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Automatic 3 Phase Advanced Active Power Factor Correction Using Microcontroller

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Abstract: *The aim of this project is to design, develop and test of a commercially viable power factor correction system with state of the art technology. In this project we are implementing microcontroller based system which will detect the phase difference between the voltage and current according to that required value of capacitance will be added or removed from the system as required automatically. And the system will continuously monitor the power factor and maintain it near unity as required. The advantage of doing this is to avoid the heavy penalty from the utility provider. Overheating of the cable can be reduced resulting overall enhanced system performance and stability.*
Keywords: *Power Factor, Power Factor Correction, Microcontroller, Capacitor Banks, 3 Phase Load, Current Transformer, Potential Transformer.*

I. Introduction

Power Factor is a way of describing how efficiently electrical power is consumed. It is the ratio of Real Power (kW) to Apparent Power (kVA). In an efficient, purely resistive circuit, all of the current delivered to the load is converted to real work (kW). **Therefore kW = kVA, and the Power Factor = 1 (Unity)**

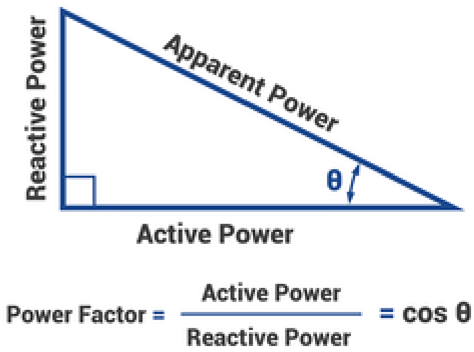

Figure 1: Power Triangle

Figure 1 show the power triangle of power factor where power factor is the ratio of active power to the apparent power which is nothing but COSϴ.

Many loads in industry today are inefficient inductive types, particularly motors and transformers. This inductance causes the current to lag behind the voltage. Subsequently, reactive currents drawn (kVAr) are used to create the magnetic field needed to operate these machines. Therefore, power is lost or 'wasted' in the magnetic field and KW's are less than kVA's, and Power Factor is less than 1.

The greater the ratio of inductive loads to resistive loads, the lower the power factor and the higher the reactive charges will be seen itemised on bills. As well as increasing transformer losses (I2R) there is the danger of blowing main fuses is the supply capacity is exceeded.

Power factor correction is the calculated introduction of capacitors to an inefficient system. The capacitors, whether static or automated, reduce current and improve the power factor of a system, bringing it as close to unity as possible. Power factor correction technology increases electrical capacity by reducing the maximum kVA drawn on an electrical system.

II. Existing Methods to Improve Power Factor

A. Static Capacitor

We know that most of the industries and power system loads are inductive that take lagging current which decrease the system power factor. For Power factor improvement purpose, Static capacitors are connected in parallel with those devices which work on low power factor.

These static capacitors provide leading current which neutralize (totally or approximately) the lagging inductive component of load current (i.e. leading component neutralize or eliminate the lagging component of load current) thus power factor of the load circuit is improved.

These capacitors are installed in Vicinity of large inductive load e.g Induction motors and transformers etc, and improve the load circuit power factor to improve the system or devises efficiency.

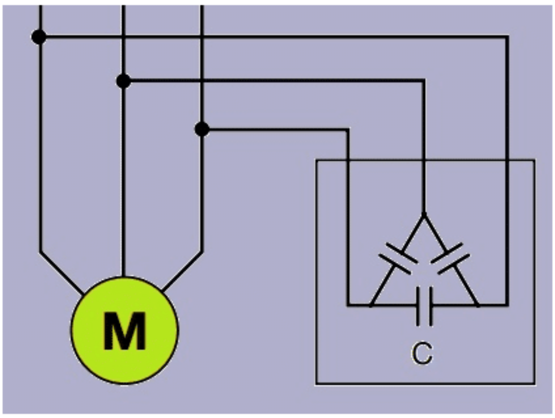

Figure 2: Static Capacitor

B. Synchronous Condenser

When a Synchronous motor operates at No-Load and over-exited then it's called a synchronous Condenser. Whenever a Synchronous motor is over-exited then it provides leading current and works like a capacitor.

