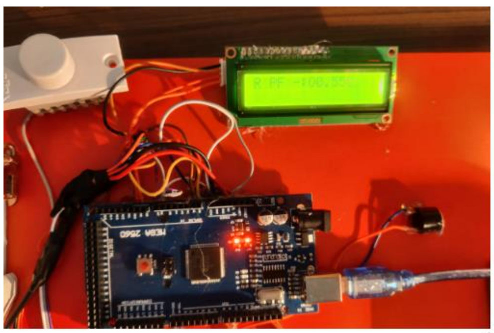

Figure 4: Power Factor Correction

IX. CONCLUSION

An effective method for raising a power system's power factor in an economical manner is Automatic Power Factor Detection and Correction. For distribution lines or factories to increase the power factor, static capacitors are a necessary component. Capacitors are only used by this system, though, in low power situations; in other cases, they are disconnected from the line. Consequently, it prolongs the life of static capacitors in addition to improving the power factor. Any distribution line's power factor can also be readily increased with a simple, inexpensive capacitor of low rating. Any distribution line's power factor can be raised from the load side by using this approach with a static capacitor. Since its rating will be surprisingly high in a high voltage transmission line, this static capacitor will be inefficient and uneconomical. The power factor of any high voltage transmission line can therefore be increased by using a variable speed synchronous condenser, whose speed can be adjusted via a microcontroller.

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