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Minimizing Penalty in Industries by Engaging Automatic Power Factor Correction Unit

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ABSTRACT: Power factor losses represent a significant factor of power losses in both industrial and domestic units. Various methods have been adopted to tackle this problem as low power factor is the big issue for any industry. The reason is that if the power factor is low the losses will increase due to which the efficiency of equipment in industry gets low down. Hence due to this the electrical supply company charge penalty due to low power factor according to their norms. This paper aims to present an indigenous technique and method which could be used for static power factor correction. It is discussed in this work that phase difference between voltage and current can be determined using zero crossing detectors, opto-couplers, EXOR gate and some basic function of AT89C52 microcontroller. APFC 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 function generator with high accuracy by using an internal timer. This time values are the calibrated as phase angle and corresponding power factor. Then the values are displayed in Liquid crystal display modules. Then the motherboard calculates the compensation requirement and accordingly switches on different capacitor banks. Voltage and current transformers have been used for transforming load voltage and current respectively to bring them in desired working range of microcontroller.

KEYWORDS: Active power, Reactive power, Power factor, AT89C52 micro controller, Penalty, Capacitor banks, Current transformer, Voltage or potential transformer.

I. INTRODUCTION

In a present world of technology it has been observed that power is very precious for all and also demand of power is always high. The demand of power is increasing day by day due to more industrialization, increase in inductive load etc. Hence the use of more inductive load in industries and at house hold, the systems power factor get lagging in nature that means the system power factor gets poor due to excess of reactive power consumed by the inductive load which increases the reactive losses. Therefore it is necessary to reduce such losses by power factor correction technique. The electrical engineering and its applications are the oldest streams of Engineering. Though these systems are quite reliable and cheaper, it has certain disadvantages. The electro mechanical protection relays are too bulky and

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needs regular maintenance. The multifunctional is out of question. Recently, the technical revolution made embedded technology cheaper, so that it can be applied to all the fields. Power factor is the ratio between the KW and the KVA drawn by an electrical load where the KW is the actual load power or active power and the KVA is the apparent load power. It is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system.

The Automatic Power factor Correction device is a very useful device for improving efficient transmission of active power. If the consumer connect inductive load, then the power factor lags, when the power factor goes below 0.97(lag) then the Electric supply company charge penalty to the consumer. So it is essential to maintain the Power factor below with in a limit. Automatic Power factor correction device reads the power factor from line voltage and line current, calculating the compensation requirement switch on different capacitor banks.

This paper discusses how the Power Factor of varying load can be measured and compensated using static methods. Measurement techniques have initially been designed and simulated using Proteus ISIS and then implemented practically. After measurements, the reactive power is compensated by switching capacitors using solid state relays by taking advantage of its long life and fully static Power Factor correction. The AT89C52 is selected as the controller of this project to take advantage from its large number of I/Os. Two parameters of load, that are voltage and current, are to be measured by microcontroller. Based on these measured readings all other necessary data is calculated to determine required capacitance to overcome the problem. Based on this calculation, capacitors are automatically brought online or offline by switching solid state relay to achieve unity power factor after displaying the essential data on liquid crystal display (LCD).

1.1 POWER FACTOR:-

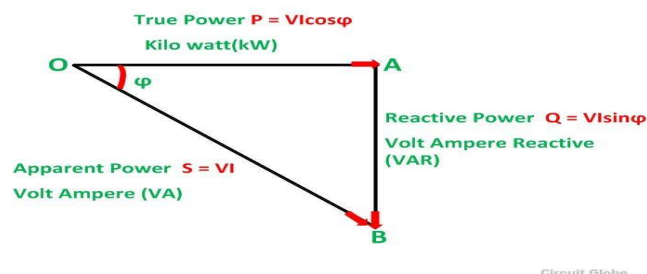


Fig 1.1.1:- Power triangle

The power factor is the ratio of the active power to the apparent power. The active power is the real power delivered to the loads such as motors, lamps etc. The reactive power is used just for the purpose of producing magnetic field for the flow of active power. The apparent power is the combination of the active and reactive power. The load current of any motor consist of the resistive component and inductive component. The inductive component consists of leakage current and magnetizing current. The leakage current is totally dependent on the load current but the magnetizing component is nearby 20 to 60% of the full load current. The capacitors are employed to reduce inductive reactance in the inductive load for here we have taken choke coil thereby reducing losses in the supply [1.1.2].

