POWER FACTOR IMPROVEMENT IN KCG COLLEGE-CASE STUDY

A PROJECT REPORT

Submitted by

THIRUMALAI.M

VIGNESH BALAJI.V

in partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

KCG COLLEGE OF TECHNOLOGY

ANNA UNIVERSITY: CHENNAI 600 025

APRIL 2018

BONAFIDE CERTIFICATE

Certified that this project report **"POWER FACTOR IMPROVEMENT IN KCG COLLEGE-CASE STUDY."** is the bonafide work of **THIRUMALAI.M AND VIGNESH BALAJI.V"** who carried out the project work under my supervision.

SIGNATURE	**SIGNATURE**
Dr.Deivasundari	**Asst.Prof.Serene.C.Kurian**
HEAD OF THE DEPARTMENT	SUPERVISOR
Electrical and Electronics Engineering	Electrical and Electronics Engineering
KCG College of Technology	KCG College of Technology
Karapakkam, Chennai- 97	Karapakkam, Chennai- 97

Submitted for the Project Work Viva-voce examination held on…………….

INTERNAL EXAMINER **EXTERNAL EXAMINER**

ACKNOWLEDGEMENT

First and foremost, I proudly thank the almighty for showering his blessings for the successful completion of this project and I deeply express my thanks and respect to my beloved parents for their invaluable love, moral support and constant encouragement in every walk of my life.

I wish to express my deep sense of gratitude to **Dr.G.Prabhakaran**, M.E., Ph.D., Principal, KCG College of Technology Chennai for having given expert guidance, kind and cooperative encouragement, inspiring and keen interest shown throughout the course of this project.

I whole heartedly thank the **Dr.P.Deivasundari** M.E, ph.D., HOD-EEE for having provided the necessary infrastructural facilities and the encouragement given during the entire course of study.

I whole heartedly thank the project review panel member **Dr.P.Samantham** Advisor-Department of Electrical and Electronics Engineering Engineering, for their feedbacks and encouragement given during the entire course study.

I proudly acknowledge my deep sense of gratitude to my guide **Ms.Serene C Kurian** Asst. Prof, Civil Engineering Department, for her enthusiastic inspiration, constant encouragement, unstinted guidance and scholarly advice imparted throughout the course of this project.

At last but not least I thank the almighty God and one and all who helped me immensely directly for the successful completion of my project.

ABSTRACT

In the present technological revolution power is very precious. So we need to find out the causes of power loss and improve the power system performance. Due to industrialization the use of inductive load increases and hence power system losses its efficiency. So we need to improve the power factor with a suitable method. In case of fixed loads, power factor correction can be done manually by switching of capacitors, but in case of rapidly varying loads it becomes difficult to maintain a high power factor by switching of capacitors. This drawback is overcome by using an APFC panel. The Proposed system based on Power Factor Improvement using Aurduino and real time analysis in KCG College.

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Introduction:

Electrical energy efficiency is of prime importance to industrial and commercial companies operating in today's competitive markets. Optimum use of plant and equipment is one of the main concerns that industries try to balance with energy efficiency for both economic and environmental reasons. As society becomes increasingly conscious of its impact on the environment, reduced energy consumption becomes more desirable, which is an achievable goal for everyone. Through the use of measures such as power factor correction, electricity consumption is optimized, which ultimately leads to reduced energy consumption and reduced CO2 greenhouse gas emissions.

Within a cost conscious market, payback considerations are also important. This report identifies the most appropriate application for power factor correction based on energy consumption, tariff metering, cost payback and emission reduction. Power factor correction is an appropriate means by which to improve the power quality of an installation. Its application is dependent though on the size of the installation and the extent that power factor correction needs to be applied. The opportunity however exists to make a significant environmental contribution whilst simultaneously providing economic benefit.

Currently, the effective use of the capacitor bank as power factor correction device has been its use as a capacitor bank for domestic use. Also known as energy stability, it will correct power factor based on the concept of employing a capacitor as a compensator of reactive current in the single phase electric circuit. However, this device proves to be less efficient because of its static operation i.e. the compensation does not vary with changes in the load.

The project titled ―Automatic Power Factor Correction‖ was developed to enable operation of a single phase capacitor bank to control the power factor such that it follows the change in the load. The present single phase capacitor bank was not able to operate with an increase or reduction in the load on the power system. Because the present system could not detect load rating that changed, its operation was inefficient and power factor correction thus obtained was not optimum. This project is using fluorescent magnetic ballast as the load.

1.1 General Theory:

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 Current Sensor. 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 of 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. 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. Automatic Power Factor Detection and Correction.

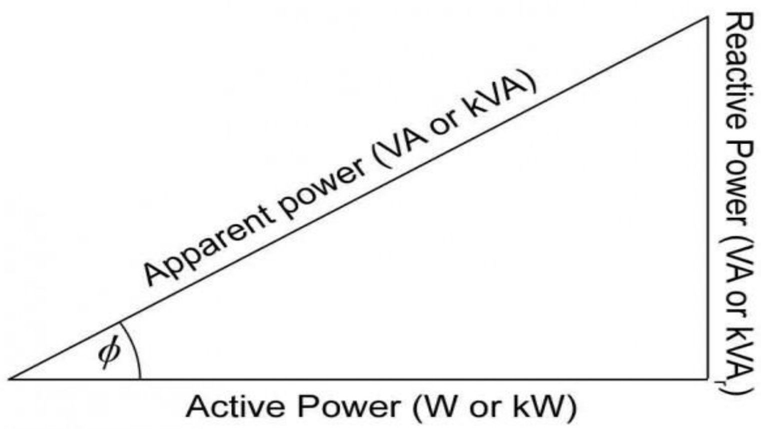
1.2 Power Factor:

Power factor is the ratio of true power or watts to apparent power or volt amps. They are identical only when current and voltage are in phase then the power factor is Unity (1.0). The power in an ac circuit is very seldom equal to the direct product of the volts and amperes. In order to find the power of a single phase ac circuit the product of volts and amperes must be multiplied by the power factor. Ammeters and voltmeters indicate the effective value of amps and volts. True power or watts can be measured with a wattmeter. If the true power is 1870 watts and the volt amp reading is 2200, then the power factor is 0.85 or 85%. True power divided by apparent power. The power factor is expressed in decimal or percentage. Low power factor is usually associated with transformers and motors. An incandescent bulb would have a power factor of close to 1.0. A one hp motor has a power factor of about 0.80. With low power factor loads, the current flowing through electrical system components is higher than necessary to do the required work. These result in excessive heating, which can damage or shorten the life of the equipment. A low power factor will also cause low-voltage conditions, resulting in dimming of lights and sluggish motor operation.

Low power factor is usually not that much of a problem in residential houses. It does however become a problem in industries where multiple numbers of large motors are used. So there is a requirement to correct the power factor in industries. Generally, the power factor correction capacitors are used for power factor correction.

For a DC circuit the power in the circuit is given by P=VI and this relation also holds good for the instantaneous power in an AC circuit. However, the average power in an AC circuit expressed in terms of rms voltage and current is:

Pavg = VIcosφ



1.1 Power Triangle

Where, φ is the phase angle between the voltage and current. The term ‗cosφ' is called the power factor. Power factor is the ration between the KW and the KVA drawn by an electrical load where the KW is the actual load 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.

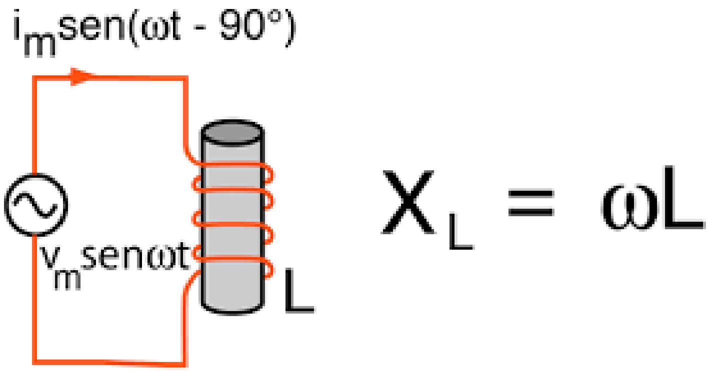
A load with a power factor of 1.0 result in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system. A poor power factor can be the result of either a significant phase difference between the voltage and current at the load terminals or it can be due to a high harmonic content or distorted/discontinuous current waveform. Poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, welder or induction furnace. A distorted current waveform can be the result of a rectifier, variable speed drive, switched mode power supply, discharge lighting or other electronic load.

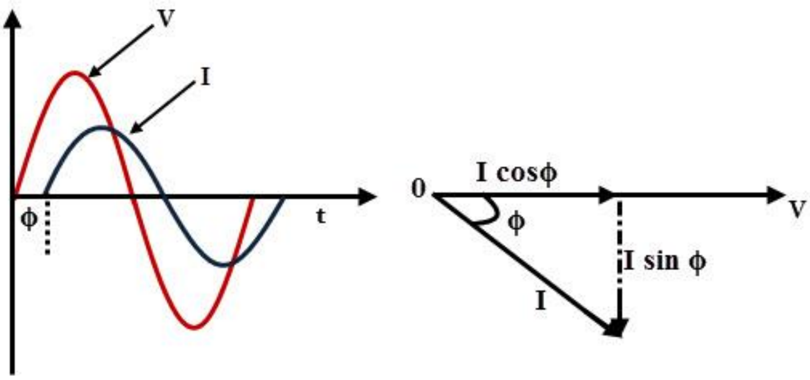
A poor power factor due to an inductive load can be improved by the addition of power factor correction, but, a poor power factor due to a distorted current waveform requires a change in equipment design or expensive harmonic filters to gain an appreciable improvement. Many inverters are quoted as having a power factor of better than 0.95 when in reality, the true power factor is between 0.5 and 0.75. The figure of 0.95 is based on the Cosine of the angle between the voltage and current but does not take into account that the current waveform is discontinuous and therefore contributes to increased losses on the supply.