When a synchronous condenser is connected across supply voltage (in parallel) then it draws leading current and partially eliminates the re-active component and this way, power factor is improved. Generally, synchronous condenser is used to improve the power factor in large industries.

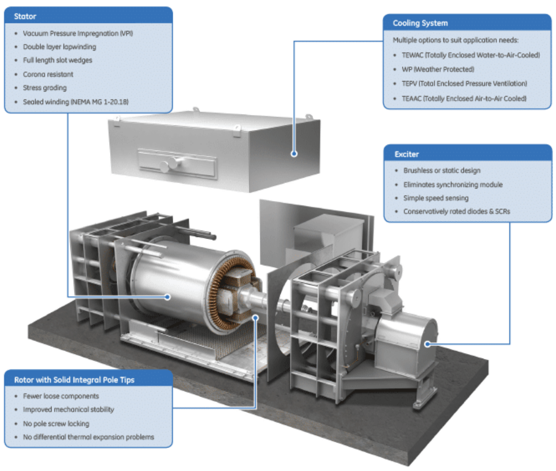

Figure 3: Synchronous Condenser

C. Phase Advancer

Phase Advancer is a simple AC exciter which is connected to the main shaft of the motor and operates with the motor's rotor circuit for power factor improvement. Phase advancer is used to improve the power factor of induction motor in industries.

Our proposed system is based on static capacitor based power factor correction as it is convenient way and very much popular, easy switching of the capacitor bank automatically.

III. Proposed Scheme

In our scheme we are proposing a system to design a APFC unit which improves the power factor of three phase load automatically. The proposed system is used for the industrial purpose where the inductive loads are used with 3 phase power supply. For this we are taking voltage and current waveforms of each phase by using potential transformer and current transformer. The signals are then passed through the ZCD (Zero Cross Detector) circuit. We get the phase difference between current and voltage waveforms which later pass through the microcontroller to nullify the time difference. To do this we use capacitor banks switched by switching circuit. The power factor then displayed and continuously monitored on the LCD. One main feature is added in the scheme is we can log the data in cloud for future reference.

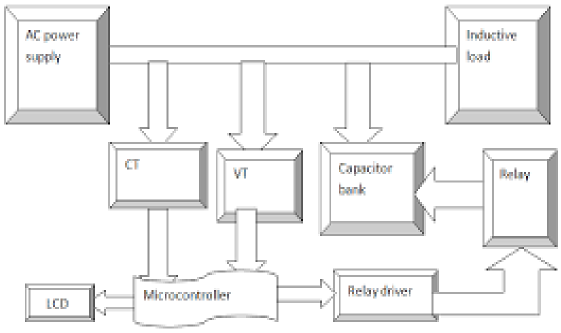

Figure4: Block Diagram

The block diagram shown in above figure 4 is considering a single phase. We have to add same blocks of AC power supply and CT & PT for another two phases.

IV. Design Methodology

Our proposed scheme consists of –

- Power supply unit
- Voltage and current sensor circuit
- Switching circuit
- Microcontroller
- Display
- Inductive load
- Capacitor bank

A. Power Supply unit

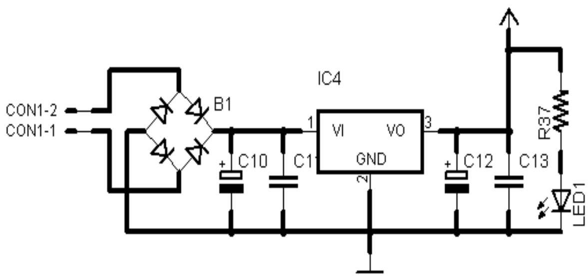

Figure 5: 5V Power Supply

The circuit operates in 5V power supply as microcontroller is being used. Hence we step down the 230V AC supply to 8V AC supply which is fed to the transformer of 8V. It is then rectified and filtered and regulated by 7805 voltage regulator IC which gives us 5V supply indicated with the help of LED1 as shown in figure 5.