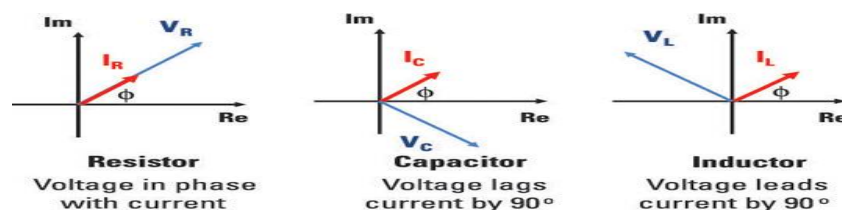


Fig 1.1.2:- voltage current vector diagram for different types of load.

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Fig 1.1.2 shows the vector diagram for different types of load. The very first figure shows the vector diagram for resistive load in which the voltage and current are in phase to each other. The second and third one is of capacitive load and inductive load in which the voltage lags current by 90° and voltage leads current by 90° . In other words we can say that the voltage and current wave form for capacitive and inductive load are out of phase.

1.2 Difference Between True Power - kW and Apparent Power - kVA and Reactive Power:-

In an AC system, such as inductive motors, transformers and solenoids, internal electrical energy is required for magnetization of items such as a motors field coils. This internal power stored and discharged within an inductive piece of equipment is referred to as reactive power and measured as volts x amps reactive (VAR). Without internal magnetization the AC equipment would not function. The more reactive power required for magnetization of the internal inductive load, the greater the unusable power and increase in apparent power (kVA) requirements within the electrical system.

As shown in diagram Fig 1.1.1, the greater the value of apparent power (kVA) the lower the power factor (P.F.) and by ratio the lower the real power available, given in kW. In layman's terms, P.F. has as more to do with the internal inductive loads of AC electrical equipment and the resultant true power kW available. A system designer endeavors to select equipment and design a system that reduces the drop in PF. A system with a low P.F. increases the energy lost in the system and requires a much greater input than can be used effectively to power equipment. Generator sets are normally rated for power factors between 0.8 and unity.

In summary apparent power kVA is the power required to serve the equipment's internal reactive load power requirements and true power kW is the power available after reactive power has been satisfied.

1.3 Adverse Effects and Why to Avoid Low Power Factor:-

A Low P.F. draws a higher internal current and the excessive heat generated will damage and/or shorten equipment life

- Increased reactive loads can reduce output voltage and damage equipment sensitive to reduced voltage.
- Low P.F. requires equipment to be constructed heavier to absorb internal energy requirements.
- Low P.F. will result in a more expensive system with equipment able to absorb internal loads and larger load requirements.
- A system designer looks to increase P.F. to lower system costs, increase reliability and increase the system's life cycle.
- Utilities will charge a higher cost to industrial and commercial clients having a low P.F.

1.4 Benefits of power factor correction:-

- Increase in efficiency of system and devices.
- Low Voltage Drop.
- Reduction in size of a conductor and cable which reduces cost of the Cooper.
- An Increase in available power.
- Line Losses (Copper Losses) I^2R is reduced.
- Appropriate Size of Electrical Machines (Transformer, Generators etc).
- Eliminate the penalty of low power factor from the Electric Supply Company.
- Low kWh (Kilo Watt per hour).
- Saving in the power bill.
- Better usage of power system, lines and generators etc.
- Saving in energy as well as rating and the cost of the electrical devices and equipment is reduced.