1.3 AC response of Inductor, Capacitor and Resistor:

1.3.1 Inductor:

An inductor with AC supply is shown in the figure below along with its Phasor diagram, which shows the phase angle between current and voltage. In case of an inductor, voltage leads current by 90^0. The voltage across an inductor leads the current because the Lenz‘ law behaviour resists the build up of the current and it takes a finite time for an imposed voltage to force the build up of current to its maximum.

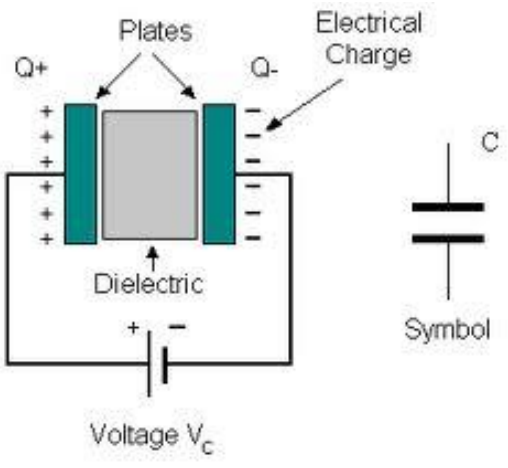




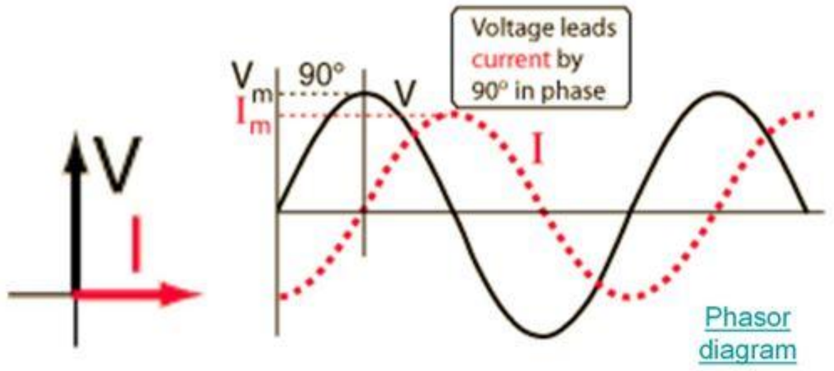
1.2 Inductive Circuit Phasor Diagram

1.3.2 Capacitor:

A capacitor with AC supply is shown in the figure below along with the waveform and Phasor diagram, which shows that the phase angle between current and voltage. In case of a capacitor, voltage lags behind the current by 90^0. The voltage across a capacitor lags the current because the current must flow to build up charge and the voltage is proportional to that charge which is built up on the capacitor plates.



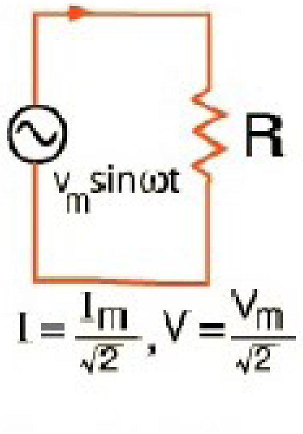
1.3 Capacitor



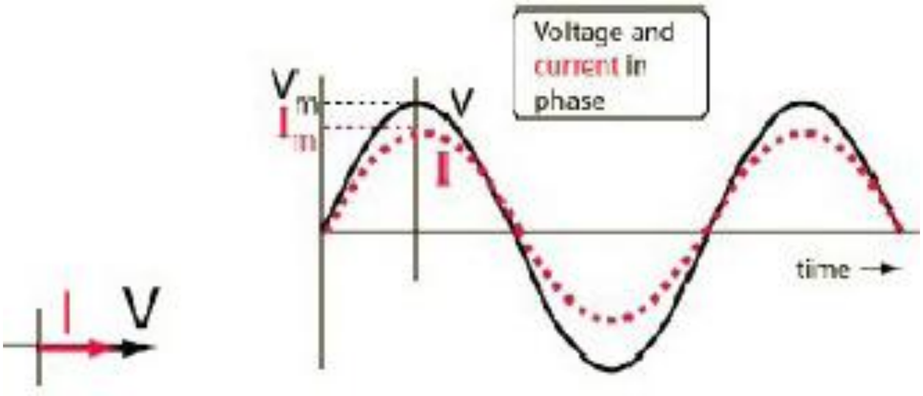
1.4 Phasor Diagram

1.3.3 Resistor:

A capacitor with AC supply is shown in the figure below along with the waveform and Phasor diagram, which shows that the phase angle between current and voltage. In case of a capacitor, the phase angle between current and voltage is 0^0. For ordinary currents and frequencies, the behavior of a resistor is that of a dissipative element which converts electrical energy into heat. It is independent of the direction of current flow and the frequency. So we say that the AC impedance of a resistor is the same as its DC resistance.



1.5 Resistor



1.6 Phasor Diagram

1.4 Causes of Low Power Factor:

The first and the foremost cause of a low power factor is the operation of highly inductive loads in the power system. As in a pure inductive circuit, current lags voltage by 90^0, this large difference in phase angle between the current and voltage causes zero power factor. Basically, all those circuits having capacitance and inductance (except tuning circuit or resonant circuit, where inductive reactance (Xl) is equal to capacitive reactance (Xc), so the circuit becomes a resistive circuit), will cause a low power factor because the inductance and capacitance causes a difference of phase (φ) between the current and voltage.

Following are the causes of low power factor:

a) Single Phase and Three Phase Induction motors, having a power factor of 0.8-0.9 at full load and 0.2-0.3 at small load while it may be at no-load.

b) Varying load in the power system is another major cause of low power factor. As we know the load on a power system varies as is evident from the load curves. During low load period, supply voltage is increased which increases the magnetizing current which causes the decreased power factor.

c) Industrial heating furnaces are highly inductive and thus cause a low power factor on the power system.

d) Electrical discharge lamps (high intensity discharge lamps), Arc lamps etc. operate at a very low power factor.

e) Transformers

f) Harmonic currents.

1.5 Disadvantage of Low Power Factor:

Power factor plays an important role in AC circuits and power dissipation in the power system is dependent on the power factor of the system. We know that the power in a three phase AC circuit is:

$$\mathbf{P = \sqrt{3}\, V \times I \cos\varphi}$$

And the current on a three phase AC circuit is:

$$\mathbf{I = P / (3\ V \times \cos\varphi)}$$

Also the power in a single Phase AC circuit is:

$$\mathbf{P = V \times I \cos\varphi}$$

And the current on a three phase AC circuit is:

$$\mathbf{I = P / (V \times I \cos\varphi)}$$

It is evident from the equations for the currents that the current is proportional to cosφ i.e. power factor. In other words, as the power factor increases the net current flowing in the system decreases and when the power factor decrease the net current in the system increases. The increased current incase of low power factor condition leads to following disadvantages.

1.6 Need of Power Factor controller:

Power factor correction is a technique of counteracting the undesirable effects of electric loads that create a power factor 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 supplier.

An electrical load that operates on alternating current requires apparent power, which consists of real power plus reactive power. Peal 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 cyclic 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, and so, the electrical load has a power factor of less than unity (1.0).

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 the power companies. Therefore, power companies require their customers, especially those with large loads, to maintain their power factors above a specified value (usually 0.90 0r higher) or be subjected to additional charges. Electrical engineers involved with the generation, transmission and consumption of electrical power have an interest in the power facto of loads because power factors affect efficiency and costs for both the electrical power industry and the consumers. In addition to the increase operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current carrying capacities.

Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1.0) 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. For 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 connected across the supply. The power factor of the motor is varied by adjusting the field excitation and can be made to behave like a capacitor when over excited.

Non-linear loads create harmonic currents in additional to the original AC current. The simple correction techniques described above do not cancel out the reactive power at harmonic frequencies, so more sophisticated techniques must be used to correct for non-linear loads.

Power factor correction is desirable because the source of electrical energy must be capable of supplying real power as well as any reactive power demanded by the load. This can require large, more expensive power plant equipment, transmission lines, transformers, switches, etc. than would be necessary for only real power delivered. Also, resistive losses in the transmission lines mean that some of the generated power is wasted because the extra current needed to supply reactive power only serves to heat up the power lines.

The electric utilities therefore put a limit on the power factor of the loads that they will supply. The ideal figure for load power factor is unity (1), that‘s a pure resistive load, because it requires the smallest current to transmit a given amount of real power. Real loads deviate from this ideal condition. Electric motor loads are phase lagging (inductive), therefore requiring capacitor banks to counter their inductance. Sometimes, when the power factor is leading due to capacitive loading, inductors (also known as reactors in this context) are used to correct the power factor. In the electric industry, inductors are said to consume reactive power and capacitors are said to supply it, even though the reactive power is actually just moving back and forth between each AC cycle.

Electric utilities measure reactive power used by high demand customers and charge higher rates accordingly. Some consumers install power factor correction schemes at their factories to cut down on these higher costs.

