INDUSTRIAL POWER PENALTY REDUCTION BY USING APFC UNIT

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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. In this paper measuring of power factor from load is done by using UNO ARDUINO and trigger required capacitors in order to compensate reactive power and bring power factor near to unity.

***IndexTerms* – APFC-Automatic power factor correction, PIC–Programmable intelligent computer PFC-Power factor correction**

I. INTRODUCTION

The power factor of an electrical system gives the idea about the efficiency of the system to do useful work out of the supplied electric power. A low power factor leads to increase in losses and also draws penalty by the utility. Modern mining industry using mechanized methods suffers from low power factor due to the use of different electric equipment which requires more reactive power. Significant savings in utility power costs can be realized by keeping up an average monthly power factor close to unity. Utilizing shunt capacitor banks for Power Factor Correction (PFC) is an exceptionally established methodology. The recent trend is to automate the switching procedure of capacitors to get greatest advantage in real time basis. Embedded systems based on Arduino can be used to monitor and control the switching of correction devices because of its dependability and execution.

II. INTRODUCTION ABOUT 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. 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).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 (%).

$$\textbf{Power factor} = \frac{Real\ power\ (KWH}{Total\ power\ (KVAR)} \times 100$$

In another way defining the power factor is 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. Power triangle is shown in figure 2.1

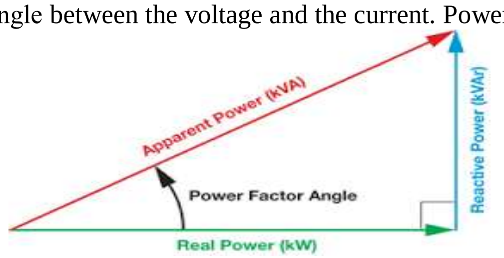

Figure 2.1 Power triangle

III. 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. 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 around ally 0.90 or higher, or be subject to additional charges. Power 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 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 may be offset by locally connected capacitors. It is also possible to effect power factor correction with an unloaded synchronous motor connect across the supply. 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 the original AC current capacitor.

There are two types of PFCs

- Passive.
- Active

Passive PFC are **t**he simplest way to control the harmonic current is to use a filter. Therefore 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 nonlinearity 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.

Active PFC are "active power factor corrector" (APFC) 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 voltage waveform (purely 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. This enables the most efficient delivery of electrical power from the power company to the consumer. Some types of active PFC are Boost, Buck and Buck-boost. Active power factor correctors can be single-stage or multi-stage. Active PFC is the most effective and can produce a PFC of 0.99 (99%).

IV. PROPOSED SYSTEM AND WORKING

The proposed system of a Automatic power factor correction (APFC) is shown in figure 4.1.

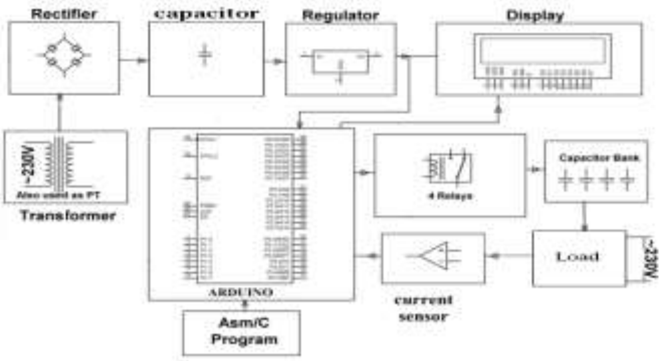

Figure 4.1: Block diagram for Automatic power factor correction (APFC)

The main power supply is directly given to the load and a step-down transformer of rating 230v to 12v to step-down the power and is directed towards the rectifier, it converts A.C to D.C. By using capacitor as a filter here to get the pure D.C and is given to the 12volts to 5 volts regulator to get the constant voltage for working the Arduino and other components like relays. Arduino is the heart of the project is dumped with the required instructions. Arduino gets 5 volts from the power supply to activate and executes the instructions step by step to get required digital output.