II. LITERATURE SURVEY

By the literature survey we have found the due to modern day development in the industrial sector the demand of the power has been increased extremely. There are more power demand arises due to the loads in industries. An electrical load can be classified in three types and they are resistive load like filament lamp, capacitive load like motor starter

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circuit, Inductive load like motor, generator etc. The majority of load in industries are inductive in nature as appliance which are used in any industries are almost similar everywhere. Motor which are used in industries are one of the common used appliance in any industries. Motor load is inductive in nature. Due to inductive nature the voltage lags current. Hence due to the phase difference between voltage and current, the reactive power loss in the system increases. Due to which the efficiency of the system becomes poor and the power factor of the system gets decreased. Because of lower power factor, industry gets charged penalty. Because according to the norms of Electrical supply company if the power factor goes below 0.97 lag they charge penalty.

This paper explains a power system theoretical basis and important parameters in power system as active power (P), apparent power (S) and reactive power (Q). Power triangle and power factor also be discussed. This paper also discusses when low power factor, consumer having to pay too much. Low power factor too is indicator that system is not efficient and will be electricity loss. Advantage or good correction power factor also be discussed. Through the process power factor improvement, demand for apparent power (S) and reactive power (Q) could be reduced to both generator and consumers. Lost electricity also could be reduced and system voltage can be increased

III. PURPOSED METHODOLOGY AND DISCUSSION

3.1 Static capacitor method:-

Most of the industrial and power system loads are inductive that take lagging current which decreases the system power factor thus decreasing the efficiency. To improve the power factor static capacitors are connected in parallel with those devices which work on low power factor. Static capacitors provide leading current that neutralizes the lagging inductive component of load current. Static capacitors are installed in vicinity of large inductive loads like induction motor transformer etc. Capacitor current is 1800 out of phase from the load's inductive contribution to current draw. The capacitor's reactive power will directly subtract from the loads reactive power.

Total KVAR= Inductive KVAR- Capacitive KVAR

This correction will not change the amount of true power consumed by the load, but will result in a substantial reduction of apparent power and of the total current drawn from the 230V source.

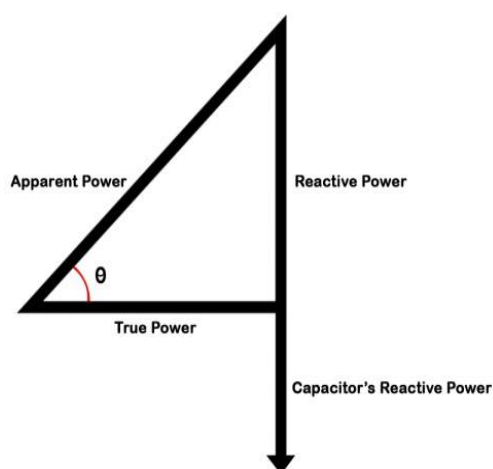


Fig 3.1.1:- Power triangle for static capacitor

The purposed system that is minimizing penalty in industry by engaging APFC unit uses the same principle method of static capacitor but the change in the system is that due to addition of microcontroller the work which is manual is now

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done automatically. The power factor correction is done automatically by automatic switching of required value of capacitor so as to overcome the reactive losses and thereby improve the power factor.