1.7 Types of Power Factor Controllers:

Generally there are three types of techniques that are employed to control the power factor. They are

1.7.1 Passive PFC

This is a simple way of correcting the non-linearity of a load by using capacitor banks. It is not as effective as active PFC, switching the capacitors in or out of the circuit causes harmonics, which is why active PFC or a synchronous motor is preferred.

1.7.2 Active PFC:

An Active Power Factor corrector 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 power factor controls the input current of the load so that the current waveform is proportional to the mains voltage waveform (a sine wave). Some types of active PFC are: Boost, Buck and Buck Boost. Active power factor correctors can be single-stage or multi-stage. Active power factor controller is the most effective and can produce a PFC of 0.99 (99%).

1.7.3 Synchronous Power factor controller

Synchronous motors can also be used for power factor correction. A shaft less motor is used, so that no load can be connected and run freely on the line at capacitive power factor for the purpose of power factor correction

1.8 Capacitive Power Factor Correction:

Capacitive Power Factor correction is applied to circuits which include induction motors as a means of reducing the inductive component of the current and thereby reduce the losses in the supply. There should be no effect on the operation of the motor itself. An induction motor draws current from the supply that is made up of resistive components and inductive components.

The resistive components are:

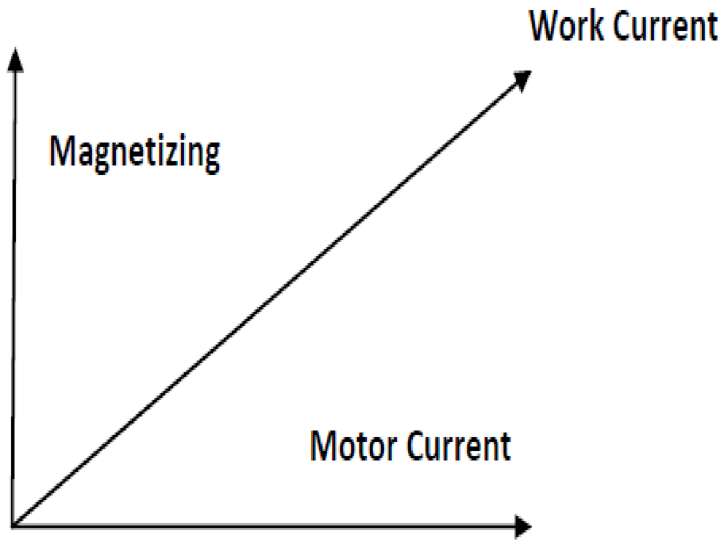
i. Load current

ii. Loss current

The inductive components are

i. Leakage reactance

ii. Magnetizing current



1.7 Current Triangle

The current due to the leakage reactance is dependent on the total current drawn by the motor but the magnetizing current is independent of the load on the motor. The magnetizing current will typically be between 20% and 60% of the rated full load current of the motor. The magnetizing current is the current that establishes the flux in the iron and is very necessary if the motor is going to operate. The magnetizing current does not actually contribute to the actual work output of the motor. It is the catalyst that allows the motor to work properly. The magnetizing current and the leakage reactance can be considered passenger components of current that will not affect the power drawn by the motor, but will contribute to the power dissipated in the supply and distribution system. Taking an example, a motor with a current draw of 100 Amps and a power factor of 0.75 the resistive component of the current is 75 Amps and this is what the KWh meter measures. The higher current will result in an increase in the distribution losses of (100 x 100) / (75 x 75) = 1.777 or a 78% increase in the supply losses.

In the interest of reducing the losses in the distribution system, power factor correction is added to neutralize a portion of the magnetizing current of the motor. Typically, the corrected power factor will be 0.92 - 0.95 some power retailers offer incentives for operating with a power factor of better than 0.9, while others penalize consumers with a poor power factor. There are many ways that this is metered, but the net result is that in order to reduce wasted energy in the distribution system, the consumer will be encouraged to apply power factor correction.

Power factor correction is achieved by the addition of capacitors in parallel with the connected motor circuits and can be applied at the starter or applied at the switchboard or distribution panel. The resulting capacitive current is leading current and is used to cancel the lagging inductive current flowing from the supply. Capacitors connected at each starter and controlled by each starter are known as "Static Power Factor Correction".

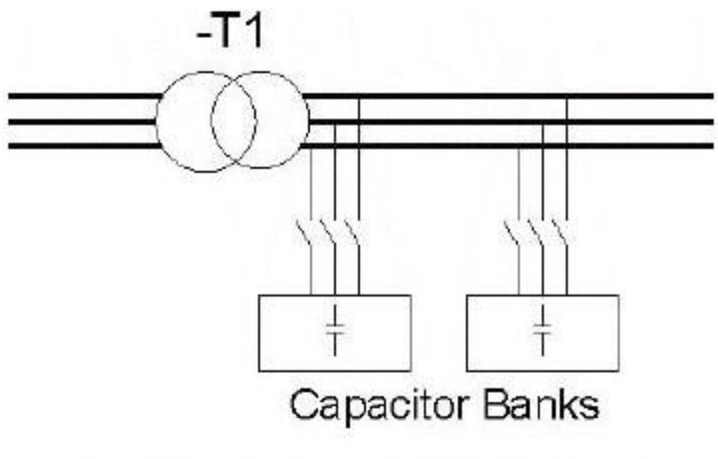
1.9

Different types of Capacitive Power Factor Correction:

1. Bulk correction
2. Static correction
3. Inverter
4. Solid-state soft starter

1.9.1. Bulk Capacitive Power Factor correction:

The power factor of the total current supplied to the distribution board is monitored by a controller which then switches capacitor banks in a pattern so as to maintain a power factor better



1.8 Bulk correction using capacitor banks

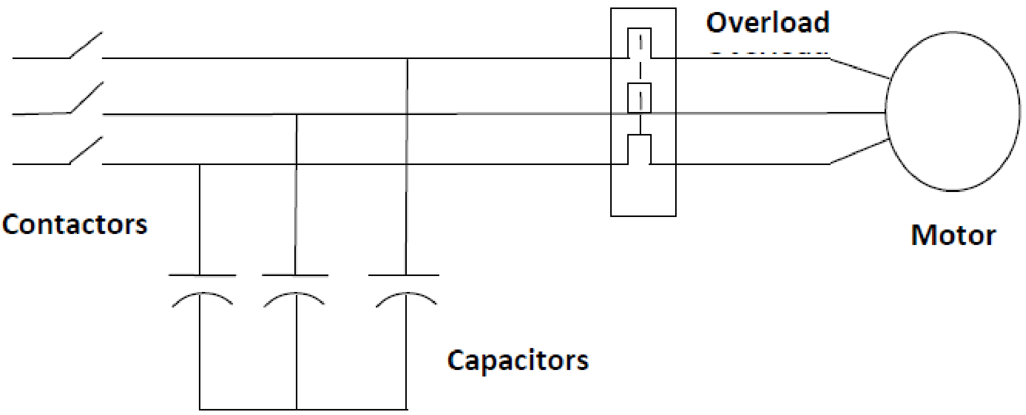
than a preset limit (typically 0.95). Ideally, the power factor should be as close to unity as possible. There is no problem with bulk correction operating at unity; however, correction should not be applied to an unloaded or lightly loaded transformer. If such a condition arises, a high Q resonant circuit is created between the leakage reactance of the transformer and the capacitors and high voltages can result.

1.9.2 Static Correction:

As a large proportion of the inductive or lagging current on the supply is due to the magnetizing current of induction motors, it is easy to correct each individual motor by connecting the correction capacitors to the motor starters. With static correction, it is important that the capacitive current is less than the inductive magnetizing current of the induction motor. In many installations employing static power factor correction, the correction capacitors are connected directly in parallel with the motor windings. When the motor is Off

Line, the capacitors are also Off Line. When the motor is connected to the supply, the capacitors are also connected providing correction at all times that the motor is connected to the supply. This removes the requirement for any expensive power factor monitoring and control equipment. In this situation, the capacitors remain connected to the motor terminals as the motor slows down. An induction motor, while connected to the supply, is driven by a rotating magnetic field in the stator which induces current into the rotor. When the motor is disconnected from the supply, there is for a period of time, a magnetic field associated with the rotor. As the motor decelerates, it generates voltage out its terminals at a frequency which is related to its speed. The capacitors connected across the motor terminals, form a resonant circuit with the motor inductance. If the motor is critically corrected, (corrected to a power factor of 1.0) the inductive reactance equals the capacitive reactance at the line frequency and therefore the resonant frequency is equal to the line frequency. If the motor is over corrected, the resonant frequency will be below the line frequency. If the frequency of the voltage generated by the decelerating motor passes through the resonant frequency of the corrected motor, there will be high currents and voltages around the motor/capacitor circuit. This can result in severe damage to the capacitors and motor. It is imperative that motors are never over corrected or critically corrected when static correction is employed.

