FINAL REPORT:

Course: Electrical Machines
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Project Name: "Phase correction power and energy logger with advance billing system"

Abstract:

This paper deals with the measurement of power and energy using AVR. The demand for power has increased exponentially over the last century. One avenue through which today's energy problems can be addressed is through the reduction of energy usage in households. This has increased the emphasis on the need for accurate and economic methods of power measurement. The goal of providing such data is to optimize and reduce their power consumption. This paper explains the process of a condensed design explaination and implementation of a laboratory –scale prototype which includes the energy measurement of the given load and its advantages

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. 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. . When ever we are thinking about any programmable devices then the embedded technology comes into fore front. The embedded is now a day very much popular and most the product are developed with Microcontroller based embedded technology. 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 function generator with high accuracy by using an internal timer. This time values are then calibrated as phase angle and corresponding power factor. Then the values are displayed in the LCD modules. Then the motherboard calculates the compensation requirement and accordingly switches on different capacitor banks. This is developed by using AVR microcontroller. Automatic power factor correction techniques can be applied to the industries, power systems and also house holds 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.

Power factor is the ratio of KW and KVA. KW is the actual load power and KVA is the apparent load power. It is a measure of how effectively the current is being converted into useful work output. Most of industrial electric loads have a low power factor not transcending from 0.8 and thus imparts to the distribution losses. Poor power factor can be the result of significant phase angle isgenerally the result of an inductive load such as an induction motor, power transformer or induction furnace. The existing of reactive power does not included in the electric bill yet this probably causes dissipation power lost at the load which results to an increment of electricity bill charge. Penalty charge is just one of the problems however there are more other problems occur if powerfactor is low. They are

A) Extra losses in feeder cables
B) Significant voltage drop
C) Reduction of effective capacity of cables
D) Voltage drop at the secondary of the transformer
E) Losses in transformer

Chapter 1:

Power factor
Power factor correction
Static correction
Supply harmonics
Supply resonance

THEORY:
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.

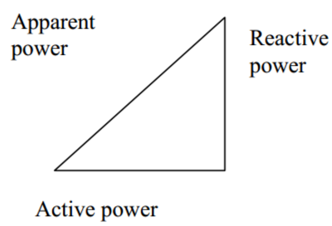


Fig 2.1

All current will cause losses in the supply and distribution 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 Apparent power Active power Reactive power into account that the current waveform is discontinuous and therefore contributes to increased losses on the supply.

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

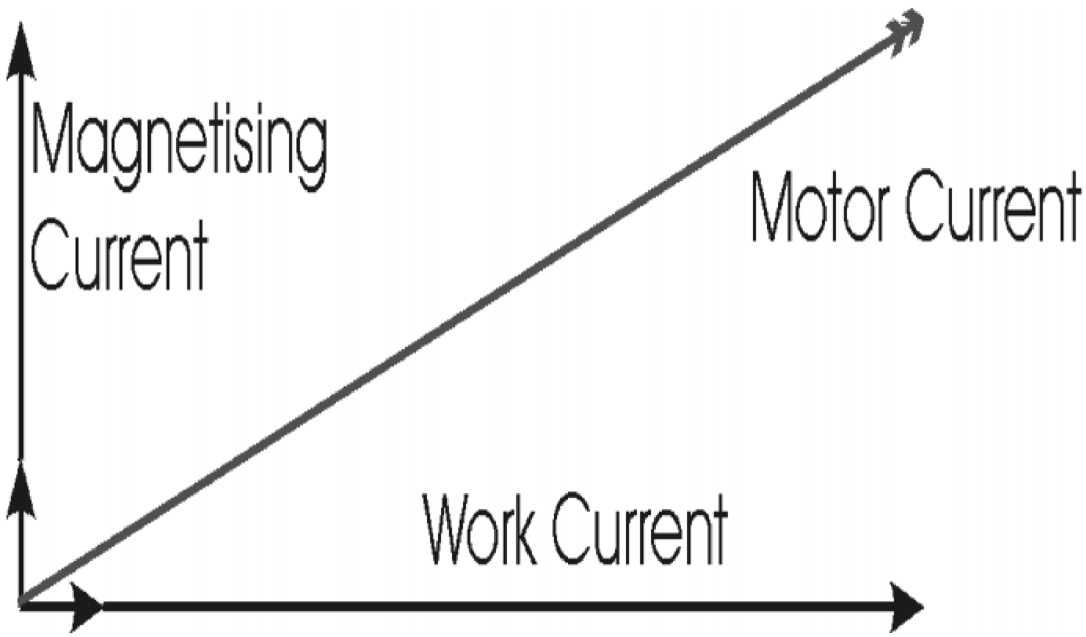


Fig 2.2

The current due to the leakage reactance is dependant 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.

