

Automatic Power Factor Controller Using Synchronous Condenser

Sayad Fahiz¹, Salmani Ramzan Ali², Shaikh Afsar Ali³, Shah Rahul⁴,
Khan Yakub⁵, Tahoora Qureshi⁶

^{1,2,3,4,5,6} (Department of Electrical Engineering, Anjuman-i-Islam Kalsekar Technical Campus, New Panvel, Maharashtra)

Abstract : The power factor correction of electrical loads is a problem common to all industrial companies. Earlier the power factor correction was done by adjusting the capacitive bank manually. The automated power factor corrector (APFC) using capacitive load bank is helpful in providing the power factor correction. Proposed automated project involves measuring the power factor value from the load using microcontroller. The design of this auto-adjustable power factor correction is to ensure the entire power system always preserving unity power factor. For the low maintenance cost and long life, synchronous condenser is used for correction method instead of capacitor bank. Harmonics are put down by synchronous condenser which can't be possible by using capacitor bank. For controlling the DC excitation of synchronous condenser as well as to improve the power factor, the power factor and generation of required control signal from microcontroller are needed to measure and monitor continuously which is also involved in this method.

Keywords : Capacitor banks, Synchronous condenser, Microcontroller, DC excitation, Power factor.

I. Introduction

Due to the preciousness of power, the industrialization is primarily increasing the inductive loading and the power factor is affected by the inductive loading. So, the power system losses its efficiency. In order to improve and compensate power factor, many organization are developing products in this field. The design are also moving forwards the miniature architecture in the present trends, this can be achieved in a product by using programmable device and most of the products are being developed with microcontroller based embedded technology. The reduction of cost and the use of extra hardware such as the use of timer, RAM and ROM can be avoided which is the greatest advantage of using microcontroller. Controlling of multiple parameters is possible because this technology is very fast and also the parameters are field programmable by the user. For efficient transmission of active power, the automatic power factor correction device is a very useful device. By connecting inductive load, the power factor lags and when the power factor goes below a certain level, then the electric company charge penalty to the consumer. So, it is essential to maintain the power factor within a limit. The power factor from the line voltage and line current is read by automatic power factor correction device , calculating the compensation requirement and switch on the different capacitor banks or synchronous condenser.

1.1 Importance of power factor in distribution system

Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers and switchgear would be increased in size (and cost) to carry the extra current. Utilities typically charge additional costs to commercial customers who have a power factor below some limit, which is typically 0.9 to 0.95.

1.2 Power Factor Correction

When a power factor problem has been identified, the traditional solution has been to install capacitor banks. This approach worked in the past, but it has become more difficult to apply capacitors in a system containing both high harmonic content and sensitive loads that cannot tolerate voltage transients. For low-speed applications, synchronous motors may be a better choice when equipped with accessories that offer power-factor control. The synchronous machine, with the aid of an intelligent excitation controller, can control power factor to reduce the plant reactive loading to the connected system.

1.3 Power factor improvement through capacitor banks

A poor power factor can be improved by adding power factor correction capacitors to the plant's distribution system. Correction capacitors provide needed reactive power (kVAR) to the load. Therefore, the Electricity Supply Company is freed from having to supply it. Power factor correction capacitors reduce the total current supplied by the Electricity Supply Company to the load and as a result the distribution system capacity is increased.

1.4 Features of capacitor banks as power factor corrector:

- Typically applied in low voltage circuits (380-690V)
- More expensive for medium voltage (3.8kV to 6.9kV)
- Depending on the size oil containment is required and enclosures.
- Flammable dielectric.
- Require filter capacitors to de-tune harmonic frequencies
- Vulnerable to switching surges
- Compensation limited to .95 lagging power factor due to over excitation and switching resonance.

1.5 Problems that are introduced by capacitor bank as power factor corrector:

Capacitors absorb a lot of harmonics and transients present in the system and develop in the system as they offer low impedance to harmonics and impulses. The energy of these harmonics and impulses heats up the capacitor and they may fail prematurely. Average expected life of a capacitor bank in a system having lots of harmonics and voltage transients is around five years. Another problem with capacitors is that they generate harmonics, specially at the time of switching on a bank. These harmonics further aggravate situation and may even cause system instability, if system inductance and capacitance form a resonant circuit. The generation of harmonics is worst if one bank is already On and another bank is switched on randomly. Incoming bank has two sources, supply and existing bank. The situation is somewhat redeemed by synchronous switching, which is a technique to switch capacitors such that voltage is at zero crossing at the time of contact. All of the above problems are solved with the help of synchronous condenser and a few more advantages are present with synchronous condenser.