B. Voltage and Current Sensor Circuit

Figure 6 shows the voltage and current sensor circuit. It is a zero cross detector circuit which compares the input voltage to the zero reference. We get square waveform at the output of the comparator in synchronize with the input waveform. We use current transformer to sense the current and is converted to the voltage by using resistor in parallel with the CT. The output of current and voltage waveform are the fed to the EX-OR gate to get the phase difference between current and voltage, which is then fed to the microcontroller.

Note that this ZCD shown in figure 6 is considering single phase. Same circuit adopted for another two phases.

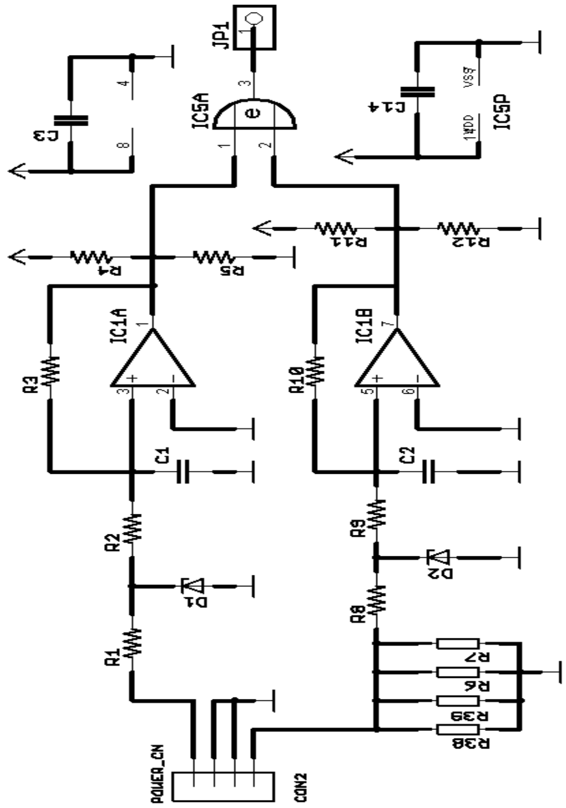

Figure 6: Voltage and Current Sensor Circuit

C. Switching Circuit

In switching circuit we are using the solid state relays. Solid State Relays are semiconductor equivalents of the electromechanical relay and can be used to control electrical loads without the use of moving parts.

Unlike electro-mechanical relays (EMR) which use coils, magnetic fields, springs and mechanical contacts to operate and switch a supply, the solid state relay, or SSR, has no moving parts but instead uses the electrical and optical properties of solid state semiconductors to perform its input to output isolation and switching functions.

Thus the main advantages of solid state relays have over conventional electro-mechanical relays is that they have no moving parts to wear out, and therefore no contact bounce issues, are able to switch both “ON” and “OFF” much faster than a mechanical relays armature can move, as well as zero current turn-off eliminating electrical noise and transient.

Figure 7: A Solid State Relay (SSR)

D. Microcontroller

The Atmel®AVR® ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed.

