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Automatic Power Factor Detector and Corrector using Arduino Mini Pro

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Abstract: *In recent years, the power quality of the ac system has become great concern due to the rapidly increased numbers of electronic equipment, power electronics and high voltage power system. Most of the commercial and industrial installation in the country has large electrical loads which are severally inductive in nature causing lagging power factor which gives heavy penalties to consumer by electricity board. This situation is taken care by PFC. Power factor correction is the capacity of absorbing the reactive power produced by a load. In case of fixed loads, this can be done manually by switching of capacitors, however in case of rapidly varying and scattered loads it becomes difficult to maintain a high power factor by manually switching on/off the capacitors in proportion to variation of load within an installation. This drawback is overcome by using an APFC panel.*

Keywords: Automatic power factor correction, embedded technology, Efficiency of the system increases, Improve the power system performance.

I. Introduction

In the present technological revolution, power is very precious and the power system is becoming more and more complex with each passing day. As such it becomes necessary to transmit each unit of power generated over increasing distances with minimum loss of power. However, with increasing number of inductive loads, large variation in load etc. the losses have also increased manifold. Hence, it has become prudent to find out the causes of power loss and improve the power system. Due to increasing use of inductive loads ,the load power factor decreases considerably which increases the losses in the system and hence power system losses its efficiency.

An Automatic power factor correction device reads power factor from line voltage and line current by determining the delay in the arrival of the current signal with respect to voltage signal from the source with high accuracy by using an internal timer. It determines the phase angle lag (ø) between the voltage and current signals and then determines the corresponding power factor (cos ø). Then the microcontroller calculates the compensation requirement and accordingly switches on the required number of capacitors from the capacitor bank until the power factor is normalized to about unity.

Automatic power factor correction techniques can be applied to industrial units, power systems and also households to make them stable. As a result the system becomes stable and efficiency of the system as well as of the apparatus increases. Therefore, the use of microcontroller based power factor corrector results in reduced overall costs for both the consumers and the suppliers of electrical energy.

Power factor correction using capacitor banks reduces reactive power consumption which will lead to minimization of losses and at the same time increases the electrical system‘s efficiency. Power saving issues and reactive power management has led to the development of single phase capacitor banks for domestic and industrial applications. The development to this project is to enhance and upgrade the operation of single phase capacitor banks by developing a micro-processor based control system.

The control unit will be able to control capacitor bank operating steps based on the varying load current. Current transformer is used to measure the load current for sampling purposes. Intelligent control using this micro-processor control unit ensures even utilization of capacitor steps ,minimizes number of switching operations and optimizes power factor correction. The Choke used in the Compact Fluorescent Lamp (CFL) will be used as an Inductive load.

II. Objectives

The main purpose of automatic power factor compensation is to help correcting the excess reactive power generate by inductive loads in the industry. With an efficient use of this device, the industry can improves efficiency of the system by reducing losses and reduced apparent power demand charges.

III. Literature Survey

3.1 Power Factor

Power factor is an energy concept that is related to power flow in electrical systems. To understand power factor, it is helpful to understand three different types of power in electrical systems.

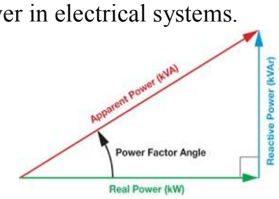

Figure A: Power Triangle

Real Power is the power that is actually converted into useful work for creating heat, light and motion. Real power is measured in kilowatts(kW)and is totalized by the electric billing meter in kilowatt-hours (kWh). An example of real power is the useful work that directly turns the shaft of a motor Reactive Power is the power used to sustain the electromagnetic field in inductive and capacitive equipment.

It is the non- working power component. Reactive power is measured in kilovolt-amperes reactive (kVAR). Reactive power does not appear on the customer billing statement. Total Power or Apparent power is the combination of real power and reactive power. Total power is measured in kilovolt-amperes (kVA) and is totalized by the electric billing meter in kilovolt-ampere-hours (kVAh). Power factor (PF) is defined as the ratio of real power to total power, and is expressed as a percentage (%).

Power factor cos φ is defined as the ratio between the Active component IR and the total value of the current I; φ is the phase angle between the voltage and the current.

3.2 Power Factor Correction

Power factor correction is the process of compensating for the lagging current by creating a leading current by connecting capacitors to the supply. A sufficient capacitance can be connected so that the power factor is adjusted to be as close to unity as possible.

Power factor correction (PFC) is a system of counteracting the undesirable effects of electric loads that create a power factor that is less than one (1). Power factor correction may be applied either by an electrical power transmission utility to improve the stability and efficiency of the transmission network or, correction may be installed by individual electrical customers to reduce the costs charged to them by their electricity service provider.