Static power factor correction should provide capacitive current equal to 80% of the magnetizing current, which is essentially the open shaft current of the motor. The magnetizing current for induction motors can vary considerably. Typically, magnetizing currents for large two pole machines can be as low as 20% of the rated current of the motor while smaller low speed motors can have a magnetizing current as high as 60% of the rated full load current of the motor. It is not practical to use a "Standard table" for the correction of induction motors giving optimum correction on all motors. Tables result in under correction on most motors but can result in over-correction in some cases. Where the open shaft current cannot be measured and the magnetizing current is not quoted, an approximate level for the maximum correction that can be applied can be calculated from the half load characteristics of the motor



1.9 Static Correction using Capacitors

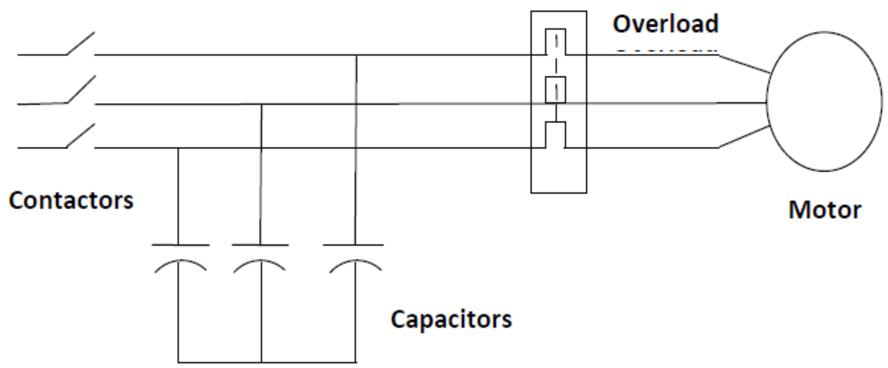
.It is dangerous to base correction on the full load characteristics of the motor as in some cases, motors can exhibit a high leakage reactance and correction to 0.95 at full load will result in over correction under no-load or disconnected conditions. Static correction is commonly applied by using one contactor to control both the motor and the capacitors. It is better practice to use two contactors, one for the motor and one for the capacitors. Where one contactor is employed, it should be up sized for the capacitive load. The use of a second contactor eliminates the problems of resonance between the motor and the capacitors.

1.9.3 Inverters:

Static power factor correction must not be used when a variable speed drive or inverter controls the motor. The connection of capacitors to the output of an inverter cause serious damage to the inverter and the capacitors due to the high frequency switched voltage on the output of the inverters. The current drawn from an inverter has a poor power factor, particularly at low load, but the motor current is isolated from the supply by the inverter. The phase angle of the current drawn by the inverter from the supply is close to zero resulting in very low inductive current irrespective of what the motor is doing. The inverter however, does not run with a good power factor. Many inverter manufacturers quote a ‗cosφ' of better than 0.95 and this is generally true, however the current is non-sinusoidal and the resulting harmonics cause a power factor (KW/KVA) of close to 0.7 depending on the input design of the inverter. Inverters with input reactors and DC bus reactors will exhibit a higher true power factor than these without. The connection of capacitors close to the input of the inverter can also result in damage to the inverter. The capacitors tend to cause transients to be amplified, resulting in higher voltage impulses applied to the input circuits of the inverter and the energy behind the impulses is much greater due to the energy storage of the capacitors. It is recommended that capacitors should be at least 75m away from inverter inputs to elevate the impedance between the inverter and capacitors and reduce the potential damage caused. Switching of capacitors, Automatic bank correction etc. cause voltage transients and these voltage transients can damage the input circuits of inverters. The energy is proportional to the amount of capacitance being switched. It is better to switch lots of small amounts of capacitance then few large amounts.

1.9.4. Solid-state soft starter:

Static power factor correction capacitors must not be connected to the output of a solid-state starter. When a solid-state soft starter is used, a separate contactor must control the capacitors. The capacitor contactor is only switched ON when the soft starter output voltage has reached line voltage. Many soft starters provide a ―top of ramp‖ or ―bypass contactor control‖ which can be used to control the PFC capacitor contactor. If the soft starter is used without an isolation contactor, the connection of capacitors close to the input of the soft starter can also cause damage if they are switched while the soft starter is not drawing current. The capacitors tend to cause transients to be amplified resulting in higher voltage impulses applied to the thyristors of the soft starter, and due to the energy storage of capacitors, the energy behind the impulse is much greater. In such installations, it is recommended that the capacitors be mounted at least 50m from the soft starter. The elevated impedance between the soft starter and the capacitors reduces the potential for damage to the thyristors. Switching capacitors, Automatic bank correction, etc. will cause voltage transients and these transients can damage the thyristors of soft starters if they are in the off-state without an input contactor. The energy is proportional to the amount of capacitance being switched. It is better to switch lots of small capacitances than few large ones. Power factor controller solid-state soft starter is shown below:



1.10 Solid-state Soft Starter

1.10 Demerits of Capacitive Power Factor Correction and its Solution:

1.10.1 Capacitor

Static power factor correction must neutralize no more than 80% of the magnetizing current of the motor. If the correction is too high, there is a high probability of over correction which can result in equipment failure with severe damage to the motor and capacitors. Unfortunately, the magnetizing current of induction motors varies considerably between different motor designs. The magnetizing current is almost always higher than 20% of the rated full load current of the motor, but can be as high as 60% of the rated current of the motor. Most power factor correction is too light due to the selection based on tables which have been published by a number of sources. The tables assume the lowest magnetizing current and quote capacitors for this current. In practice this can mean that the correction is often less than half the value that it should be and the consumer is unnecessarily penalized. Power factor correction must be correctly selected based on the actual motor being corrected.

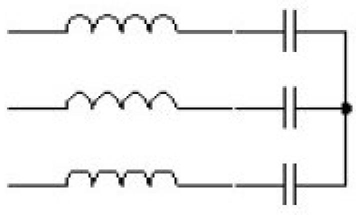
1.10.2 Supply Harmonics:

Harmonics on the supply cause a higher current to flow in the capacitors. This is because the impedance of the capacitors goes down as the frequency goes up. This increase in current flow through the capacitor will result in additional heating of the capacitor and reduce its life. The harmonics are caused by many non-linear loads; the most common in the industrial market today, are the variable speed controllers and switch mode power supplies. Harmonic voltages can be reduced by the use of a harmonic compensator, which is essentially a large inverter that cancels out the harmonics. This is an expensive option. Passive harmonic filters comprising resistors, inductors and capacitors can also be used to reduce harmonic voltages. This is also an expensive exercise. In order to reduce the damage caused to the capacitors by the harmonic currents, it is becoming common today to install detuning reactors in series with the power factor correction capacitors. These reactors are designed to make the correction circuit inductive to the higher frequency harmonics. Typically, a reactor would be designed to create a resonant circuit with the capacitors above the third harmonic, but sometimes it is below.

Adding the inductance in series with the capacitors will reduce their effective capacitance at the supply frequency. Reducing the resonant or tuned frequency will reduce the effective capacitance further. The object is to make the circuit look as inductive as possible at the 5th harmonic and higher, but as capacitive as possible at the fundamental frequency. Detuning reactors will also reduce the chance of the tuned circuit formed by the capacitors and the inductive supply being resonant on a supply harmonic frequency, thereby reducing damage due to supply resonance amplifying harmonic voltages caused by non-linear loads.

1.10.3Detuning Reactors:

Detuning reactors are connected in series with power factor correction capacitors to reduce harmonic currents and to ensure that the series resonant frequency does not occur at a harmonic of the supply frequency. The reactors are usually chosen and rated as either 5% or 7% reactors. This means that at the line frequency, the capacitive reactance is reduced by 5% or7%. Using detuning reactors results in a lower KVAR, so the capacitance needs to be increased for the same level of correction. When detuning reactors are used in installations with higher harmonic voltages, there can be a high resultant voltage across the capacitors. This necessities the use of capacitors that are designed to operate at a high sustained voltage. Capacitors designed for used at line voltage only, should not be used with detuning reactors. Check the suitability of the capacitors for use with line reactors before installation. The detuning reactors can dissipate a lot of heat. The enclosure must be well ventilated, typically forced air cooled. The detuning reactors must be specified to match the KVAR of the capacitance selected.



1.11 Detuning reactors in series with the capacitors.

1.10.4Supply Resonance:

Capacitive Power factor correction connected to a supply causes resonance between the supply and the capacitors. If the fault current of the supply is very high, the effect of the resonance will be minimal, however in a rural installation where the supply is very inductive and can be high impedance, the resonance can be very severe resulting in major damage to plant and equipment.

To minimize supply resonance problems, there are a few steps that can be taken, but they do need to be taken by all on the particular supply.

1. Minimize the amount of power factor correction, particularly when the load is light. The power factor correction minimizes losses in the supply. When the supply is lightly loaded, this is not such a problem.

2. Minimize switching transients. Eliminate open transition switching - usually associated with generator plants and alternative supply switching, and with some electromechanical starters such as the star/delta starter.

3. Switch capacitors on to the supply in lots of small steps rather than a few large steps

4. Switch capacitors on o the supply after the load has been applied and switch off the supply before or with the load removal.

Harmonic Power Factor correction is not applied to circuits that draw either discontinuous or distorted current waveforms. Most electronic equipment includes a means of creating a DC supply. This involves rectifying the AC voltage, causing harmonic currents. In some cases, these harmonic currents are insignificant relative to the total load current drawn, but in many installations, a large proportion of the current drawn is rich in harmonics. If the total harmonic current is large enough, there will be a resultant distortion of the supply waveform which can interfere with the correct operation of other equipment. The addition of harmonic currents results in increased losses in the supply. Power factor correction for distorted supplies cannot be achieved by the addition of capacitors. The harmonics can be reduced by designing the equipment using active rectifiers, by the addition of passive filters (LCR) or by the addition of electronic power factor correction inverters which restore the waveform back to its undistorted state. This is a specialist area requiring either major design changes, or specialized equipment to be used.

1.11 Applications of Power Factor Controllers:

1.11.1Electricity industry: power factor correction of linear loads:

Power factor correction is achieved by complementing an inductive or a capacitive circuit with a (locally connected) reactance of opposite phase. For a typical phase lagging power factor load, such as large induction motors, this would consist of a capacitor bank in the form of several parallel capacitors at the power input to the device.

