# 8 Steps Power Factor Correction Automation for 2200VA Single Phase Household

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**Abstract**. An automated power factor correction system can optimize energy efficiency and reduce costs for a single-phase household load of 2200 VA. Voltage-current phase differences can be corrected using automated power factor correction devices, such as capacitors, greatly enhancing power factor proximity to unity. As utilities frequently base their charges on power factor performance, this adjustment not only improves power utilization efficiency but also reduces wastage associated with reactive power consumption. Embedding power factor correction within residential electrical systems appears as a practical and effective strategy for adjusting energy consumption as automation technology develops in accessibility and sophistication. A control system that could automatically correct power for a single phase of 2200 VA to achieve 0.95 to 1 power factor was developed as a result of the system test. The system is intended to reduce inductive reactance power to a maximum of 960 VAR, with a minimum of 120 VAR. 8 steps of correction level provide higher resolution and capacity of power factor correction.

**Keywords:** Power factor correction, Microcontroller, Energy efficiency, Energy conservation.

## 1. INTRODUCTION

Power factor correction(PFC) method is essential for electrical efficiency and energy conservation. The relationship between active power (watts) and perceived power (VA) in an electrical system must be optimized for power factor correction. While apparent power includes the reactive power component, which does no work but is required to balance off the effects of inductance and capacitance in the circuit, active power is the power that is actually employed to perform work (such as producing light or driving machines).

The power factor in household loads relates to how efficiently electrical power is used in a residential setting. It is an evaluation of how well current and voltage are in

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phase (aligned) in an electrical circuit. A high power factor implies that the current and voltage are well-aligned, whereas a low power factor shows that they are out of phase.

The power factor is not a major concern in many houses because most appliances and equipment have a very simple load, frequently consisting of resistive materials such as heating elements and incandescent light bulbs. These loads often have a power factor close to one, indicating that the current and voltage are in phase and the power drawn is sufficient.

However, due to the inclusion of reactive components such as capacitors and inductors, some modern electronic equipment such as computers, LED lighting, and certain types of motors used in appliances may have slightly lower power factors. These loads add a reactive power component that accomplishes no beneficial work but contributes to the overall current required from the power supply.

While low power factors in domestic loads may not result in considerable energy waste or financial consequences as they do in industrial settings, they can nevertheless have an impact:

- Increased Current: Lower power factor loads necessitate greater currents to produce the same amount of active power. This can put additional strain on the electrical cables and circuit breakers.
- Reduced Efficiency: Some energy is lost while reactive power passes through the system, reducing overall power distribution efficiency[1].
- Utility Billing: Penalties or charges for low power factor loads may be imposed by some utilities, however this is less typical in residential settings[2].

The power factor correction (pfc) method uses capacitors to lower the reactive power component in order to boost an AC circuit's efficiency and decrease current consumption. The power factor in an AC circuit might be anything between 0 and 1. When the power factor is 1, sometimes referred to as a unity power factor, all the electricity is being used for useful purposes, such as powering equipment or lighting.

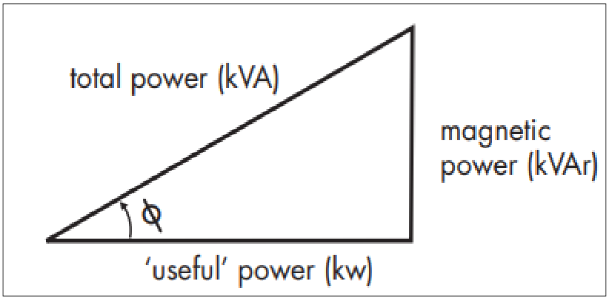

**Fig. 1.** The active power, reactive power, and apparent power of the AC circuit are represented by the power triangle in the right-angle triangle.

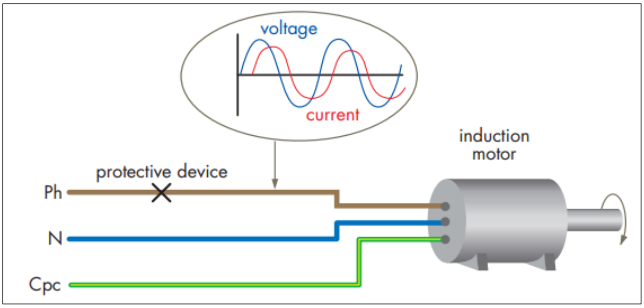

**Fig. 2.** Power factor effect shown electrical load wave form[3].

Reactive power, which does not contribute to productive work but still needs to be provided and transmitted by the power distribution system, causes some electrical power to be lost when the power factor falls below 1, which means that some electrical power is being wasted. To calculate the capacitor needed, use this equation:

$$\text{required capacitance}(\mu\text{F})=\frac{159.155\times10^{6}\times\text{Required Reactive(kVAR)}}{(\text{Voltage(volt)})^{2}\times\text{frequency(Hz)}}$$

So, the reactive power capacity that can be compensated :

$$\text{Required Reactive(kVAR)}=\frac{\text{required capacitance}(\mu\text{F})\times(\text{Voltage(volt)})^{2}\times\text{frecuency(Hz)}}{159.155\times10^{6}}$$

From the system design, using 8 capacitors which each 8 µF, so the maximum reactive power can be compensated is 8 ×120 VA = 960 VA.