An electrical load that operates on alternating current requires apparent power, which consists of real power and reactive power. Real power is the power actually consumed by the load. Reactive power is repeatedly demanded by the load and returned to the power source, and it is the cyclical effect that occurs when alternating current passes through a load that contains a reactive component. The presence of reactive power causes the real power to be less than the apparent power, so the electric load has a power factor of less than one.

The reactive power increases the current flowing between the power source and the load, which increases the power losses through transmission and distribution lines. This results in operational and financial losses for power companies. Therefore, power companies require their customers, especially those with large loads, to maintain their power factors above a specified amount especially a roundly 0.90 or higher ,or be subject to additional charges. Electrical engineers involved with the generation, transmission, distribution and consumption of electrical power have an interest in the power factor of loads because power factors affect efficiencies and costs for both the electrical power industry and the consumers.

In addition to the increased operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current capacities.

Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1) through various methods. Simple methods include switching in or out banks of capacitors or inductors which act to cancel the inductive or capacitive effects of the load, respectively. example, the inductive effect of motor loads.

IV. Block Diagram

Microcontroller is the base automatic controlling of power factor with load monitoring is shown in fig.

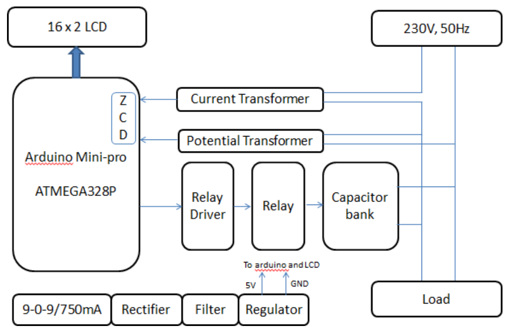

Figure B: Block Diagram of PFC using ATMEGA 328

The principal element in the circuit is PIC microcontroller. The current and voltage single are acquired from the main AC line by using Current Transformer and Potential Transformer. These acquired signals are then pass on the zero crossing detectors. Bridge rectifier for both current and voltage signals transposes the analog signals to the digital signal. Microcontroller read the RMS value for voltage and current used in its algorithm to select the value of in demand capacitor for the load to correct the power factor and monitors the behavior of the enduring load on the basis of current depleted by the load. In case of low power factor Microcontroller send out the signal to switching unit that will switch on the in demand value of capacitor.

The tasks executed by the microcontroller for correcting the low power factor by selecting the in demand value of capacitor and load monitoring are shown in LCD. The power factor of the motor is varied by adjusting the field excitation and be made to behave like a excited. Non-linear loads create harmonic currents in addition to theoriginal AC current capacitor when over. There are two types of PFCs:

1. Passive.
2. Active

4.1 Passive PFC

The simplest way to control the harmonic current is to use a filter :it is possible to design a filter that passes current only at line frequency 50Hz.This filter reduces the harmonic current, which means that the non-linear device now looks like a linear load. At this point the power factor can be brought to near unity, using capacitors or inductors as required. This filter requires large-value high- current inductors, however, which are bulky and expensive.

A passive PFC requires an inductor larger than the inductor in an active PFC,but costs less. This is a simple way of correcting the non linearity of a load is by using capacitor banks.It is not as effective as active PFC.Passive PFCs are typically more power efficient than active PFC. (Wolfle,W.H2003).

4.2 Active PFC

An active power factor corrector"(activePFC) is a power electronic system that controls the amount of power drawn by a load in order to obtain a power factor as close as possible to unity. In most applications, the active PFC controls the input current of the load so that the current waveform is proportional to the mains voltage waveform (a sine wave). The purpose of making the power factor as close to unity as possible is to make the load circuitry that is power factor corrected appear purely resistive (apparent power equal to real power). In this case, the voltage and current are in phase and the reactive power consumption is zero.

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4.3 Ardiuno Pro

The original, true-blue Arduino is open-source hardware, which means anyone is free to download the design files and spin their own version of the popular development board. Spark Fun has jumped on this opportunity and created all sorts of Arduino variants, each with their own unique features, dimensions, and applications. Now one of those variants has landed in your hands; congratulations! It's a wild world out there in microcontroller-land, and you're about to take your first step away from the wonderful – though sometimes stifling – simplicity of the Arudino Pro Mini.

