Power Factor Correction Using Programmable Logic Control Based Rotary Method

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Abstract. The power factor value of an induction motor is low. This power factor value is due to the large reactive power. Therefore, it is necessary to add capacitors to improve the power factor. The addition of this capacitor uses a capacitor bank with the rotary method. This rotary method is expected to be able to improve the low power factor. The method used is to determine the set point of the desired power factor. Then this method will add the value of the capacitor bank if it does not meet the set point. If it exceeds the set point value, this method will reduce the value of the capacitor bank. For programming this method using Programmable Logic Control. Programmable Logic Control can perform real time monitoring. The results of the test method showed that the capacitor bank worked to improve the power factor optimization. From the power factor of the drilling machine 0.54 to 0.86 in the test. Further developments can make capacitor sizes smaller and more varied in order to optimize the power factor.

1. Introduction

The problems that exist in the industry, especially in the load of 3-phase motors with high power are due to the low quality of the power factor caused by inductive electric loads. This type of inductive load will cause a low power factor [1]–[3]. Therefore, a research was conducted to determine how much power factor was generated, and the power that could be saved both before and after repairs. The improvement of the power factor can be carried out by installing capacitors. However, using different power tools can cause the power factor value to be variable. To improve the value of the power factor which is not fixed, it can be done by installing a capacitor which should be automatically changing in parallel with the load [4], [5].

Reactive power has an effect on the installed or used electrical power. This reactive power loss can cause increased power losses, increased voltage drop, worsened power factor and reduced power delivery capacity. In addition, this excessive reactive power will also result in an increase in apparent power, so that it will affect the occurrence of a low power factor. To minimize these losses, an additional reactive power source is needed, so that later it will be used to compensate for the reactive power required by the load, namely by installing a capacitor bank [6]. Good power quality will improve: voltage drop, power factor, power losses, and installed or used power capacity. To correct the power factor caused by inductive loads. a reactive power compensator is needed, namely with the help of a control system by a Programmable Logic Controller (PLC) as an automatic stepping capacitor bank controller [7], [8]. In order to streamline the installed capacitor so that it can work optimally as needed. Power factor correction in 3 phase induction motor using this rotary method uses PLC as the main
control and HMI as the display. From the HMI display, you can set the desired capacitor bank changes automatically.

2. System Control Section

2.1. PLC

PLC (Programmable Logic Controller) is a microprocessor used for automation of industrial processes such as monitoring and controlling machines on the assembly line of a factory. The PLC has input and output associated with external devices. Inputs on the PLC are usually sensors. The output on a PLC for example is a DC motor. The programming language used to operate a PLC is different from ordinary programming languages. The language used is Ladder, which only contains input-process-output. It is called a ladder, because the programming language looks like a ladder. The type of PLC used in this research is the Modicon M221 PLC.

2.2. HMI

Human Machine Interface (HMI) is a software interface between a machine or plant and an operator or observer. Generally HMI consists of a central computer or several separate computers that function to monitor and control machines, plants or processes in a factory. The purpose of using HMI is to collect and display information from the process at the plant. HMI can be connected directly with PLC. With the development of increasingly sophisticated technology, the use of PLC and HMI has become one of the things that are mandatory in manufacturing production machines. This is mandatory because it avoids human error and avoids human dependence on production capacity.

2.3. Software SoMachine Basic

SoMachine basic is a software for programming PLC M221. This software is free software, only required to register when installing it. As the name implies, which is SoMachine basic, this software can only program M221 PLC. This software is for PLC programming with many variants, this software can also be used for HMI programs etc.

3. Method

3.1. Schematic Research Diagram

The stepping capacitor bank design using the PLC and HMI-based rotary method can be seen from the unit design system diagram in Figure 1. The system diagram above explains the entire workflow of the stepping capacitor bank. In the picture made, the main source of 3 phase 380 VAC is explained with control rather than capacitors using a PLC that has been programmed and all controls and information
will appear on the HMI screen, where the Cos phi meter is a sensor whose data will be entered into the PLC for processing and displayed in real time numbers. On the HMI display, besides the HMI, there are also pushbutton and indicator lights that can be operated manually by the user without going through the HMI display.

3.2. Cos phi Sensor

The following is the hardware of the Cos phi sensor that can be used for monitoring and control system of stepping capacitor bank with PLC and HMI-based rotary methods. The sensor is installed parallel to the load and then processed by Arduino. Arduino is programmed to detect the power factor of a program. Before Arduino there was a current and voltage sensor module. CT is used to reduce the current and voltage ratio in the motor before comparing the current and voltage waves. Wiring diagram of the PZEM sensor as shown in Figure 2.