1.6 Synchronous condenser & its advantage over capacitor bank

Synchronous condenser is a synchronous motor running in over excited conditions. Synchronous motor is a three phase motor which has a 3 phase armature winding and a DC field winding. It also has a starting winding called amortisseur winding. This winding helps motor start from rest as an induction motor and when speed reaches near synchronous speed, excitation is switched on and it pulls rotor in synchronism with armature rotating field. Advantages are given below:

- Reliability is very high.
- Step-less adjustment of power factor.
- No generation of harmonics.
- Is not affected by harmonics.
- Expected life almost 25 years.
- Low maintenance; only periodic bearing greasing is necessary.

II. Methodology

Calculating the power factor of the circuit from the phase angle and a correction action is initialized to compensate this phase difference by synchronous condenser using the proposed control scheme. Figure 1 provides the simplified circuit description of the overall system. The overall system can be divided into different parts. These are:-

- DC power supply unit.
- Power factor measurement unit.
- Automatic control unit.
- Power factor correction unit.

The principle of operation:-

- Current Transformer (CT) and Potential Transformer (PT) step down the voltage and current level.
- The output of CT and PT are given as input for ZCD.
- ZCD converts sinusoidal voltage and current wave from CT and PT into square wave.
- Two square waves corresponding to voltage and current are given to the input of XOR gate.
- If there is a phase difference between two inputs of XOR gate, the output of the XOR gate remains

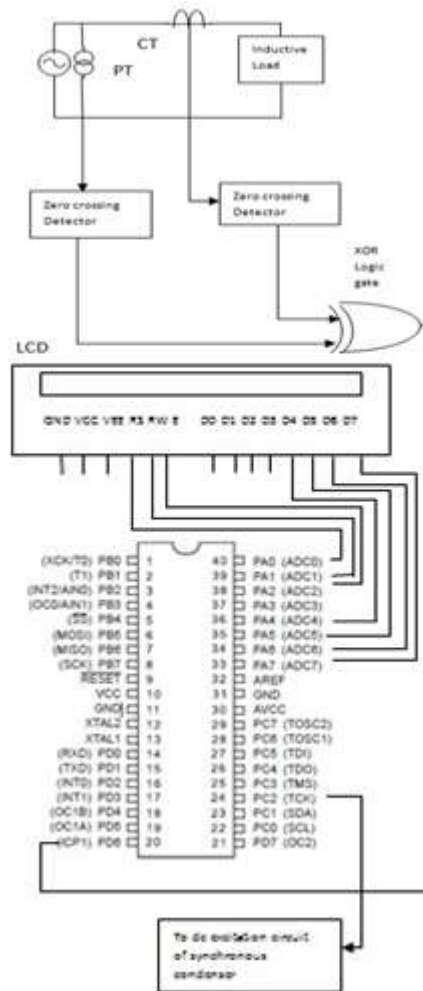


Figure 1: System Model

high for a period equal to that phase difference.

- The output of XOR is given as the input of microcontroller. Microcontroller calculates the phase difference between them as well as power factor.
- According to the difference between measured power factor and desired power factor, microcontroller generates control signal and controls the excitation current of synchronous condenser.
- LCD module is connected to the PORT A of AVR microcontroller.
- The system power factor can be monitored by LCD.
- This process continues until the measured power factor equals the desired power factor.