Case-1:

In this case load as resistive load. The current sensor senses the current value and sends the signal to the Arduino. If the sensed current is less than the preset value in the Arduino program, relays will not triggered to switch on the capacitors to the load and also displayed the unity power factor in the display board.

Case-2:

In this case load as inductive load. The current sensor senses the current value coming from the load and sends the signal to the Arduino. If the sensed current is greater than the pre-set value in the Arduino program, the relay will triggered to switch on the capacitors one by one to the load up to its required.

The relay circuit receives the signal from the Arduino and increases power factor insteps by connecting the condensers to the load. Thus Automatic power factor correction is done.

V. RESULTS AND DISCUSSION

The general arrangement of industrial power penalty reduction by using APFC unit kit is shown in below figure 5.1.

Figure 5.1: Arrangement of Industrial power penalty reduction by using APFC unit

Monitoring of load without correction when the resistive load and inductive load is connected

When the load is connected to the APFC unit, ultimately the load current is sensed by the sensor and sends the signal to the analog pins of the arduino. This load current is compared with the reference current setting in the Arduino program . If this load current is less than or equal to the reference current, then the arduino will not send any signal to the relays. Thus the capacitors will not connect to the load and also displays a NEARLY UNITY POWER FACTOR on the LCD board. The resistive load is connected to the APFC unit is shown in figure 5.2.

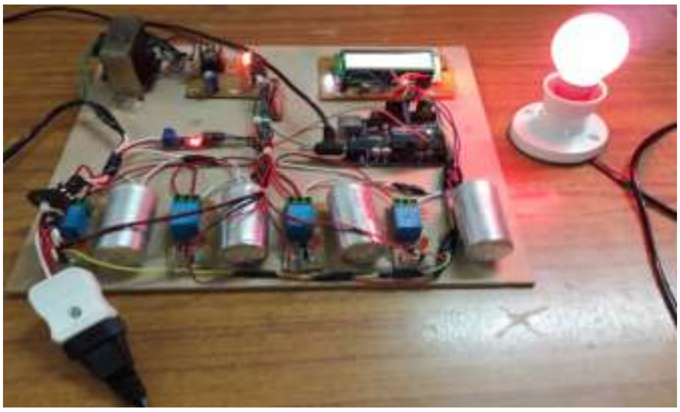

Figure 5.2 Resistive load connected to the APFC unit

When the inductive load is connected to the APFC unit, before correction **Initial load power factor 0.5** is displayed on the LCD board. Inductive load connected to the APFC unit before is shown in below figure 5.3