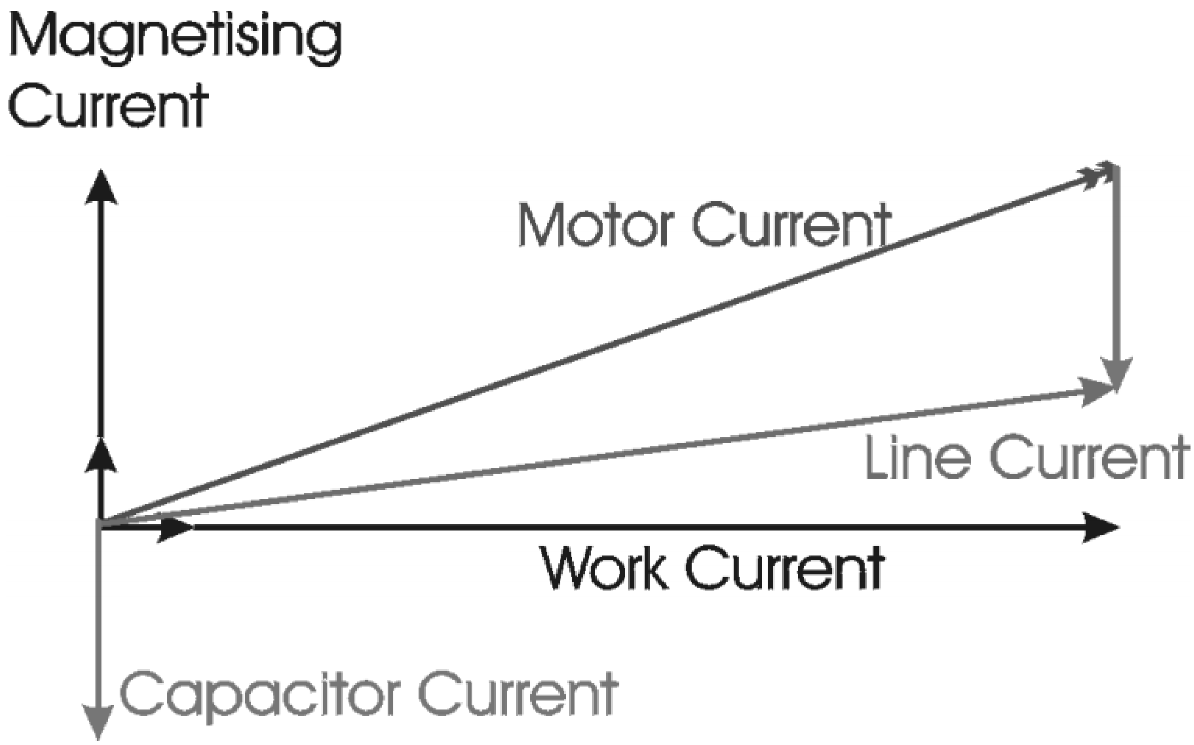


Fig 2.3

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".

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 can not 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.

