Hardware Implementation of Automatic Power Factor Correction Unit For Industry

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Abstract. Power factor correction has always been challenging task. Most of electrical energy is wasted due to leading and lagging power factor. Thyristor switch modules are widely used in the rolling mills where more fluctuating load is available. The thyristor switch module with the reactor and capacitor is used for the compensating the reactive power in electrical power system. Automatic power factor correction unit is required to keep unity power factor and optimize current consumption. Harmonics is reduced by connecting detuned reactor/inductor in series with capacitor and thyristor switched module. This paper shows design and hardware implementation of thyristorised automatic power factor correction unit for three phase circuit in an industry. The unit is flexible to maintain nearly unity power factor. The outcome is confirmed and acquired that the recommended circuit is perfect to produce improved output.

Keywords. Power factor correction, hardware, implementation, thyristor

1. Introduction
Power factor is the commitment between working (active) power and full energy consumed (apparent power). Automated power factor correction unit is extremely beneficial to increase the transmission of energy effortlessly. Energy must need to be maintained inside a limit. As inductive load is related, power factor lags and whenever power factor goes below then a punishment is charged to the organization [1]. Hence, one should keep power factor within limit. Power triangle is shown in figure 1. Thyristorised units are quite well-known and proves to become advantageous with much better power factor. Thyristorised automatic power factor correction unit is designed to improve power factor immediately once the power factor falls below a constraint that is particular is obviously predefined. Connection and disconnection of the capacitor to and from the system occurs at zero crossing. This connection that is smooth transient effects like waveform distortions, generation of switching spikes etc., usually produced by electromechanically switched system this is really contactor-based [2]. The response period of this is certainly a lot higher than electromechanically turned systems. Therefore, this produces to immediately establish solution to improve power factor with quick reaction starts from 20ms, it provides a response into the issue.

The automatic power factor improvement panel is a compact electrical panel consisting of circuit breakers, relays, capacitor banks, microcontrollers, thyristors which automatically control or improve the power factor when the power factor becomes low due to large inductive load in an electrical system[3]. Generally, all companies having inductive loads have an power factor improvement unit in their main LT Panel Control room. The power factor improvement unit always connected in parallel to the main incoming of the whole electrical circuit[4].
There are mainly two types of power factor improvement unit are commonly used, contactor switched power factor improvement unit, thyristor based power factor improvement unit. Contactor switched power factor improvement unit are built with special capacitor switching contactors which are connected with capacitor banks and act as a valve for capacitor bank. [5,6,8] When the power factor goes low contactor will be turned on and connect the capacitor bank to the load circuit. Thyristor based power factor improvement unit are built with thyristor switching modules(TSM). They also act as a valve of the capacitor bank to connect or disconnect with the load circuit.

2. Thyristorized automatic power factor improvement unit
Here, use of thyristor in automatic power factor correction unit is discussed. Mostly SCR or TRIAC is used for these types of design. So, thyristors are used to make a switch or valve between the capacitor bank and the load circuit. Suppose in an power factor improvement unit numbers of capacitor bank is there, so we do not need to connect all of them at a time to the load circuit[10]. When the power factor goes very low then we required to connect more capacitor banks to the load, when the power factor is near to the unity then we required to connect few capacitor banks to the load circuit. [11,12 16]

So, there are microcontrollers, CT, relay circuits to sense the reactive current, and they continuos monitor the power factor of the whole electrical system as shown in figure 2. According to the power factor value or relative power demand, the microcontroller send the signals to the gate terminal of the thyristors to trigger them. Once the thyristor got triggered they will connect the capacitor bank with the load circuit to compensate the reactive power or to maintain the power factor.
The thyristor gate triggering pulses are generated using zero cross over cathodic firing techniques. Zero cross over technique means they use the alternating current at zero points (which comes between a positive and a negative half cycle) where voltage is completely zero. When the voltage across thyristor is zero, that time only they will be fired by gate pulses. This technique is used to prevent the generation of transients, voltage spikes, and harmonics during switching action[13-14]. Some improvements in the power at industry and domestic loads is proposed in [15-17]. Attributes of thyristor switching module feature Inrush current protected, amount of changing without delay, No noise emission during altering functions, Automatic thermal cut off, lightweight module, possible for contacts, user-friendly operation, no transients because of zero flipping technology, zero differential voltage switching with precise automatic zero recognition thinking (zero voltage switching ‘ON’ and zero active flipping ‘OFF’), long procedure life, over temperature protection above 70 degree Celsius, dv/dt protection using RC Snubber circuit[9].