III. Control Scheme

Microcontroller ATmega32 has been used here. The pin diagram, features, internal architectures of microcontroller are available from standard datasheet of ATmega32. The control system is done by the following steps:

3.1 Algorithm

An Algorithm is developed to make ATmega32 read the input and respond accordingly. An algorithm of the control scheme is shown in as shown in Figure 5

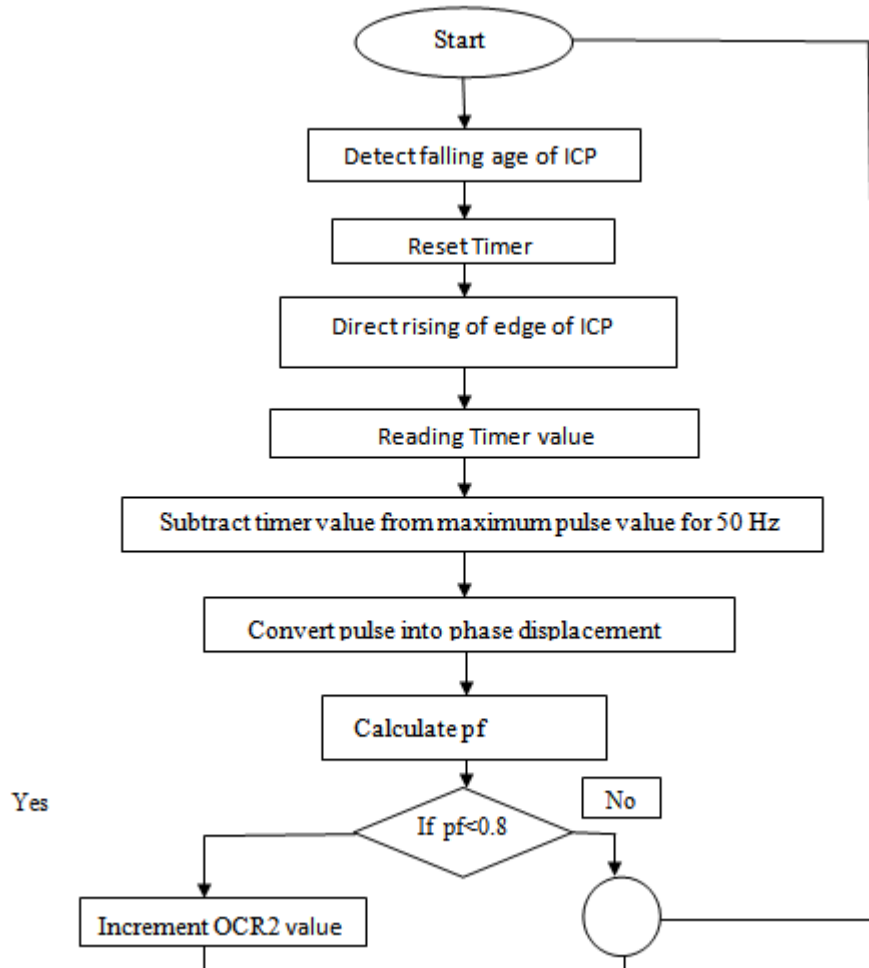


Figure 2: Program Algorithm

3.2 Comparison of power factor and generation of control signal:

Power factor of the system is calculated continuously by using an infinite loop and it is compared to desired power factor. After comparison necessary control signal is generated at the output port of microcontroller. The timer value increases to a certain limit. It looks like a ramp signal. There is a preset value of OCR1. It continuously compares timer value and OCR1 value and gives corresponding pulse width modulation. If power factor is less than the desired value then OCR1 value is changed and pulse width is also changed according to the difference between actual power factor and desired power factor.

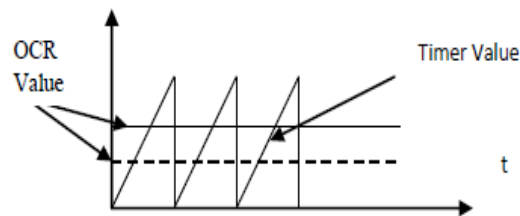


Figure 3-Comparison of timer value and preset OCR value

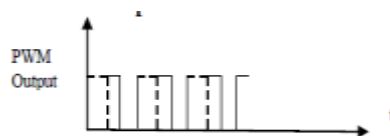


Figure 4- PWM output

3.3 Power Factor Calculation

The 16-bit Timer/Counter unit allows accurate program execution timing, wave generation and signal timing measurement. The timer/counter incorporates an Input Capture unit that can capture external events and give them a time-stamp indicating time of occurrence. The external signal indicating an event, or multiple events, can be applied via the ICP pin of microcontroller

Let, CLK CPU = 4MHz

Pre-scale=8 CLK

timer = (4 MHz)/8 = 500 kHz T timer = 1/(500 kHz) = 2 μ s

So, 2 μ s is needed to count pulse 1.