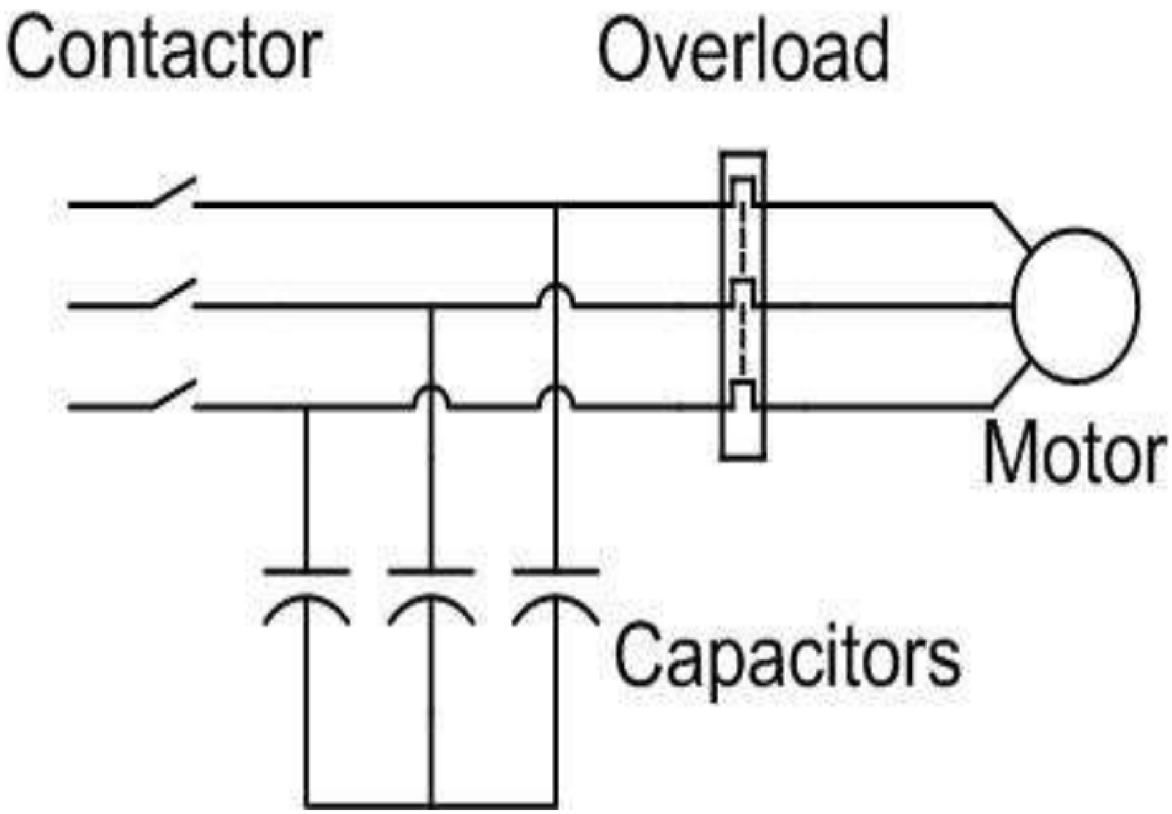


Fig 2.4

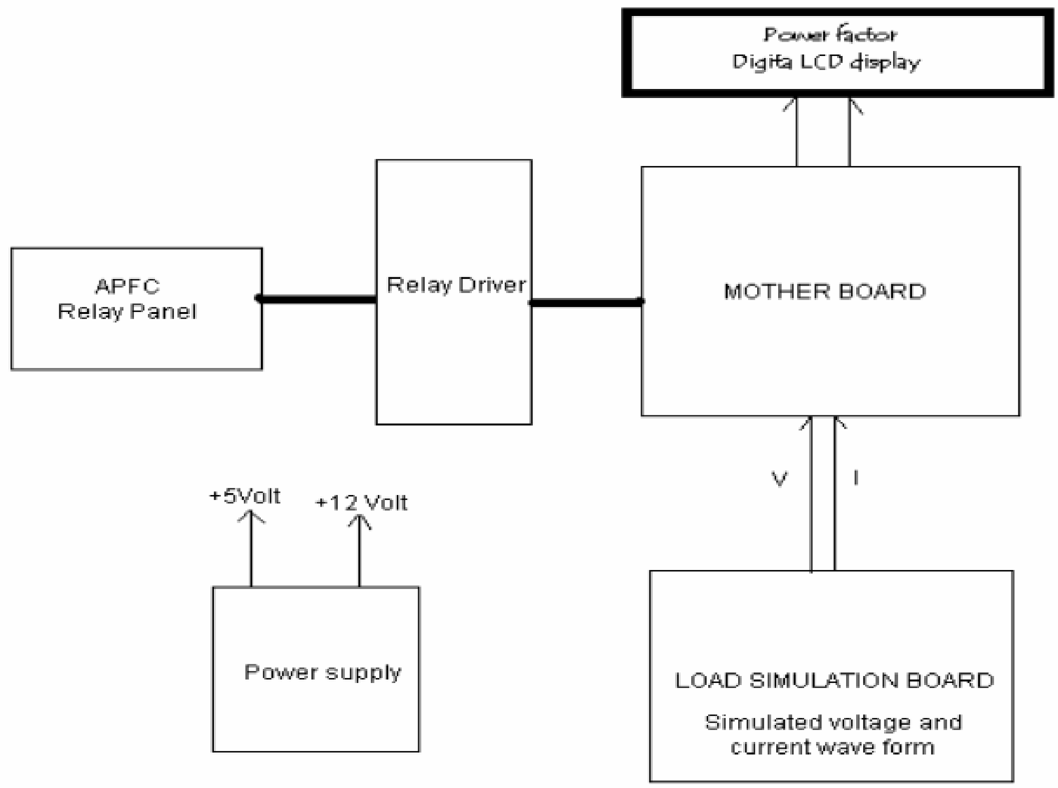
It is dangerous to base correction on the full load characteristics of the motor as in some cases, motors can exhibit a high leakage reactance and correction to 0.95 at full load will result in over correction under no load, or disconnected conditions. Static correction is commonly applied by using on e 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.