3.2 Block diagram of purposed system:-

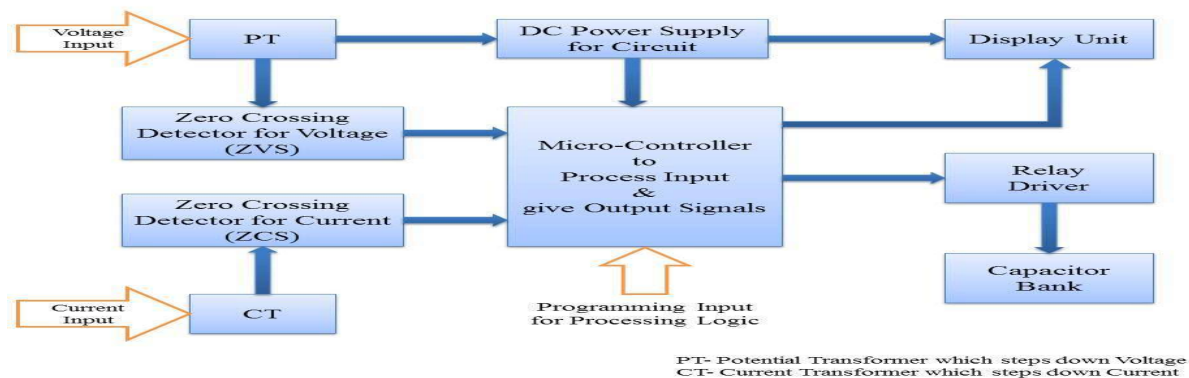


Fig 3.2.1:- Block diagram of APFC unit

An AT89C52 microcontroller is used in this project as a central processing unit to calculate the power factor and to switch the capacitors. The working of this project is explained with the help of the above block diagram. It uses a potential transformer to supply the voltage to the Resistor divider network (like zero voltage crossing circuit), which detects the zero crossing of the voltage wave form. These voltage pulses from the operational amplifier are applied to the AT89C52 microcontroller as interrupt signals.

Similarly, a current transformer is used here to give the current wave to the Resistor divider network wherein the operational amplifier or ZCD output is enabled for every 10 ms by comparing the zero position of the current with the predefined setting. This signal is also applied to the AT89C52 microcontroller as an interrupt signal. The microcontroller finds time elapse between these two interrupts and substitutes it in a certain equation for calculating the power factor. If this power factor value is above 0.96 then the AT89C52 doesn't send any command signals to the relay driver to switch the capacitors on. But, if it is less than 0.96, then the AT89C52 sends command signals to the relay driver so that the capacitor bank on.

Therefore, these capacitors reduce the lagging nature of the load by giving leading currents to it. The number of capacitors' switching depends on the value of the power factor – very low power factor needs all the capacitor, whereas high power factor needs none of those.

3.3 Hardware model:-

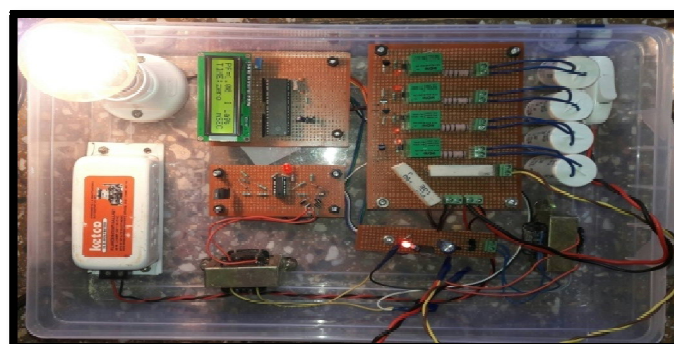


Fig3.3.1:- Hardware model of APFC unit

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The proposed work can be explained in the form of block diagram as shown in figure 3. It comprises of following 8 blocks [1],