Instead of using a capacitor, it is possible to use an unloaded synchronous motor. This is referred to as a _Synchronous Condenser‘. It is started and connected to the electrical network. It operates at full leading power factor and puts VARs onto the network as required to support a systems voltage or to maintain the system power factor at a specified level. The condensers installation and operation are identical to large electric motors.

The reactive power drawn by the synchronous motor is a function of its field excitation. Its principal advantage is the ease with which the amount of correction can be adjusted. It behaves like an electrically variable capacitor.

1.11.2 Switched-mode power supplies: power factor correction of non-linear loads:

A typical switch-mode power supply first makes a DC bus, using a bridge rectifier or similar circuit. The output voltage is then derived from this DC bus. The problem with this is that the rectifier is a non-linear device, so the input current is highly nonlinear. That means that he input current has energy at harmonics of the frequency of the voltage.

This presents a particular problem for the power companies, because they cannot compensate for the harmonic current by adding capacitors or inductors, as they could for the reactive power drawn by the linear loads. Many jurisdictions are beginning to legally require PFC for all power supplies above a certain power level.

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 frequencies (i.e. 50 Hz or 60 Hz). This filter kills 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 or expensive.

It is also possible to perform active power factor correction. In this case, a boost converter is inserted between the bridge rectifier and the main input capacitors. The boost converter attempts to maintain a constant DC bus voltage on its output while drawing a current that is always in phase with and at the same frequency as the line voltage. Another switch-mode converter inside the power supply produces the desired output voltage from the DC bus. This approach requires additional semiconductor switches and control electronics, but permits cheaper and smaller passive components. It is frequently used in practice. This feature is useful in power supplies for laptops and cell phones.

Chapter 2:

Literature Review

Title : Automatic Power Factor Correction to reduce the power requirement

Author : Aniket V. Kulkarni

Publication: ISSN (Print) : 2319 – 2526, Volume-2, Issue-6, 2013

Description: The proposed system states that the power factor improvement using microcontroller with the help of Zero Crossing Detector. Through this device the phase angle of voltage and current can detected and the fetched values are fed to the microcontroller. The microcontroller can be programmed to switch on the capacitor banks if the power factor lags by unity.

Title : Automatic Power Factor Correction by Continuous Monitoring

Author : Aparna Sarkar and Umesh Hiwase

Publication: International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 10, April 2015

Description: The proposed system states the automatic Power Factor Correction and improvement. With the help of ZCD the power factor can be measured and the values are fed to the microcontroller. Here the switching process is done automatically with help of Relay matrix. This proposed system has an advantage that can be erected with minimum amount of cost with latest technology. The power factor measurement is also accurate.

Title : **Microcontroller Based Automatic Power Factor Correction**

Author : A.Mariya Chithra Mary etal

Publication : **Volume 4, Special Issue 4, April 2015**

Description : The proposed system states the 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 power supply with high accuracy by

using an internal timer. This time values are then calibrated as phase angle and corresponding power factor. Then the microcontroller calculates the compensation requirement and accordingly switches on different capacitor banks. Automatic 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 increases. The use of microcontroller reduces the costs.

Title : AUTOMATIC POWER FACTOR CONTROL BASED ON PLC

Author : GANGA YAZHINI M etal

Description : The proposed method is facilitated with PLC is mainly used to get an accurate and automatic correction of power factor values, this method is enhanced due to eradicate the faults or difficulties faced in existing system.

Here the transformer is acts as a input module , from the transformer ac current is converted in to dc by using rectifier, then it is given to the micro controller through zero crossing detector with required input , then it passes to the PLC, which control the entire process ,it continuously monitoring the inductive loads ,if the power factor lags means it passes the instruction to switch on the capacitor in order to maintain almost to unity power factor.

Title : Automatic Power Factor Controller (APFC) with GSM

Author : Prof. S.M.Chaudhari1 etal

Publication : International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 04 Issue: 02 | Feb -2017

Description : The proposed system states that the AC input i.e. 230V from the mains is step down by transformer to12V and is fed to the rectifier. The output obtained from the rectifier is a pulsating DC voltage. So in order to get a pure dc voltage, the output voltage from the rectifier is fed to a filter to remove any AC components present even after rectification. The supplied voltage and current signals taken through potential transformer and current transformer. The two sinusoidal waveforms are given to ADC pins of microcontroller and active and apparent power is calculated and thus power factor is calculated. It controls the capacitor bank as required to compensate for leading or lagging power factor.

If required compensation is not obtained after adding the capacitors, an alert is sent to the users mobile via GSM.

Chapter 3

Load Estimation in KCG College :

In KCG College, there is a requirement of large power like Industries. So the power factor of the college should be maintained by unity. Electrical power supply companies have to bear the brunt of low power factor by installing equipment's and transmission lines of higher ratings, larger sizes and of higher ratings. In addition they may have to install power factor correction equipment. Thus, the power utility companies impose a penalty on the consumers whose power factor is below 0.85 lagging in the electric power bill.

Power factor correction is a technique of counteracting the undesirable effects of electric loads that create a power factor 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 supplier.

An electrical load that operates on alternating current requires apparent power, which consists of real power plus 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 cyclic 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, and so, the electrical load has a power factor of less than unity (1.0).

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 the power companies. Therefore, power companies require their customers, especially those with large loads, to maintain their power factors above a specified value (usually 0.90 0r higher) or be subjected to additional charges. Electrical engineers involved with the generation, transmission and consumption of electrical power have an interest in the power factor of loads because power factors affect efficiency and costs for both the electrical power industry and the consumers. In addition to the increase operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current carrying capacities.

Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1.0) 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. For 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 connected across the supply. The power factor of the motor is varied by adjusting the field excitation and can be made to behave like a capacitor when over excited.

Non-linear loads create harmonic currents in additional to the original AC current. The simple correction techniques described above do not cancel out the reactive power at harmonic frequencies, so more sophisticated techniques must be used to correct for non-linear loads.

Power factor correction is desirable because the source of electrical energy must be capable of supplying real power as well as any reactive power demanded by the load. This can require large, more expensive power plant equipment, transmission lines, transformers, switches, etc. than would be necessary for only real power delivered. Also, resistive losses in the transmission lines mean that some of the generated power is wasted because the extra current needed to supply reactive power only serves to heat up the power lines.

3.1 Load Details

The details of the existing system are follows. The total load of our College is about 320kVA, The total demand of the college is concern, 470kVA. The transformer which are used to step down the voltage from the main line. The rating of the transformer is stepping down as 11kV/440V. The current transformer and the voltage transformer is used in the session. The current transformer is on the ratings of 200/5A. The potential transformer is on the ratings is 500kVA of 11kV/110V. As per the relay is concern AB switch and the ACB switch is used.

The rating details of the Generators which are installed are, There are two generators are installed. The rating of the first generator is about 250KVA, and the rating of the second generator is 180KVA. Both the generators are run in the domain source of diesel.

3.2 Panel Details:

The existing system in KCG college has its main panel in power house. From the LT incomer the main panel receives about 600A of current. In KCG college 16 feeders are there for depending upon loads. The details of Load panel are given in the table.

Out of 16 panel one is for Main Lighting Panel (MLP) which further 8 small Lighting panel. The Small Lighting Panel (SMLP) are distributed for different loads of different bocks in college. The Lighting Panel Load details are given in the table 2.1.

3.3 Details of Feeders with Ratings

3.1 Main Panel Details

Feeder No.	Name of the Feeder	Rating (A)
1.	Academic Block	400
2.	Mechanical Wing	400
3.	Admin Block	400
4.	Aero Building	400
5.	School	250
6.	Chacko Hall	250
7.	Chako Annex	125
8.	St.Thomas Hall	250
9.	Canteen	125
10.	Pumping Station	250

11.	EPL Workshop	250
12.	KMC Hall	250
13.	Sewage Treatment Plant	250
14.	Capacitor Bank	250
15.	Main Lighting Panel	250
16.	Dental Lab	250

3.2 Lighting Panel Load Details

Feeder No.	**Name of the Feeder**	**Rating (A)**
i.	Academic Block	125
ii.	Mechanical Wing	125
iii.	Admin Block	125
iv.	Aero Building	200
v.	School	125
vi.	Chacko Hall	125
vii.	Chako Annex	125
viii.	St.Thomas Hall	125

3.4 LT Incomer Report:

As to regulate the power and power factor, the Energy Management System (EMS) has been mounted in KCG College. Through EMS report the power regulations can be analysed. The report has been in below table.