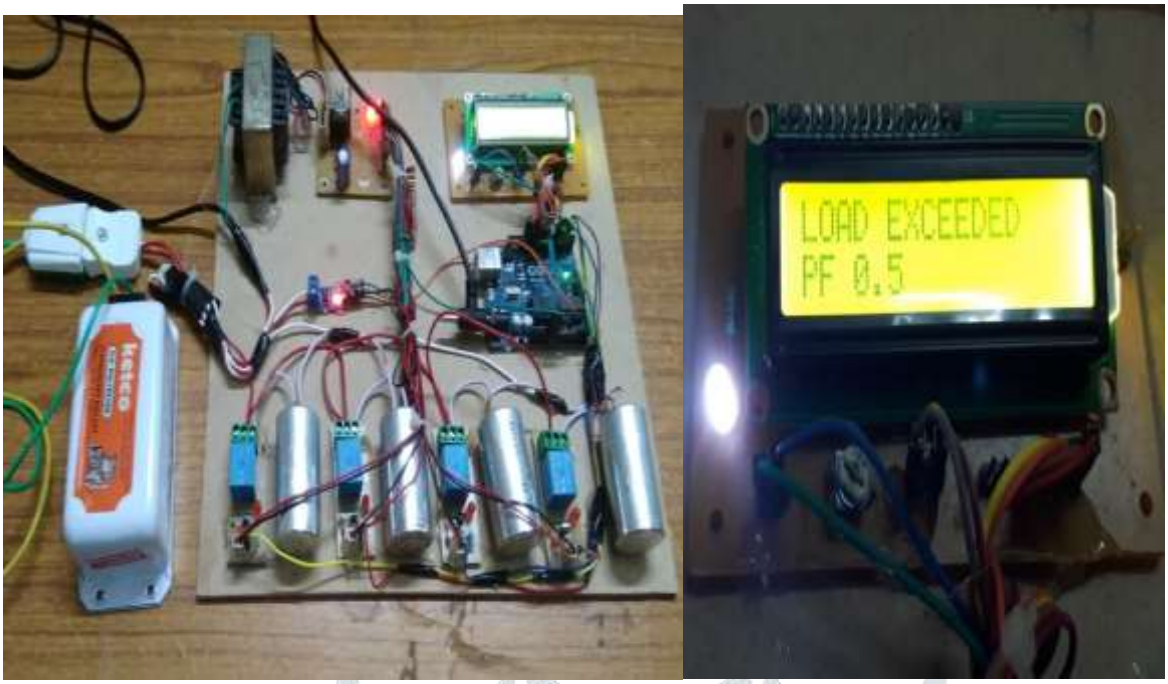

Figure 5.3 Inductive load connected to APFC unit before correction

Monitoring of load with correction

When the inductive load is connected to the APFC unit, then the load current is sensed by current sensor and sends the signal to the analog pins of the Arduino. This load current is compared with the reference current. If the load current is greater than the reference current then the Arduino will trip the relay and then capacitors will connect with the load step by step and finally **improved power factor 0.98** displayed on the LCD board. Thus the reactive power will reduce and the power factor will be increase. The inductive load is connected to the Arduino is shown in the below figure 6.3.

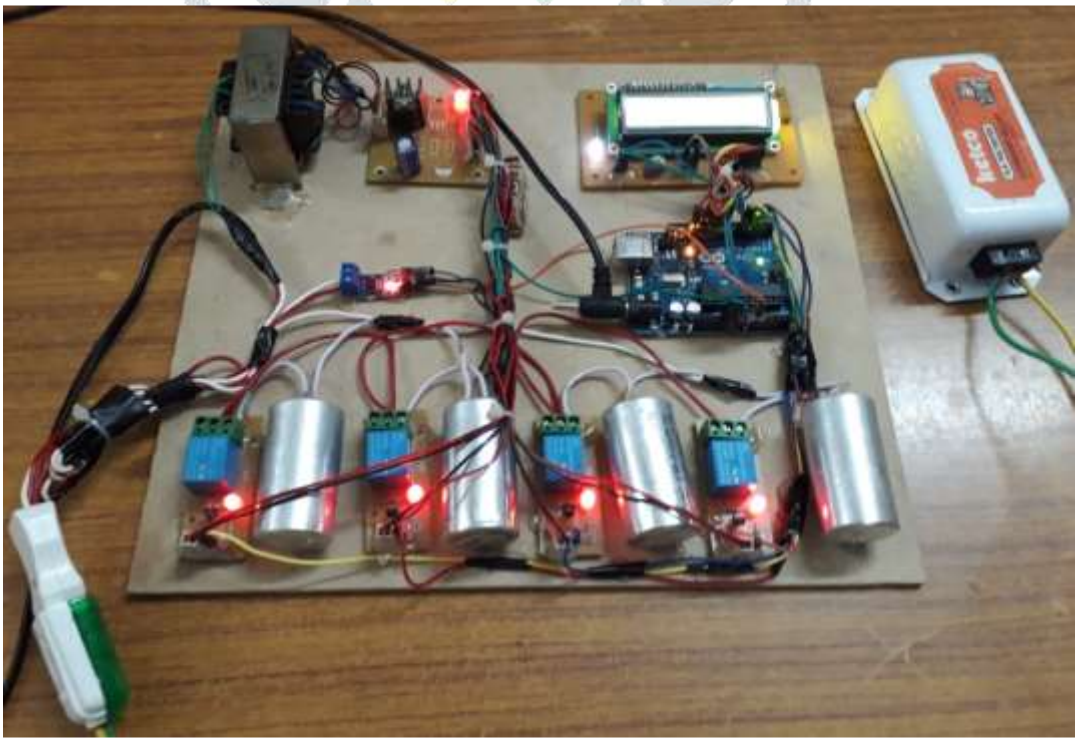

Figure 5.4 Inductive load connected to the APFC unit

Step by step improvement is shown in figures 5.5, 5.6, 5.7 and 5.8.