10ms is needed to count pulse = (10ms * 1)/2 μ s = 5000

So, maximum pulse value=5000.

The input to the ICP pin is shown in Figure 2. Microcontroller detects its falling or rising edge as declared in the program. The timer value from one falling edge to next rising edge is taken first. Now this value is subtracted from the maximum pulse value [5]. This is the timer value of displacement between voltage and current.

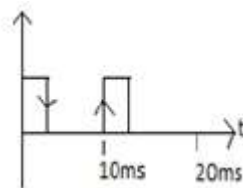


Figure 5: Output from XOR logic gate

Now, from the main signal we get,

10ms is equal to displacement = 3.1516 radian

1 μ s is equal to displacement = (3.1516/10000) radian

= 0.00031516 radian Now, pulse width, $t = 2\mu\text{s} * (5000 - \text{clock number})$

Angle, $\alpha = 0.00031516 * 2\mu\text{s} * (5000 - \text{clock number})$ radian

= 0.000628 * (5000 - clock number) radian

Power factor = $\cos(\alpha)$.

Here clock number is variable depending on the signal. Power factor can be easily calculated by this method.

3.4 Generation of control signal:

Power factor of the system is calculated continuously by using an infinite loop and it is compared to desired power factor. After comparison necessary control signal is generated at the output port of microcontroller. The timer value increases to a certain limit. It looks like a ramp signal. There is a preset value of OCR (Output Compare Register). It continuously compares timer value and OCR value and gives corresponding pulse width modulation. If power factor is less than the desired value then OCR value is changed and pulse width is also changed according to the difference between actual power factor and desired power factor.

IV. Simulation & Result

The experimental results can be divided into 5 sections. They are-

- Test the voltage and current level
- Detecting Zero crossing
- Finding time gap between voltage and current
- Power factor calculation and monitoring
- Generation of control signal for power factor correction. The output signal of Exclusive-OR gate is now suitable to pass through the ICP pin of the microcontroller and the microcontroller calculates the power factor. LCD is interfaced with microcontroller and LCD displays the power factor.

The complete simulation circuit of this thesis work is shown in figure and the power factor is measured continuously and required PWM signal is generated. The PWM signal generated from microcontroller shown in figure 7.



Figure 6: LCD interfacing with micro-controller.

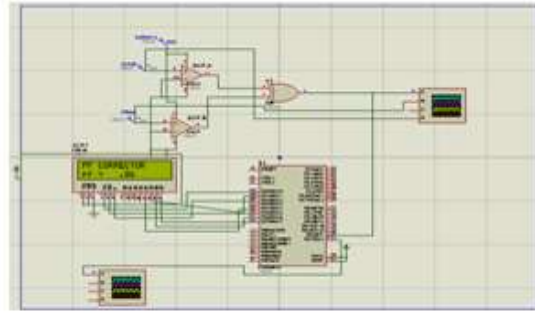


Figure 7: Simulation of PWM generation

V. Conclusion

A well-organized technique for power factor calculation and correction is shown in this paper. Because of high cost of synchronous condenser the correction technique has been given theoretically but the PF calculation has been done practically. It is necessary to use synchronous condenser in high voltage system instead of capacitor bank because of long life of condenser. The power factor of the line is continuously monitored through the microcontroller. Here, required controlled signal is produced automatically for correction and it is a time saving technique. The technique is also very economical in comparison with capacitor bank. In order to improve power factor a variable speed synchronous condenser can be used in any high voltage transmission line and the speed of synchronous condenser can be controlled by microcontroller through the thyristor.

VI. Future Work

In order to control the excitation of the synchronous condenser with the power system is not a very easy task. By developing various easy ways for changing the speed of the condenser in order to change the excitation of the condenser. On the other hand, many other control devices such as PLC can be used for PF calculation and correction. The practical implementation of the correction scheme has not been possible here. Proper calculation is necessary for implementation, because the excitation control is very sensitive.

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