## 2. METHOD

A control system designed to improve the power factor for household loads. Generally, typical inductive household electrical loads will be enhanced by adding capacitors to correcting the power factor. Arduino microcontroller control device is chosen as control system due its low cost and minimal power consumption[4]. A 2200VA load was chosen since it is frequently utilized in Indonesian households. The goals of this control system is to archieve 0.95-1 power factor. 0.95 power factor value is a standart from some Europe country regulation to avoid reactive power charge[5].

The principle of automation method works by reading the power factor value and then gradually adding capacitors one by one. The PZEM-004T sensor measures the power factor of a household load. This sensor provides high accuracy of power factor reading result[6]. The PZEM-004T sensor can only measure the power factor's intensity. PZEM-004T is incapable to identify within inductive or capacitive loads. The number of capacitors connected to the load is controlled by an 8-channel 5-volt relay. Increase the number of relay channel steps to improve the resolution of the power factor correction. The flowchart of power factor control system can be seen in the Fig. 3. As 8 relay used, 8 capacitors connected to the load, as an identical 8 µF of each capacitor.

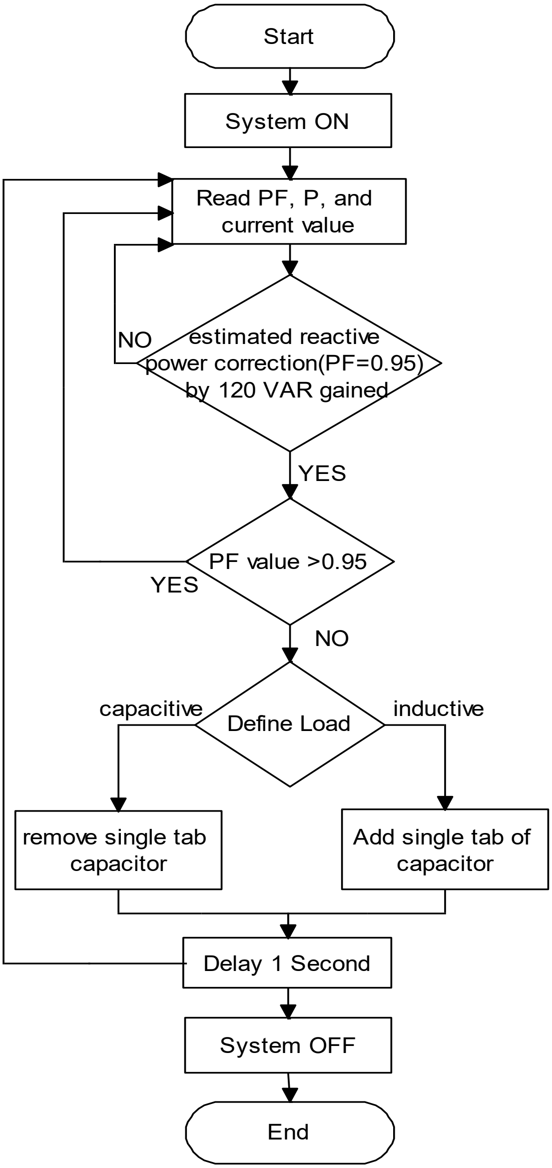

**Fig. 3.** Microcontrollers working flowchart shown how the system looping works to correcting the aim power factor corrected to reach above 0.95.

The system stops adding capacitors when the power factor value reach higher than 0.95. This power correction system's design use 8 capacitors, each of 8 μF capacity. It is expected that the system may increase reactive power by 1,647 VA with this configuration. Instead, it can raise the power factor from 0.64 to 0.95 at the maximum allowed current is 10 A. When the reactive power being corrected approaches the 120 VAR capacity of a single capacitor, the smallest power improvement can become active. In order to attain 0.95 power factor, the power factor correction system will only turn on when the reactive power correction exceeds 120 VAR and above. One second delay at each looping process is used due to make sure the change of capacitor effect. The system's control circuit for power correction shown in Fig. 4.