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.

SUPPLY 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 can not 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.

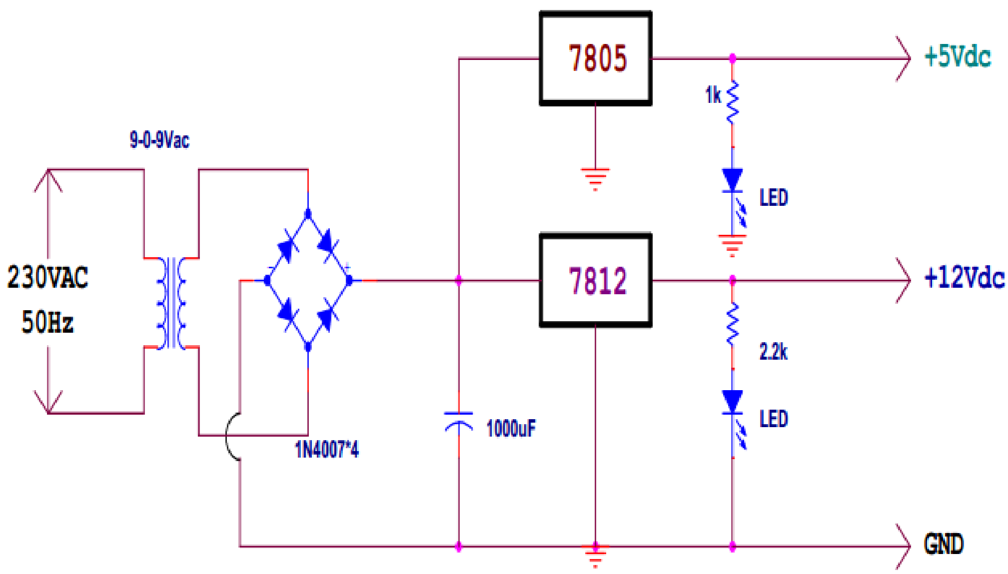
BLOCK DIAGRAM OF AUTOMATIC POWERFACTOR



MODULES:

POWER SUPPLY: In this power supply we are using step-down transformer, IC regulators, Diodes, Capacitors and resistors. Explanation: - The input supply i.e., 230V AC is given to the primary of the transformer (Transformer is an electromechanical static device which transform one coil to the another without changing its frequency) due to the magnetic effect of the coil the flux is induced in the primary is transfer to the secondary coil. The output of the secondary coil is given to the diodes. Here the diodes are connected in bridge type. Diodes are used for rectification purposes. The out put of the bridge circuit is not pure dc, some what rippled ac is also present. For that capacitor is connected at the output of the diodes to remove the unwanted ac, capacitor are also used for filtering purpose. The both (-ve) terminal of the diode (D2 & D3) is connected to the (+ve) terminal of the capacitor and thus the input of the IC Regulator (7805 & 7812). Here we are using Voltage regulators to get the fixed voltage to our requirements." Voltage regulator is a CKT that supplies a constant voltage regardless of changes in load currents. These IC's are designed as fixed voltage regulators and with adequate heat sinking can deliver o/p currents in excess of 1A. The o/p of the IC regulator is given to the LED through resistors, When the o/p of the IC i.e , the voltage is given to the LED, it makes its forward bias and thus LED gloves on state and thus the +ve voltage is obtained. Similarly , for –ve voltage ,here the both +ve terminals of the diodes(D1 & D4) is connected to the –ve terminals of the capacitors and thus to the I/p of the IC regulator with respect to ground. The o/p of the IC regulator(7912) which is a –ve voltage is given to the terminal of LED, through resistor, which makes it forward bias, LED conducts and thus LED gloves in ON state and thus the –ve voltage is obtained. The mathematical relation for ac input and dc output is Vdc=Vm /3.141 (before capacitor) Vd=Vm (after capacitor).