![Cos phi Sensor PZEM Wiring Diagram](image)

Fig. 2. Cos phi Sensor PZEM Wiring Diagram

3.3. Capacitor

![Capacitor Bank Wiring Diagram](image)

Fig. 3. Capacitor Bank Wiring Diagram

Capacitor Bank is an electrical panel component connected in parallel or in series between power bank one and other power banks. A capacitor bank is a collection of several capacitors that have the same specifications and have a total capacity value for all capacitors. Capacitor banks can correct low power factor values. The application of capacitor banks is widely used in industry, home and in car audio. Installation of bank capacitors can be seen in Figure 3. A three-phase capacitor bank is a delta-mounted single-phase capacitor. This capacitor is installed parallel to the resistor to remove the voltage stored in the capacitor. The capacitor values on each capacitor bank must have the same magnitude as the others in a delta circuit. Each step has a different capacitor value.
Here are the capacitor sizes at each step:

- Step 1 = 3 uF
- Step 2 = 4 uF
- Step 3 = 5 uF
- Step 4 = 9 Uf

3.4. Rotary Method

The power factor improvement process uses the rotary method. This rotary method uses a 4 step capacitor. If the step 1 capacitor cannot improve the power factor then a step 2 capacitor will be added. If the step 2 capacitor cannot be added the next step in sequence. if the power factor value exceeds the set point then the additional step capacitor will be reduced. The concept of the rotary method on the capacitor is shown in Figure 4.

![Rotary Method Diagram](image)

Fig. 4. Rotary Method

4. Result and Discussion

In program testing and HMI, this is a combination stage between previous tests, entered into the program to be displayed on the HMI display. HMI is a monitoring center for all stepping activities ranging from manual or automatic systems, power factor to capacitor / step that is running. The test steps are as follows:

- Make sure the PLC and HMI trainer modules used are active and in accordance with those used.
- Upload the PLC program to the PLC device using USB B mini, the program can be monitored on a computer or laptop that is connected to USB B mini.
- Upload the HMI design to the HMI device using a USB Printer cable.
- Connect the RS485 to RJ45 communication cable from the Com HMI to the PLC Modbus Port so that the two devices are connected to each other.
- Run the program by pressing RUN on the PLC to make the program work.

Perform some tests as follows:

- Run manually or automatically on the system
- When the point is less than the minimum set point (0.85) and when the set point is fulfilled
- When the point is more than the set point maximum (1), will the system break the capacitor bank.
- At no load, will the system disconnect all the capacitor banks.

4.1. Manual and Automatic System Testing

There are 2 systems that can be operated in testing, namely the manual system and the automatic system. Both of these systems can be monitored on the HMI when one system is running.
Fig. 5. Manual System Testing

The position when manual, the capacitor stepping will be done using the button manually. Using the push button on and off to turn the capacitor bank on or off. At manual time, you can also see the cos phi value in the system. When manual we use a push button to turn on the capacitor. The power factor increases with each additional capacitor. This system is only different in how to turn on the capacitor bank. Manual system testing can be seen in Figure 4.

Fig. 6. Automatic System Testing

When the automatic system works, the stepping system will work automatically. By reading the Cosphi sensor (pzem) as an analog input and the system will work automatically. when the push button is automatic, it will not function if pressed because the system is working automatically. when automatic, all systems will work automatically except for the load to be used. Stepping will work from step 1 to meet the minimum set point (0.85). Automatic system testing can be seen in Figure 5.

4.2. Testing when the point is less than the minimum set point (0.85) and when it is met

Testing if the point is below the value of the set point (0.85), and stepping will work from the very beginning step until the set point is met or exceeds the minimum set point. In order for the minimum set point to be met, the capacitor bank must be turned on. The point will continue to increase if the capacitor bank works, this stepping will stop when the set point is met.

Fig. 7. Testing When the Set Point Has Not Been Fulfilled
The image when the system is running and stepping will work from the beginning to the last step. When the minimum set point (0.85) is met, the stepping will stop. At each step the capacitor values differ from the smallest step 1 to the largest step 4. When stepping starts the capacitor bank the lagging indicator light will light up because the load is still unbalanced, it tends to be inductive. This stepping aims to balance the load by adding a capacitor bank.

Table 1. The results of adding capacitors to variations in load

| Inductive Load          | Cos Phi Early | Cos Phi Late | Step Capacitor Used              |
|-------------------------|---------------|--------------|----------------------------------|
| Drilling Machine 220V 550W | 0.54          | 0.86         | Capacitor 2 and Capacitor 3 (2.5 µF + 5 µF) |
| Sitting Drilling Machine 220V 350W | 0.69          | 0.91         | Capacitor 1 2.5 µF               |
| Water Pump 220V         | 0.6           | 0.92         | Capacitor 2 and Capacitor 3 (2.5 µF + 5 µF) |

Table 1 illustrates the addition of capacitors that affect the power factor value. Power factor correction for various types of loads can be performed. The power factor improvement process uses the rotary method. If the step 1 capacitor cannot improve the power factor then a step 2 capacitor will be added. If the step 2 capacitor cannot be added the next step in sequence. If the power factor value exceeds the set point then the additional step capacitor will be reduced.

5. Conclusion
From all the test data that has been obtained, it is concluded that:

a. PLC program can communicate well with HMI
b. Expenses can be added / reduced immediately without having to repeat the ongoing steps
c. Power factor can be monitored manually or automatically on the HMI

The suggestions used for further development of the tool are as follows:

a. You can add a Step Capacitor Bank so you can be more accurate with a smaller and larger capacitor.
b. Can add IOT-based monitoring so that it can also be monitored continuously without being in the field of work.
c. You can add a disturbance detection sensor to a damaged capacitor so that it does not interfere with the system's work optimally.

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