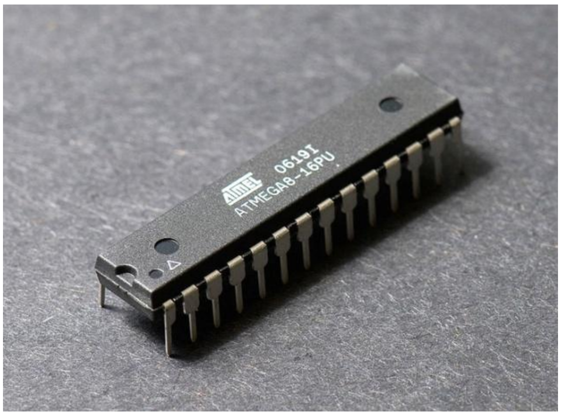

Figure 8: ATMEGA8 Microcontroller

We are using atmega8 microcontroller in our project because it is very popular and cheapest microcontroller and provides many features in lesser pins. With program memory of 8Kbytes, ATMEGA8 application is very versatile. There are different compilers are present like AVR STUDIO, Code Vision Avr etc. We are using Code Vision Avr compiler for programming as it automatically generates the system generated program with simply few settings. Inbuilt libraries are available in Code Vision Avr hence ease of programming.

In this project we are sensing the phase shift between the voltage and current signal and based on the observation, the necessary action is taken place like switching the particular capacitor bank.

E. Display

We are using 16X2 LCD display to display the power factor. We can also display the 3 phase voltage and current depending on the requirement.

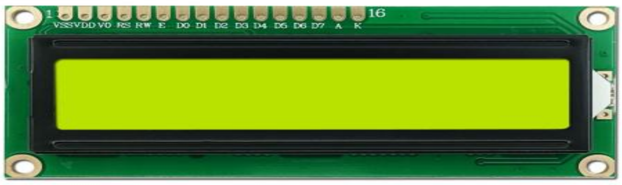

Figure 9: 16X2 LCD

F. Inductive Load

As this project is basically for industrial purpose, the inductive loads are used. In our scheme we are using the coil as the inductive load. The inductive coil is used in many industries for induction heating, brazing, annealing, melting furnace etc. operations. Hence there is a current lag behind the voltage causing the poor power factor. Hence maximum power cannot be utilized.

The figure 10 shows the current and voltage waveform for different loads and inductive circuit phasor diagram.

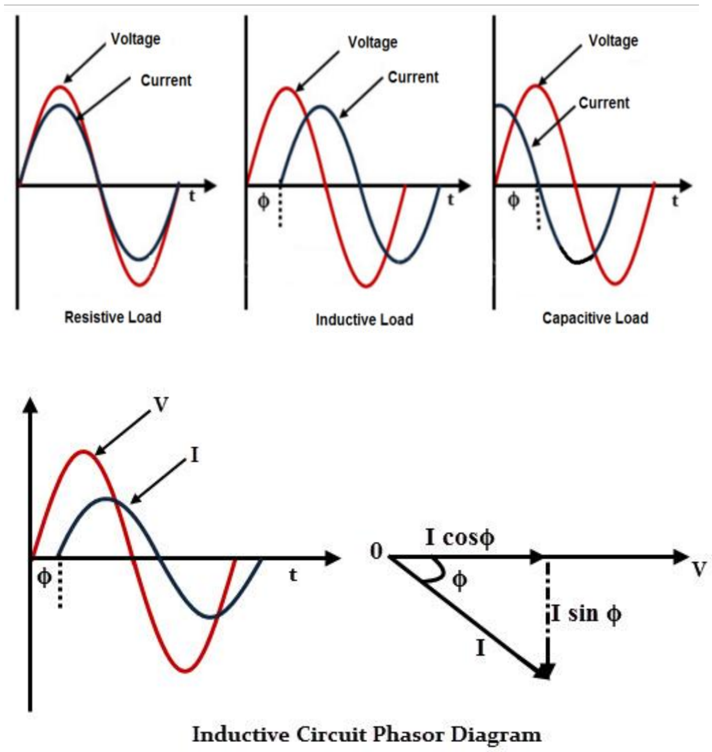

Figure 10: Different loads and Inductive Circuit Phasor Diagram

G. Capacitor Bank

Improving power factor means reducing the phase difference between voltage and current. Since the majority of loads are of inductive nature, they require some amount of reactive power for them to function.
A capacitor or bank of capacitors installed parallel to the load provides this reactive power, and thus less reactive power flows through the line. The capacitor banks reduce the difference between voltage and current.