3.3 LT incomer report

Report Selection Date From: 2015-09-18 00:00 to 2015-09-19 15:03										
Time	**kW**	**kVA**	**ir**	**iy**	**ib**	**Rv**	**yv**	**bv**	**pf**	**hz**
19-12-2017 02:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 03:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 04:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 05:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 06:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 07:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96

19-12-2017 08:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 09:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 10:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 11:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 12:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 13:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 14:00:00	12.9	21.1	26.6	27	33.6	243.3	241.4	242.9	-0.61	49.96
19-12-2017 15:00:00	111.3	115.5	168.3	168.3	171.6	227.4	226.2	228.3	0.96	50.04
19-12-2017 16:00:00	125.2	129.1	190.6	199	174.1	229.3	228.1	230.1	0.97	50
19-12-2017 17:00:00	46.3	49.5	66.4	72.1	69.9	237.9	236.7	238.7	0.94	50.08
19-12-2017 18:00:00	39.4	41.4	52.9	56.9	69.7	230.6	229.4	231.1	-0.95	49.99
19-12-2017 19:00:00	51.5	53.7	74	62.6	95.3	231.6	230.9	232.2	0.96	50.01
19-12-2017 20:00:00	48	50.7	76.5	62.8	76.9	234.3	233.5	235	0.95	50.03
19-12-2017 21:00:00	43.6	46	65.9	56.6	72.3	236	235	236.8	0.95	50.04

19-12-2017 22:00:00	41.2	43.4	62.7	51.5	66.7	240.1	239	240.9	0.95	50.08
19-12-2017 23:00:00	38.8	41	57	46.9	66.1	241.5	240.7	242.1	-0.95	50.06
20-12-2017 00:00:00	39.1	41.3	56.4	50.8	63	242.4	241.8	243.3	-0.95	50.07
20-12-2017 01:00:00	38.2	40.6	55.3	50.3	61.7	242.6	241.9	243.7	-0.94	49.99
20-12-2017 02:00:00	36.7	39.5	54.8	45.3	62	243.5	242.6	244.7	-0.93	50.1
20-12-2017 03:00:00	36.3	39.3	53.8	45.1	61.5	244.6	243.7	245.5	-0.93	50.06
20-12-2017 04:00:00	37.6	40.3	53.7	49.5	61.4	244.5	244	245.7	-0.93	50.09
20-12-2017 05:00:00	41.8	44	65.8	50.7	64.3	243.1	242.5	244.4	-0.95	50.04
20-12-2017 06:00:00	40.2	42.6	67.2	49.6	60.4	239.8	239.5	241.2	-0.94	50.09
20-12-2017 07:00:00	44.2	45.6	61.6	58.1	76.9	232	230.9	232.8	-0.97	49.97
20-12-2017 08:00:00	10.4	12.7	8	12.9	35.3	225.8	224.2	225.7	-0.82	49.99
20-12-2017 09:00:00	84.5	90.7	133.7	155.3	116.5	224.2	222.3	224.9	0.93	50.03
20-12-2017 10:00:00	77.4	89.1	134.6	120.1	148	221.4	220.2	221.8	0.87	50.07
20-12-2017 11:00:00	70.7	94.3	153.6	133	125.9	228.7	227.3	229.9	0.75	50.07

20-12-2017 12:00:00	86.5	110.8	193.7	154.2	137.6	227.9	227	229.6	0.78	50.02
20-12-2017 13:00:00	63.5	84	121.4	139.2	103.9	230.9	229.1	231.7	0.76	50.06
20-12-2017 14:00:00	96.9	118.1	183.8	177	149.4	231.6	230.3	232.7	0.82	49.99
20-12-2017 15:00:00	125.3	149.1	227.4	219.9	204.2	229.2	227.6	230	0.84	50.03
20-12-2017 16:00:00	112.3	127.9	178.9	178.5	195.7	231.6	229.9	232.1	0.88	50.03
20-12-2017 17:00:00	39.9	42.3	62.7	61.8	56.8	233.3	231.8	234.2	0.94	50.02
20-12-2017 18:00:00	47.2	49.6	77.1	64.3	71	233.4	232	234.3	0.95	50.07
20-12-2017 19:00:00	46.8	49.4	74	63	72.1	236.4	234.9	236.9	0.95	50.04
20-12-2017 20:00:00	47	50	69.8	63	77	238.6	236.9	239.1	0.94	50.1
20-12-2017 21:00:00	48.5	51.4	71.8	57.1	84	241.7	240.2	241.5	0.94	50.1
20-12-2017 22:00:00	43.2	45.6	72.6	52.2	66.8	238.2	237.1	238.9	0.95	50.09
20-12-2017 23:00:00	37.6	40.2	58.6	45.2	63.2	240.4	239.3	241.2	-0.94	49.98
21-12-2017 00:00:00	35.8	38.9	56.3	43.7	61.1	241.5	240.8	242.1	-0.92	50.03
21-12-2017 01:00:00	37.3	40.3	59.4	44.7	61.9	242.8	242.1	243.6	-0.93	50.07

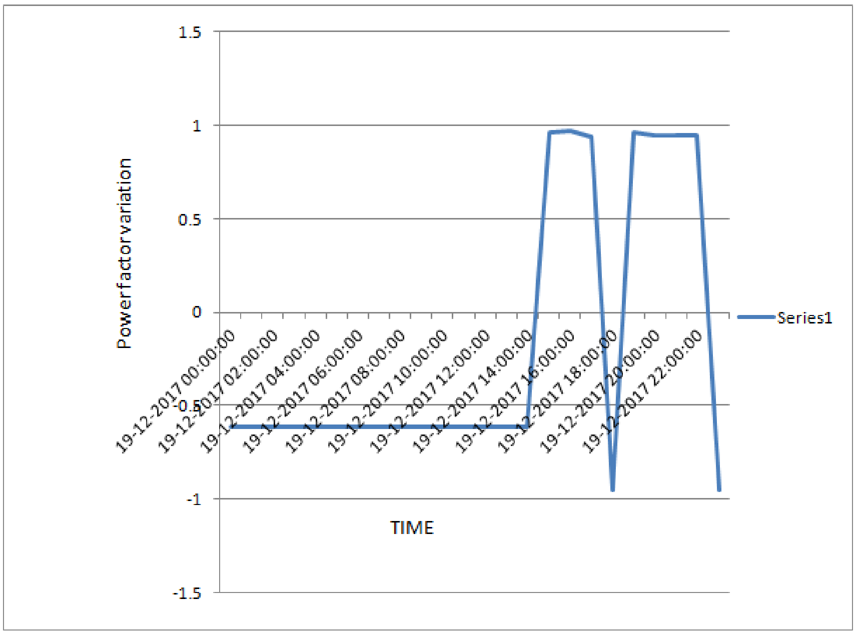
21-12-2017 02:00:00	36.4	39.7	56.2	44.7	61.8	243.9	243	244.5	-0.92	50.03
21-12-2017 03:00:00	36.9	40.1	56.8	45.4	62.2	244.3	243.4	244.7	-0.92	49.98
21-12-2017 04:00:00	36.1	39.5	55.4	45.1	61	244.6	244.2	245.3	-0.91	50.07
21-12-2017 05:00:00	46.8	48.8	73.9	55.3	71.7	243	242.1	243.7	0.96	50.08
21-12-2017 06:00:00	44.3	46.4	79.1	51.3	63.3	239.7	238.9	240.1	-0.95	50.08
21-12-2017 07:00:00	39.3	41.5	48.7	54.9	75.3	232.5	230.8	232.1	-0.95	49.98
21-12-2017 08:00:00	34.7	36.8	40.7	54.8	65.3	228.9	227.4	229.3	-0.94	50.02
21-12-2017 09:00:00	122.8	129.6	199.5	196.8	182.2	224.5	222.7	225.1	0.95	50.07
21-12-2017 10:00:00	120	130.8	210.8	199.5	179.5	221.8	220.5	223	0.92	50.07
21-12-2017 11:00:00	160	169.2	263.8	250	242.4	223.8	222.9	224.7	0.95	50.03
21-12-2017 12:00:00	140.3	148.7	222.5	228.5	208	225.7	224.5	226.6	0.94	50.07
21-12-2017 13:00:00	130.4	136.8	200	222.4	182.2	226.4	224.9	227.5	0.95	50.07
21-12-2017 14:00:00	151.2	163.9	249.1	261.2	213.6	226.7	225	227.9	0.92	49.99
21-12-2017 15:00:00	146.2	158	248.3	236	215.3	225.9	224.5	227.2	0.93	50.03

21-12-2017 16:00:00	118.4	131	218.3	189.5	168.6	227.3	226	228.8	0.9	50.06
21-12-2017 17:00:00	41.7	44.4	70.5	57.4	66.8	228.3	227	229.1	0.94	50.02
21-12-2017 18:00:00	42.7	44.7	63.1	55.8	76.7	229	228	229.4	0.95	50.09
21-12-2017 19:00:00	43.3	45.8	68.3	59.4	70.9	231.1	229.9	231.6	0.94	50.04
21-12-2017 20:00:00	48.4	51.1	74.4	63.4	80.4	234.7	233.6	234.9	0.95	50.09
21-12-2017 21:00:00	51.5	54.4	77.8	69.4	83.4	236.1	235	236.6	0.95	50.03
21-12-2017 22:00:00	45.5	47.8	70.3	55.9	73.2	239.7	238.8	240.1	0.95	50.12
21-12-2017 23:00:00	41.9	44.2	63.6	48.5	70.4	242	241.2	242.6	-0.95	50.02
22-12-2017 00:00:00	42	44.4	63.5	47.8	70.8	243.6	242.7	244.3	-0.95	50.02
22-12-2017 01:00:00	38.7	41.6	57.4	47.8	65	245.3	244.3	246	-0.93	50.02
22-12-2017 02:00:00	39.6	42.5	57.8	47.4	66.7	247.1	246.1	247.5	-0.93	50.04
22-12-2017 03:00:00	39.3	42.3	58	48	64.9	247.7	246.8	248.4	-0.93	50.04
22-12-2017 04:00:00	39.1	42.2	57.9	47.6	65	247.7	246.8	248.4	-0.93	50.1
22-12-2017 05:00:00	40.3	43.1	62.1	49.2	63.8	246	245	246.7	-0.94	50.05

22-12-2017 06:00:00	42.9	45.3	66.4	55.4	65.5	242.2	241.2	242.6	- 0.95	50.02
22-12-2017 07:00:00	53.6	54.7	69.2	76.2	89.3	233.8	232.4	233.5	- 0.98	49.87
22-12-2017 08:00:00	41.9	43.4	46	70.8	71.5	231.2	229.8	231.2	- 0.96	49.97

53

With the help of above table we can find the variation of power factor for each and every hour. It is observed that the power factor lags during peak hours and it maintains the unity during normal load period. The graph is plotted between time and power factor LT incomer report.