POWER SUPPLY



Power and Power Measurement

Power is rate of expending energy. Watt is the unit for power(joule per second (J/s)). The difference in potentials between two points is equal to the energy per unit charge and this is required to move electric charge between the points, as we know, electric current measures the charge per unit time (in coulombs/second). The electric power *p* is given by the product of the current I and the voltage V (in joules/second = watts).P=work done per unit time=qV/t=IV Where: *q* is electric charge in coulombs, *t* is time in seconds, *I* is electric current in amperes, *V* is

electric potential or voltage in volts.

Energy: The amount of energy used (or supplied) depends on the power and the time for which it is used. Energy is defined by scientists as the ability to do work. This energy is found in different forms, such as light, heat, sound, and motion. There are many forms of energy, but they can all be put into two categories:
potential and kinetic.
E=P*t
Where: E= energy in watt hrs, P= power in watts, t= time taken in sec

DC Circuits:

DC circuits mainly consists of only of resistive (Ohmic, or linear) loads, Joule's law can be combined with Ohm's law ($V = I \cdot R$) to produce alternative expressions for the dissipated power:
P=I2R=V2/R
where *R* is the electrical resistance.

AC Circuits: Eenergy storage elements such as inductance and capacitance results in periodic reversals of the direction of energy flow which are alternating in nature.

Active Power:

The power consumed by the resistive elements in the circuit or the portion of power flow that, averaged over a complete cycle of the AC wave form, results in net transfer of energy in one direction is known as real power ,also called as Active power. It is the power that is actually being consumed by the load.

<u>Reactive power</u>:

Power flow due to storage elements that returns to the source in each cycle is known as reactive power.

When the voltage and current are periodic with the same fundamental frequency, the instantaneous power is also periodic with twice the fundamental frequency.