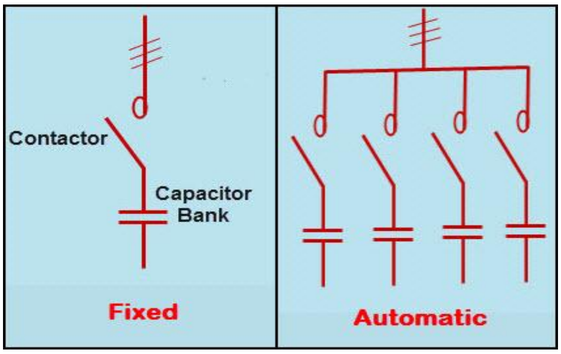

Figure 11: Capacitor Bank

V. Power Factor Calculation

In **power factor calculation**, we measure the source voltage and current drawn using a voltmeter and ammeter respectively. A wattmeter is used to get the active power.
Now, we know P = VIcosφ watt

$$From\ this\ \cos\phi = \frac{P}{VI}\ or\ \frac{Wattmeter\ reading}{Voltmeter\ reading \times\ Ammeter\ reading}$$

Hence, we can get the electrical power factor.
Now we can calculate the reactive power Q = VIsinφ VAR
This reactive power can now be supplied from the capacitor installed in parallel with the load in local. The reactive power of a capacitor can be calculated using the following formula:

$$Q = \frac{V^2}{X_C} \Rightarrow C = \frac{Q}{2\pi f V^2}\ farad$$

In **power factor improvement**, the reactive power requirement by the load does not change. It is just supplied by other devices, thus reducing the burden on the source to provide the required reactive power.

VI. APFC Flowchart

Figure 12 shows the flow diagram for the APFC system.

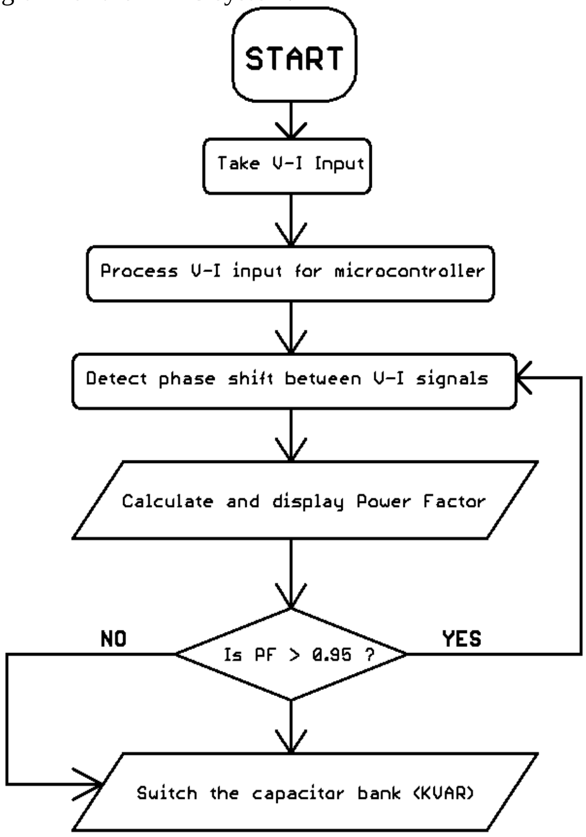

Figure 12: Flowchart of APFC

VII. Result & Conclusion

This technique is used to overcome power losses due to low power factor associated with household and industries. By installing calculated KVAR of capacitor into the circuit, the power factor can be improved, thus reducing the losses. Hence the system becomes stable and efficiency increases. The use of microcontroller reduces the costs. The automated operations ease the operation of the device and make life flexier.

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