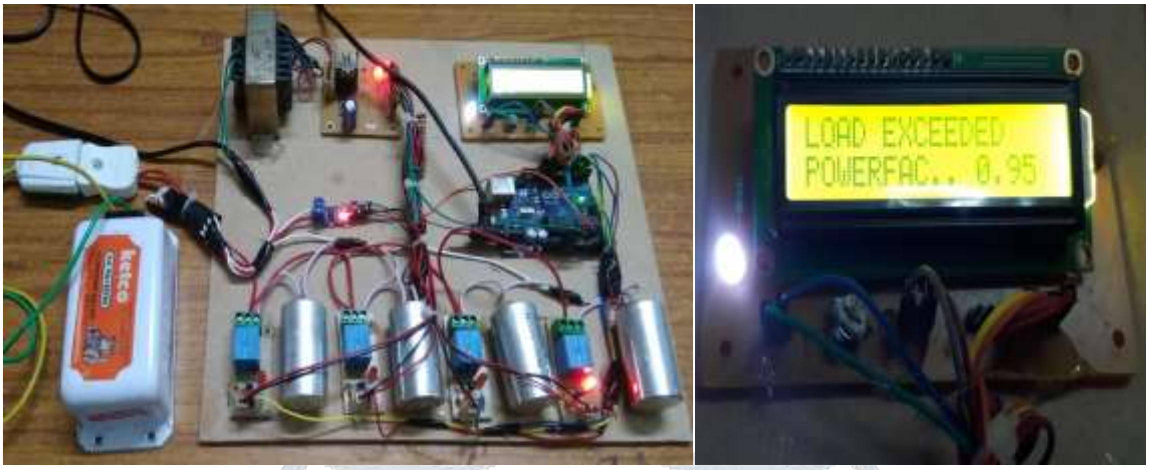

Figure 5.5 Inductive load at power factor 0.95

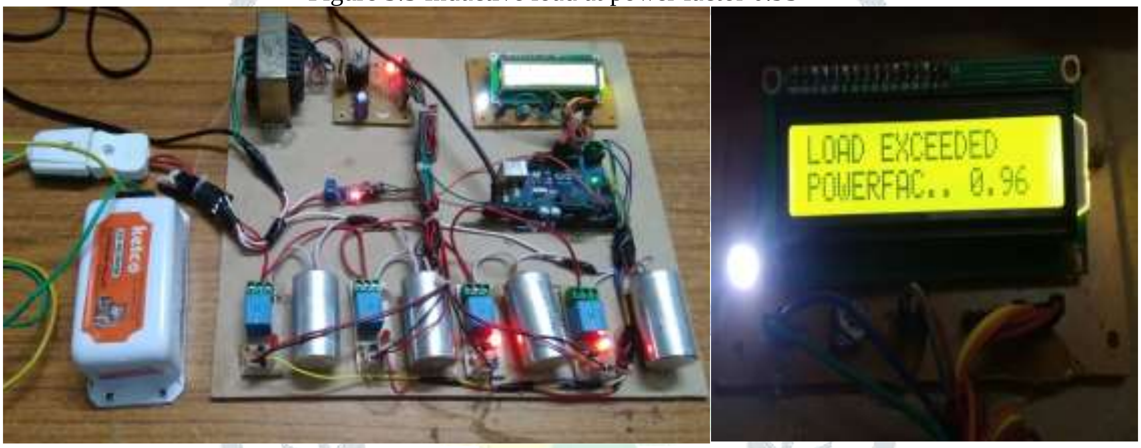

Figure 5.6 Inductive load at power factor 0.96

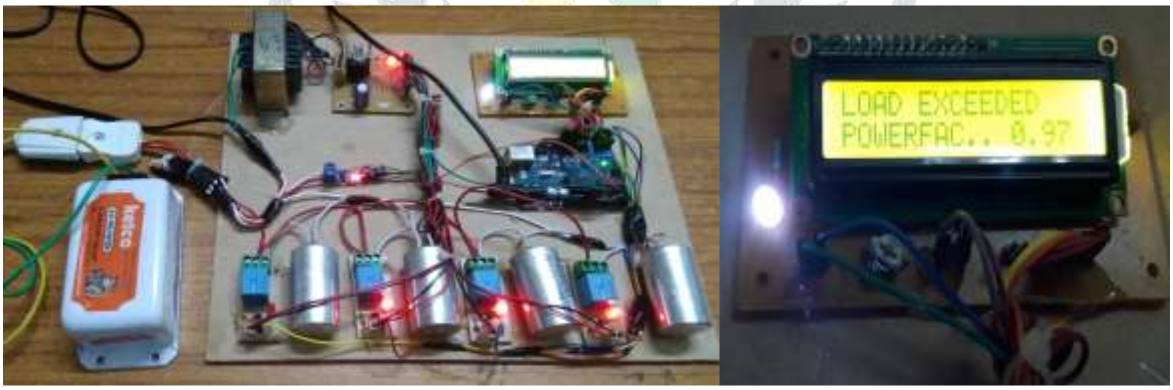

Figure 5.7 Inductive load at power factor 0.97

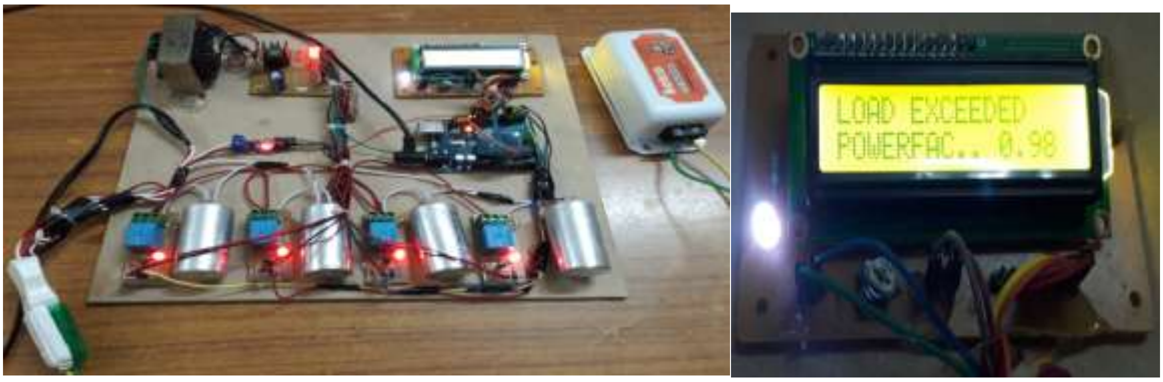

Figure 5.8 Inductive load at power factor 0.98

Table 5.1 shows the variation of analysis of variation for current, reactive power and apparent power. With constant voltage, as the power factor is increases, there is a great reduction in current reactive power and apparent power.

Voltage (Volts)	Current (Amps)	Power Factor	Real Power (KW)	Reactive Power (KVAR)	Apparent Power(KVA)
230	0.4	0.5	0.046	0.084	0.095
230	0.21	0.95	0.046	0.043	0.0629
230	0.208	0.96	0.046	0.0133	0.0479
230	0.206	0.97	0.046	0.0115	0.047
230	0.204	0.98	0.046	0.0092	0.046

Table 6.1 Analysis of Variation for Current, Power Factor, Reactive Power And Apparent Power

VI.CONCLUSION

The automatic power factor detection and correction provides efficient techniques 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 cutoff from line. Thus, it not only improves the power factor but also increases the life time of static capacitors. The power 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 and inefficient line to improve power factor and the speed of synchronous condenser can be controlled by Arduino.

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