3. Design methodology
The power factor improvement unit is certainly product that is consists of modules. They collectively communicate to obtain a charged power factor modification. These modules have as follows: power, power factor improvement relay, voltage & current sensing, TSM module, detuned reactor, capacitor bank as shown in figure 3.

![Design of thyristorised automatic power factor correction unit](image)

Controlling for PFC are usually of significant significance when you consider the power factor improvement system. They gauge the energy this is really actual and link or disconnect capacitor stages to obtain a specific price this is certainly desired costs[7,15]. The mains voltage is stepped down to sense for relay. The relay should have the product range voltage and current from the existing transformer (CT) installed close to your metering part of purchase determine energy that is electric. CT and PT from HT and LT side are shown in figures 4 and 5.

The harmonic filter (Detuned) is to limit the flow of harmonic current from non-linear loads on the reactor to the fixed impedance loads (eg capacitor). It prevents harmonic current and voltage amplitude from increasing in systems with non-linear loads & limits the harmonic current flowing on the capacitor. This prevents heat and high current stresses and allows the capacitors to have a longer
operating life. Also, prevents to overcurrent and heating problems on transformers, bus bars, cables, switchgear, protection equipment, etc.

As discussed earlier, TSM are used to make a switch or valve between the capacitor bank and the load circuit especially for fast switching operations. Capacitor bank can refer to a large number of capacitors with varying values. Show and a parallel combination of capacitors provide a range of capacitance required to compensate for a low energy factor. Because of the load neighbourhood, the size of the capacitors is determined by the needed KVAR demand.

![CT and PT from HT side](image1)

**Figure 4.** CT and PT from HT side

![CT and PT from LT side](image2)

**Figure 5.** CT and PT from LT side

4. **Hardware implementation**

Figure 6 shows the design of hardware of thyristorised automatic power factor correction unit. In the panel shows the assembly arrangement of the thyristor, relay, capacitor, reactor etc. The AC can provide 230v AC mains electricity at a frequency of 50Hz. However, in order to operate the portions, DC power is required. To reduce the 230V supply to 12V, a voltage transformer is used (or 24V). This AC signal will be converted to DC with the help of a bridge rectifier and filtering capacitors. The ultimate DC voltage that is steady is almost always attained with the use of ICs or SMPS module can be utilized.
5. Result

Figure 7 shows the result of the hardware implementation. In above, the power factor shows the 0.99 almost Unity. For power factor enhancement, a Thyristorised module is used to automate the switching of a capacitor bank. Power factor improvement is beneficial in any installation since a low power factor, when rectified, results in cost savings through decreased demand charges and lower low power factor penalties. Beside from penalties such as maximum demand charges and penalties for poor power factor, there are other penalties to consider. Additional machinery can be linked to the supply without extending these services since the factory cabling and supply equipment can be relieved of a significant wattless or reactive load. In addition, the system's voltage drop is minimised. Comparison between contactor switched, fixed compensation, and thyristor switched system is shown in table 1.
Table 1. Comparison between contactor switched, fixed compensation, and thyristor switched system

| Parameters                  | Contactor based          | Fixed Compensation | Thyristor switched |
|-----------------------------|--------------------------|--------------------|--------------------|
| Switching time              | 30-120 s                 | Continuously connected | 20ms-1s          |
| Maintenance                 | Moderate                 | Frequent           | Less               |
| Capacitor life              | Reduced                  | Low                | Enhanced           |
| Switching device            | Contactors              | Miniature Circuit Breaker | Thyristor switched module |
| Response to power factor correction | Slow               | Leading during no load or less load | Fast              |
| Cost                        | Moderate                 | Minimum           | High               |

6. Conclusion

The low power factor is mostly due to the fact that the majority of power loads are inductive and as a result needs lagging currents. Some device that consumes leading power should be connected in parallel with the load to improve the power factor. A capacitor is an example of such a gadget. The capacitor pulls a leading current that partially or fully neutralises the load current's trailing reactive component. This improves the load's power factor. In this paper, automatic power improvement unit is designed and implemented which keeps unity power factor and optimises current consumption. Harmonics is reduced by connecting detuned reactor/inductor in series with capacitor and TSM. Implemented system is found to improve the response as shown in the results. Such automatic power factor correction units are extremely helpful in manufacturing industries where induction motors are mostly used.

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