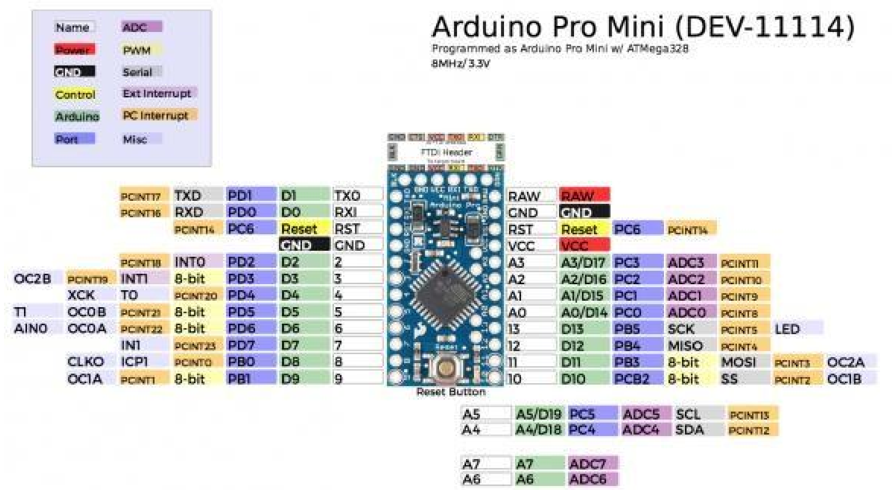

Figure: Aurdino Mini Pro Pin Out

4.4 Voltage Transformer

A voltage transformer or a potential transformer is a wire-wound, static electromagnetic device that is used to transform the voltage level of input voltage. A transformer has two windings: a primary winding to which the input is connected and a secondary winding from which the transformed voltage obtained.

The input voltage is transformed (either stepped up or down)according to the turns ratio of the primary and the secondary windings. The transformer used in the power supply here gives an output of +12Vor-12V or a total of 24V for an input voltage of 230V.

Figure: Voltage Transformer/Potential transformer

4.5 Potential Transformer

A potential transformer, a voltage transformer or a laminated core transformer is the most common type of transformer widely used in electrical power transmission and appliances to convert mains voltage to low voltage in order to power low power electronic devices.

A potential transformer is typically described by its voltage ratio from primary to secondary. A 600:120 potential Transformer would provide an output voltage of 120V when a voltage of 600V is impressed across the primary winding. The potential transformer here has a voltage ratio of 230:24 i.e., when the input voltage is the single phase voltage 230V, the output is 24V.

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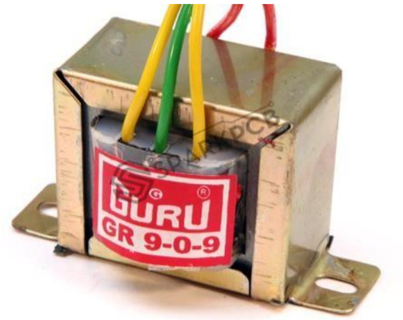

Figure: Potential Transformer

4.6 Current Transformer

The current transformer is an instrument transformer used to step-down the current in the circuit to measurable values and is thus used for measuring alternating currents. When the current in a circuit is too high to apply directly to a measuring instrument, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can in turn be conveniently connected to measuring and recording instruments. A current Transformer isolates the measuring instrument from what may be a very high voltage in the monitored circuit.

Figure: Current transformer

V. Calculations

Suppose Actual P.F is 0.8, Required P.F is 0.98 and Total Load is 0.44kVAR (Motor 1HP).
Power factor = kwh / kvah kW = kVA x Power Factor
= 0.44 x 0.8 = 0.352
Required capacitor = kW x Multiplying Factor
= (0.8 x 516) x Multiplying Factor
= 0.352 x 0.547 (See Table to find Value according to P.F 0.8 to P.F of 0.98)
= 0.193 kVar

VI. Advantages

- Avoid Power Factor Penalties.
- Reduced Demand Charges.
- Increased Load Carrying Capabilities in Existing Circuits.
- Improved Voltage.
- Reduced Power System Losses

VII. Disadvantages

- They have a short service life ranging from 8 to 10 years.
- They are easily damaged if the voltage exceeds the rated value.
- Once the capacitors are damaged, their repair is uneconomical.

VIII. Applications

1. Automobile Industries

2. Pharmaceutical Industries
3. Cement Industries
4. Chemical Plants
5. Printing Industries

IX. Conclusion

Automatic Power Factor Detection and Correction provides an efficient technique to improve the power factor of a power system by an economical way. Static capacitors are invariably used for power factor improvement in factories or distribution line. However, this system makes use of capacitors only when power factor is low otherwise they are cut off from line. Thus, it not only improves the power factor but also increases the life time of static capacitors. The power factor of any distribution line can also be improved easily by low cost small rating capacitor. This system with static capacitor can improve the power factor of any distribution line from load side. As, if this static capacitor will apply in the high voltage transmission line then its rating will be unexpectedly large which will be uneconomical & inefficient. So a variable speed synchronous condenser can be used in any high voltage transmission in to improve power factor & the speed of synchronous condenser can be controlled by microcontroller.

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