2.1 LT incomer Graph plot

3.5 Admin Block Report:

As LT Incomer, the power regulation has been monitored for admin block in KCG College. But here the report is monitored for only input power and power factor for a particular period of time as shown in the below table.

3.4 Admin Block Report

Time	kW	pf
19-12-2017 15:00:00	15.4	0.91
19-12-2017 16:00:00	9.7	0.83
19-12-2017 17:00:00	1.1	0.84
19-12-2017 18:00:00	0.7	0.85
19-12-2017 19:00:00	0.7	0.85
19-12-2017 20:00:00	0.8	0.87
19-12-2017 21:00:00	0.8	0.85
19-12-2017 22:00:00	0.7	0.82
19-12-2017 23:00:00	0.7	0.82
20-12-2017 00:00:00	0.7	0.8
20-12-2017 01:00:00	0.8	0.85
20-12-2017 02:00:00	0.7	0.82
20-12-2017 03:00:00	0.8	0.84
20-12-2017 04:00:00	0.7	0.81
20-12-2017 05:00:00	0.8	0.83
20-12-2017 06:00:00	0.7	0.84

As compared to LT incomer the admin block report huge variations because of using different loads.

Chapter 4:

Case Study

4.1 Case Study1: Machines Lab (EEE Dept):

To study further about power factor dissipation the Machines lab of EEE department is so choosen as one of the case study. The load details and ratings of various machines in machines lab were studied, analysed and the values are tabulated in the table 3.1. To calculate the power factor the selectively four machines are switched on and made to run for few minutes simultaneously. After few minutes the load has been increased nearly to maximum for each machine. The readings are tabulated and the power factor has been calculated. The values of the power factor has been tabulated and shown in the table 3.2. The list of machines in the machine lab is as follows

4.1 List of Machines

Name of the Machine	**Rated Current(A)**	**Rated Power(KW)**
DC SHUNT MOTOR(G)	21	3.5
DC COMPOUND MOTOR(G)	18.5	3.5
DC SHUNT MOTOR	18.6	3.5
DC SHUNT MOTOR(G)	18.6	3.5
DC SHUNT MOTOR(IG)	21	3.5

DC Series MOTOR	20	3.5
DC compound MOTOR	18.6	3.5
DC SHUNT MOTOR	21	3.5
3F ALTERNATOR	7	5.2
INDUCTION MOTOR	7.5	3.7
SLIP RING MOTOR	4	3.7
INDUCTION MOTOR(CAP)	9.9	3.7
SYNCHRONOUS IM	7	.7
ALTERNATOR	7	5(kVA)
DC SHUNT MOTOR	18.8	3.5
V.V.V.F.	5.5	2.2

4.2 Power Factor calculation

Machine	**Watts (KW)**	**Voltage (V)**	**Load current (A)**	**Apparent power(KVA)**	**Cos □**
1	3.5	220	14.5	4.1	0.85
2	3.5	220	15.8	4.4	0.79
3	3.5	220	10.6	3.85	0.90
4	3.5	220	18.5	4.8	0.83

With the above details we can found that the some machines lag the power factor. Even machines lags below 0.85. It may leads to high cost of penalty while considering industry level. So it is immediate need to improve the power factor.

4.2 Case Study 2: IT Lab

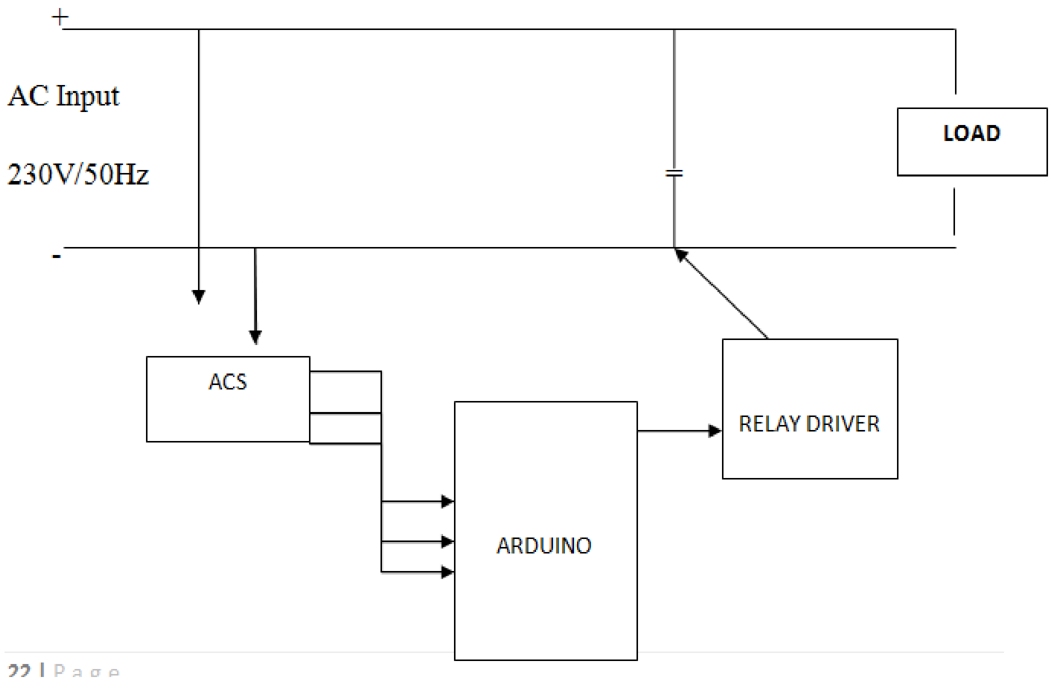
To find further more bulk loads as in machines lab the IT lab in KCG College is so choosed as another case study. In this lab there are about 74 workings systems along with projectors and printers. So it may consumes large amount of power and lags power factor by unity. Though computers consumes less power than machines do, it is need to consider during peak hours. During peak hours or power failure problem it creates huge impact in power factor.

Chapter 5:

Hardware Model:

The power factor lagging in KCG College has been studied and analysed. As to demonstrate the hardware is designed for the proposed system in small level using aurduino. Though some industries has manual switching of capacitor banks, this project proposes for automatic switching of capacitor banks as to improve the power factor. The circuit diagram and hardware description are as follows.

5.1 Circuit diagram



5.1 Circuit Diagram

5.2 Circuit Description:

The above circuit diagram shows the automatic power factor correction Using arduino. The load used here is resistive and inductive load. The resistive load used is incandescent lamp and inductive load is electrical choke. Number capacitors varies depend upon the load. The 4-channel relay driver is used for switching purpose. Initially the power is calculate by current sensor. Through the current sensor the current and voltage can be measured and the values are fed to arduino. With the help of arduino the values of power factor can be calculated with the values of voltage and current. The digital output of arduino shows the the values of voltage, current and power factor in the serial monitor. The arduino is programmed as the following:

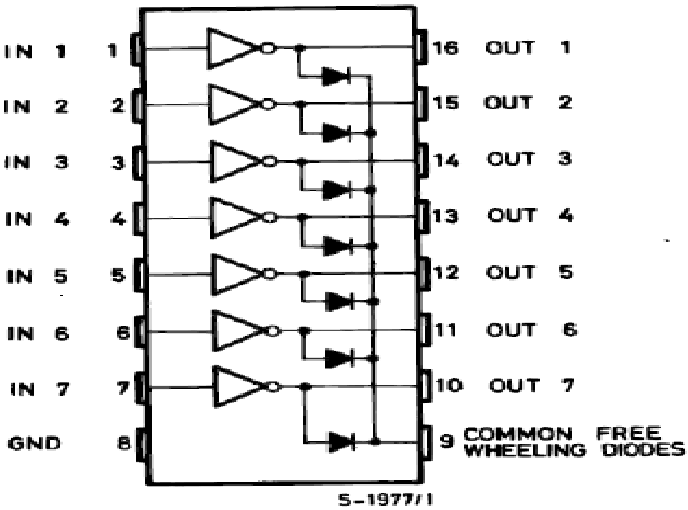
If the power factor lags below unity the relay driver switches the capacitor bank with respect to the values of power factor.

Once the power factor is improved by switching the capacitor banks the it is improved to unity the relay driver switch off from the capacitor bank. Then again the power factor lags below the unity and the relay switches on and so on. The switching operation can be delayed as to our wish with the help of program.