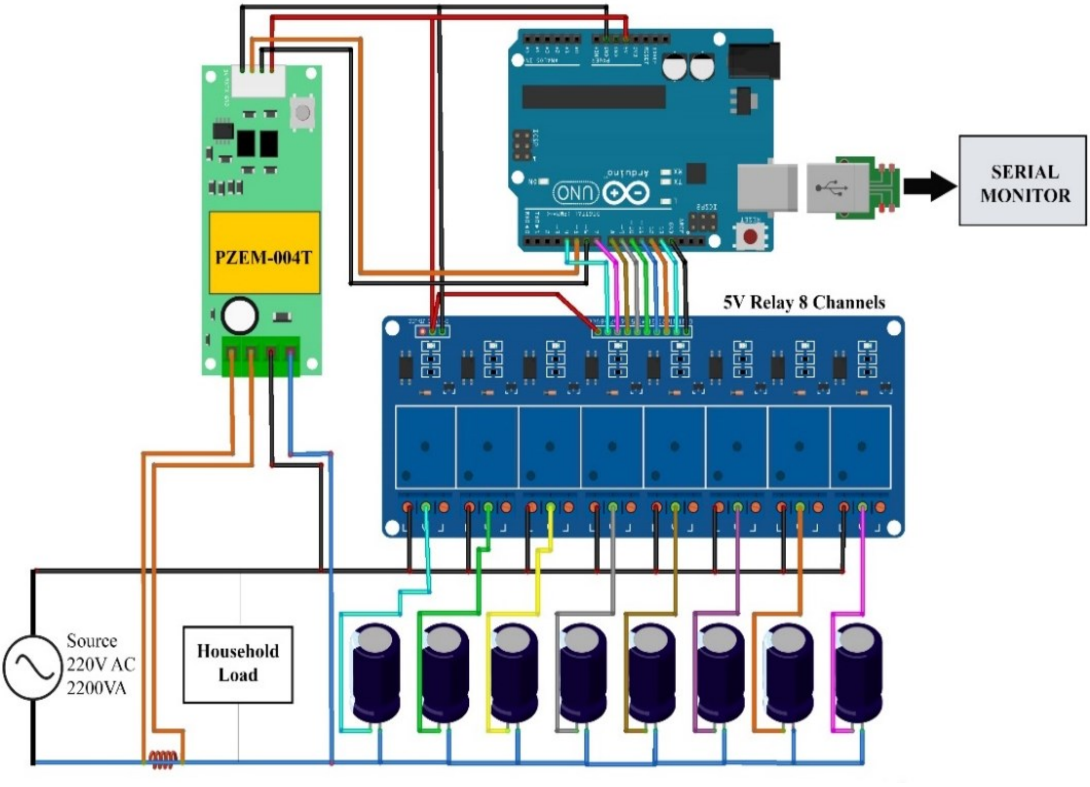

**Fig. 4.** Wiring diagram of 8 tabs power correction system.

## 3. RESULT

The devices system performace are tested by varying household load. The load commonly used in testing as inductive household load such as fans, vacuum cleaners, blenders, and bulb lamps. The number of active capasitor tab indicate how much the system does the correction. The testing process and testing result are shown in Fig 5. and TABLE 1.

**Fig. 5**. Testing the power correction control system using household load.

**TABLE I.** POWER CORRECTIN AUTOMATION TESTING RESULT

| Current (ampere) | Active Power(watt) | Power Factor (before correction) | Number of Active Capacitor Tab | Power Factor (after correction) |
|---|---|---|---|---|
| 0,51 | 109.32 | 0,84 | 0 | 0.84 |
| 1,03 | 212.34 | 0,85 | 1 | 0.99 |
| 2,03 | 404.2 | 0,91 | 1 | 0.98 |
| 3,14 | 161.95 | 0,22 | 6 | 0.99 |
| 4,06 | 526.53 | 0,56 | 6 | 0.99 |
| 5,04 | 602.78 | 0,5 | 8 | 0.99 |
| 6,06 | 946.09 | 0,66 | 7 | 0.97 |
| 7,02 | 1,253.61 | 0,77 | 7 | 0.98 |
| 8,04 | 1,527.67 | 0,83 | 5 | 0.96 |
| 9,06 | 1,755.5 | 0,85 | 5 | 0.96 |
| 9,99 | 1,990.75 | 0,88 | 4 | 0.95 |

From the conducted tests, a power factor correction control system has been developed with power factor corrected values ranging from 0.95 to 1. At lowest current test, it is evident that power factor correction cannot reach minimum at 0.95 because the reactive power is less than 120 VA, causing a single capacitor to be too large for its correction. Moving forward, further development can be pursued by varying the capacitance of the capacitor utilized.

The device's issue is that it requires an interval of delay in order for the PZEM-004T sensor to read the cos phi values and measure the active and reactive power. The PZEM-004T sensor's inability to recognise either an inductive and a capacitive load is another issue contributing to this delay. When the power factor changes or deviates from the specified standard, the programme developed must be reset to disconnect the capacitor.

## 4. CONCLUCSION

Implementing power factor correction automation for a single-phase 2200 VA household load has substantial benefits, optimizing energy efficiency and curbing costs. By deploying automated power factor correction devices like capacitors, voltage-current phase disparities can be rectified, substantially improving power factor proximity to unity. This adjustment not only heightens power utilization efficiency but also curtails wastage linked to reactive power consumption, translating to discernible reductions in energy expenses, as utilities frequently bill based on power factor performance. As automation technology progresses in accessibility and sophistication, embedding power factor correction within residential electrical systems emerges as a pragmatic and efficacious strategy for fine-tuning energy consumption. From the system test, its developed a control system that could do power correction automatically for single phase 2200 VA to get 0.95 to 1 of power factor. The system designed to reduce inductive reactance power at maximum 960 VAR, while the minimum of inductive reactance power is 120 VAR. The technology that has been developed is expected to be used to automatically enhance the power factor of houses loads, thus enhancing energy efficiency while cutting electricity costs.

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