- **Power supply:-**Power supply unit consist of step down potential transformer which converts 230v ac to 12v ac. It is then passed through the rectifier and gets converted to 12v dc which is then filtered as output of rectifier is pulsating dc. Then it is passed through voltage regulator which limits the voltage to 5v and though this the micro controller circuits get operated.
- **CT & PT:-**
Current transformer (CT) is connected series with line, and Potential transformer (PT) is connected parallel with supply line. CT & PT are used to step down the voltage and current for resistor divider network.
- **Resistor divider network:-**
Resistor voltage dividers are commonly used to create reference voltages, or to reduce the magnitude of a voltage so it can be measured. A simple example of a voltage divider is two resistors connected in series, with the input voltage applied across the resistor pair and the output voltage emerging from the connection between them.
- **Comparator unit (ZVS & ZCS):-**
It compares the value of voltage and current from CT and PT and gives this value to microcontroller. Here ZVS compares voltage signal and ZCs compares current signal and then it is given to microcontroller.
- **AT89C52 microcontroller:-**
The heart of any embedded system is a microcontroller which is responsible for all the logical processing. It takes input, processes it according to the program written to it and then gives the processed output. The AT89C52 provides the following standard features: 8K bytes of flash, 256 bytes of RAM, 32 I/O lines, watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.
- **Display unit (LCD 16*2):-**
A microcontroller program must interact with the outside world using input and output devices that Communicate directly with a human being. One of the most common devices attached to a microcontroller is a Liquid crystal display. Some of the most common LCDs connected to the microcontroller are 16x2 displays.
- **Relay:-**
Relay outputs are provided which operate to connect or disconnect the capacitor banks depending upon of the power factor conditions.
- **Capacitor:-**
Capacitor bank is an assembly of number of capacitors which are used to contribute KVAR in the electrical system and finally improve the power factor. Shunt capacitors bank are arrangements of series/paralleled connected units.

The same implementation has been made with single phase induction motor. Here instead of choke as a inductive load we have taken induction motor as a load.



Fig 3.3.2:- Complete Assembly of Motor Along with APFC

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The motor is fed from single phase supply and the motor is gradually loaded in steps. The variations in motor parameters are observed and the motor parameters like voltage, current, power and power factor are recorded. These observations are recorded before and after implementation of APFC scheme which is presented in the result section. Here the single phase induction motor represents the inductive load which consumes reactive power and due to which it result to the low power factor.

IV. EXPERIMENTAL RESULTS

The method was implemented on induction motor. By comparing data of induction motor before implementation of APFC and after implementation of APFC we can observe that PF of IM is improved and for the same value of power, current drawn by an induction motor is reduced. E.g. no load current IM before employing APFC is 2.6A and it is reduced to 1.8A after employing APFC. The results of before and after implementation are shown in Table 1 and 2 respectively in fig 4.1.1 and fig 4.1.2. The same data is used to plot the change in variation of power factor and motor current for the same values of motors active power requirements.

Voltage (V)	Current (A)	Power (W)	Active Power(VA)	Power factor
200	2.6	120	520	0.23
198	2.8	260	554.4	0.467
194	3.0	340	584	0.584
194	3.2	400	620.8	0.640
192	3.4	440	652.8	0.670

Fig 4.1.1:- Table 1 before employing APFC unit

As per above table we can analyze that before employing APFC unit to the system the power factor is low and also the value of current is more. Hence due to this the losses in the motor increases. Now if the losses in the system increases the efficiency of the system goes low and it affects the motor performance.

Voltage (V)	Current (A)	Power (W)	Reactive Power (VA)	Power factor
200	1.8	120	360	0.27
196	2.1	260	411.6	0.631
196	2.4	340	470.4	0.723
196	2.7	400	529.2	0.756
195	3.0	440	585	0.752

Fig 4.1.2:-Table 2 after employing APFC unit

As per the above figure 4.1.2 , here table 2 determines the reading of following parameter after employing the APFC unit in the system. When the Automatic power factor correction is employed in the system we can see in the table 2 that the value of current in the induction motor is reduced and so the losses in the motor reduced. As a result power factor of system is improved. This makes system more efficient. We can also conclude that the power factor of any system is inversely proportional to the current of that system.

V. CONCLUSION

It can be concluded that power factor correction techniques can be applied to the industries, power systems and also households to make them stable and due to that the system becomes stable and efficiency of the system as well as the apparatus increases. The use of microcontroller reduces the costs. Due to use of microcontroller multiple parameters can be controlled and the use of extra hard ware such as timer, RAM, ROM and input output ports reduces. The

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switching of capacitors is done automatically by using the contactors and thus the power factor correction is more accurate. Thus in this paper presented the possible advanced method for the correction of the power factor.

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