5.3 Relay Driver:

The ULN2001A, ULN2002A, ULN2003A and ULN2004A are high voltage, high current Darlington arrays each containing seven open collector Darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout. The four versions interface to all common logic families

5.1 Relay driver



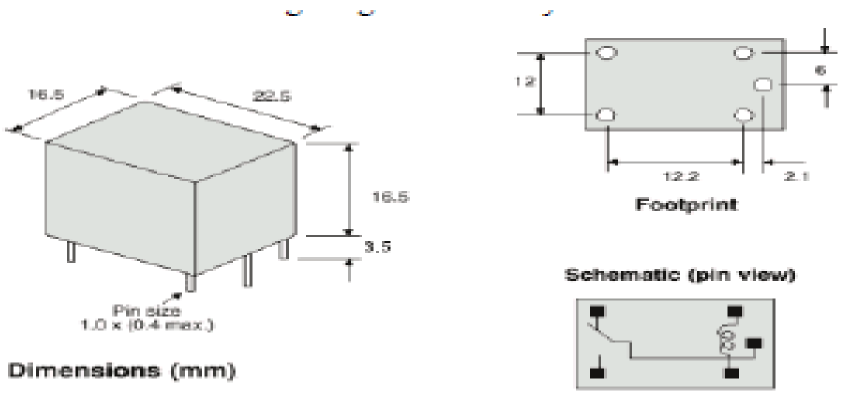
5.2 Relay Driver Pin Diagram

These versatile devices are useful for driving a wide range of loads including solenoids, relays, DC motors, LED displays filament lamps, thermal print heads and high power buffers. The ULN2001A/2002A/2003A and 2004A are supplied in 16 pin plastic DIP packages with a copper lead frame to reduce thermal resistance. They are available also in small outline package (SO-16) as ULN2001D/2002D/2003D/2004D.

5.3.1 Relay Operation:

The relays used in the control circuit are high-quality Single Pole-Double Throw (SPDT), sealed 12V Sugar Cube Relays. These relays operate by virtue of an electromagnetic field generated in a solenoid as current is made to flow in its winding. The control circuit of the relay is usually low power (here, a 12V supply is used) and the controlled circuit is a power circuit with voltage around 230V a.c.

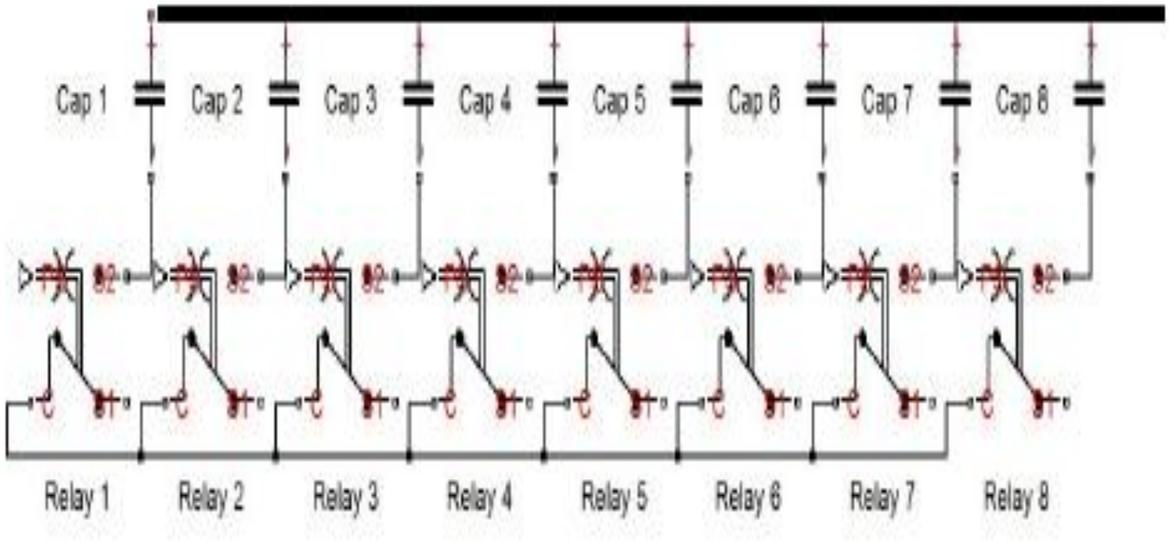
5.3 Sugar Cube Relay



5.4 Relay Circuit Diagram

The relays are individually driven by the relay driver through a 12V power supply. Initially the relay contacts are in the ‗Normally Open' state. When a relay operates, the electromagnetic field forces the solenoid to move up and thus the contacts of the external power circuit are made. As the contact is made, the associated capacitor is connected in parallel with the load and across the line. The relay coil is rated upto 14V, with a minimum switching voltage of 10V. The contacts of the relay are rated upto 7A @ 270C AC and 7A @ 24V DC.

5.4 Capacitor Bank:



5.5 Capacitor Bank Circuit Diagram

A capacitor bank is a grouping of several identical or non-identical capacitors interconnected in parallel or in series with one another. These groups of capacitors are typically used to correct or counteract undesirable characteristics such as power factor lag or phase shifts inherent in alternating current electrical power supplies. Capacitor banks may also be used in direct current power supplies to increase stored energy and improve the ripple current capacity of the power supply. The capacitor bank consists of a group of eight (8) a.c capacitors, all rated at 230V, 50 Hz i.e., the supply voltage and frequency. The value of capacitors is different and it consists of four capacitors of 2.5micro farad, two capacitors of 4.5 micro farad and two remaining capacitors are rated at 10□farads each. All the capacitors are connected in parallel to one another and the load. The capacitor bank is controlled by the relay module and is connected across the line. The operation of a relay connects the associated capacitor across the line in parallel with the load and other capacitors.

5.5 Arduino:

5.5.1 Introduction:

The Microcontroller or the processing module is an interfacing and controlling module, that interfaces the various peripherals and other modules used in the circuit. It integrates the function of current sensor and relay driver.

5.6 Arduino ATmega 328

5.5.2 Overview:

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an

ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

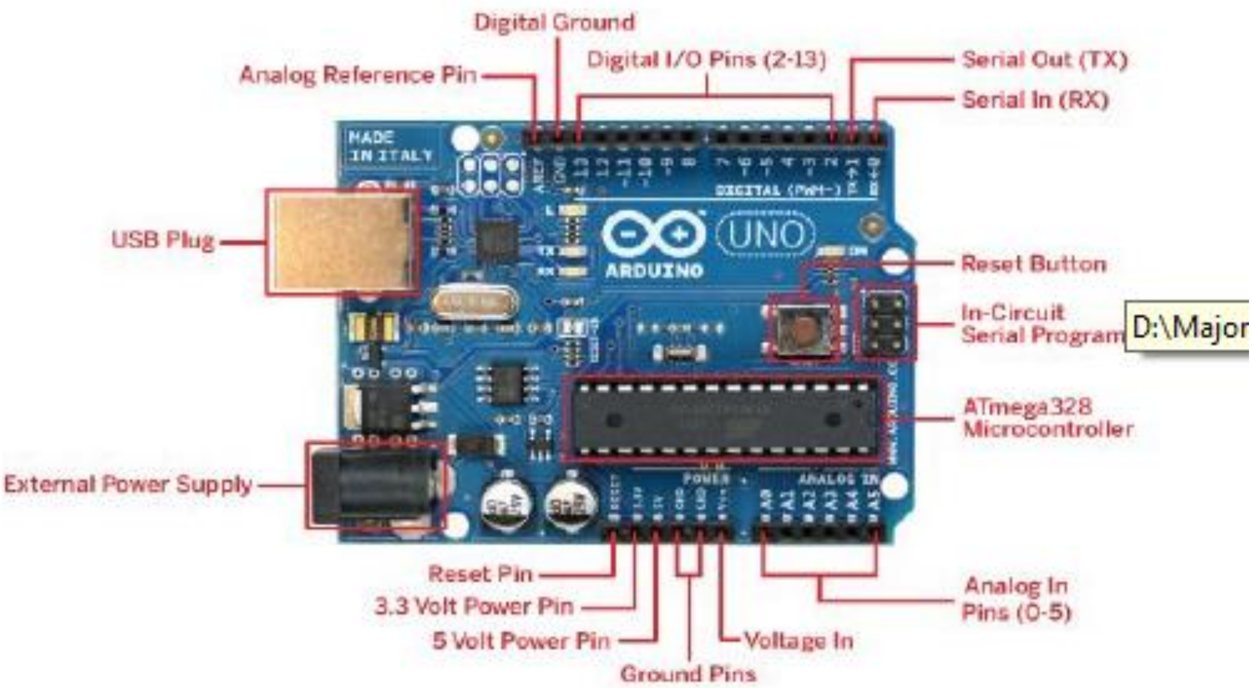
Revision 2 of Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to pit into DFU mode.

Revision 3 of the Uno board has the following features:

a. 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5V and with the Arduino Due that operates with 3.3V. The second one is a not connected pin that is reserved for future purposes.

b. Stronger RESET circuit.

c. ATmega 16U2 replace the 8U2.



5.7 Arduino ATmega 328-pin details

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

5.5.3 Power:

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

1. VIN: The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
2. 5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.

3. 3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
4. GND: Ground pins.
5. IOREF: This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

5.5.4 Summary

5.1 Characteristics of Arduino with ratings

Characteristics	Ratings
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage(recommended)	7-12V
Input Voltage(limits)	6-20V
Digital I/O Pins	14
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328)
SRAM	2KB (ATmega328)
EEPROM	1 KB(ATmega328)
Clock Speed	16 MHz

5.6 ACS712

A current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current. The generated signal could be analog voltage or current or even a digital output. The generated signal can be then used to display the measured current in an ammeter, or can be stored for further analysis in a data acquisition system, or can be used for the purpose of control.

The sensed current and the output signal can be:

Alternating Current input,

  - Analog output, which duplicates the wave shape of the sensed current.
  - Bipolar output, which duplicates the wave shape of the sensed current.
  - Unipolar output, which is proportional to the average or RMS value of the sensed current.
- Direct Current input,
  - unipolar, with a unipolar output, which duplicates the wave shape of the sensed current
  - digital output, which switches when the sensed current exceeds a certain threshold

5.8 ACS71

Chapter 6

Conclusion:

The 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 line to improve power factor & the speed of synchronous condenser can be controlled by microcontroller or any controlled device.

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