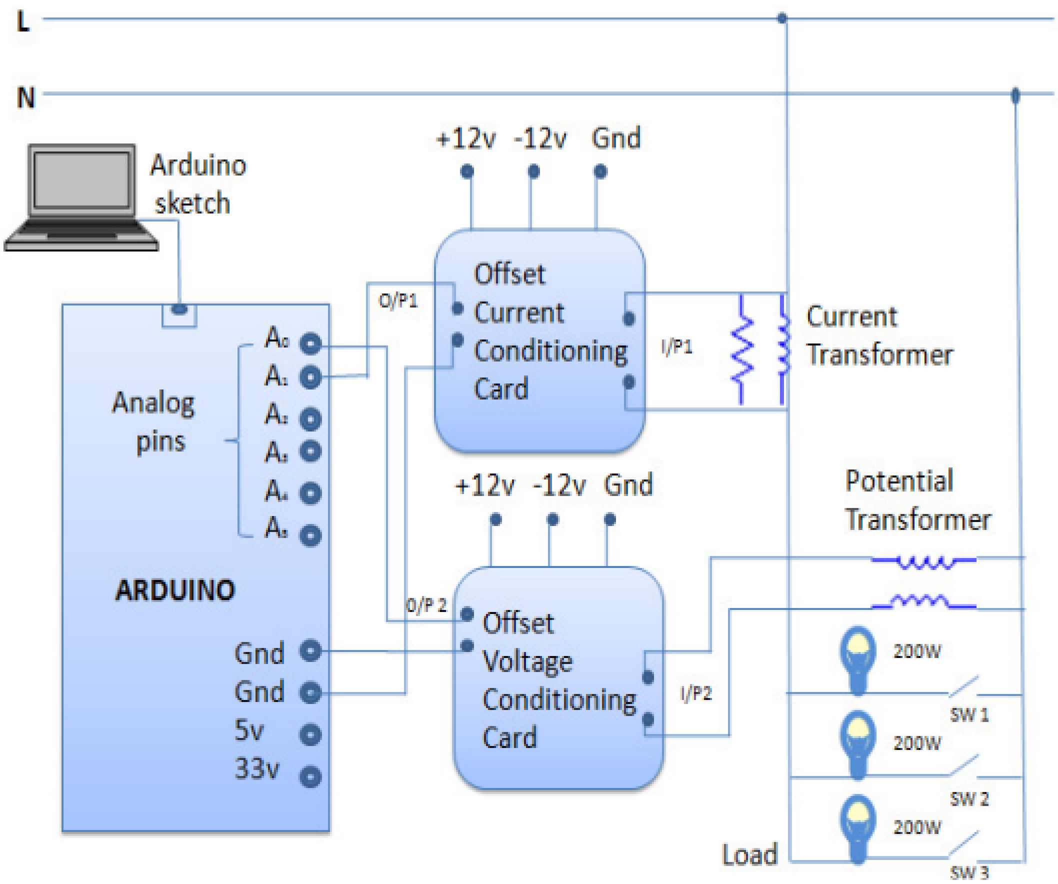


Figure-3(a)
Block diagram for Power Measurement

ZERO CROSSING DETECTOR:

As the name indicates the zero crossing detector is a device for detecting the point where the voltage crosses zero in either direction. As shown in the circuit diagram 2 the first section is a bridge rectifier, which provides full wave rectified output. This is applied to the base of the transistor through a base resistor, R2. The capacitor charges to maximum of the bridge rectified output through the diode, D2. This charge is available to the transistor as VCC. The capacitance value is kept large in order to minimize ripple and get perfect dc. The transistor remains OFF until the Cut-in voltage VBE is reached.

During the OFF period of the transistor the output will be high and approximately equal to VCC.

Once the transistor is ON and IB increases according to the input wave, the transistor moves slowly towards saturation where the output reduces to the saturation voltage of the transistor which is nearly equal to zero

Initially VBE = Cut-in voltage of diode, the capacitor will charge through the diode Vm where Vm is the maximum amplitude of the rectified wave. Now the diode is revers biased and hence does not provide a discharging path for the capacitor, which in turn has two effects. Variation in VCC. It will provide base current to the transistor in the region where both diode and transistor are OFF. Thus an output square wave is produced whenever the input voltage crosses zero thereby acting as a zero crossing detector. A zero crossing detector literally detects the transition of a signal waveform from positive and negative, ideally providing a narrow pulse that coincides exactly with the zero voltage condition. At first glance, this would appear to be an easy enough task, but in fact it is quite complex, especially where high frequencies are involved. In this instance, even 1 kHz starts to present a real challenge if extreme accuracy is need.

CAPACITOR BANK

Capacitors are commonly used within a lot of power system, especially electronic constructed circuitry. In three phase power system, capacitors normally installed within an isolating nonconductor metal box, which called capacitor bank, they are fixed or switched. Fixed banks are connected permanently to the primary conductors through fused switches. Switch capacitors banks are tied to primary system through automated switch, allowing KVAR. This scheme is tend to reduce loss by driving the line leading with first turn on before it is turn off, this is referred as the "two-thirds rule". Taking a daily load cycle, compare with fixed capacitor bank, switching capacitor bank is generally more expensive thus it is essential to take accounting of the cost of installation so that its time value worth for the investment.

A. CAPACITOR SIZE

1) First step is to measure present (old) KVA and PF, or.
get them from power bill
2) Then to calculate active power,'
Active Power (kW) $=PF_{old} * KVA_{old}$
3) Calculate system $kVAR_{sys}$
$kVAR_{sys} = [KVA_{old}^2 - KW^2]^{1/2}$
3) Identify a target PF_{new}
4) Calculate the new kVA using target PF_{new}:
$KVA_{new} = kW/ PF_{new}$
5) Calculate $KVAR_{new}$ once target PF_{new} is achieved:
$KVAR_{new} = [KVA_{new}^2 - KW^2]^{1/2}$
7) $KVAR_{new}$ is the difference between $kVAR_{sys}$ added capacitor's kVAR:
$KVAR_{new} = kVAR_{sys} - KVAR_{cap}$
8) So kVAR of the capacitors to be installed is _
$KVAR_{cap} = kVAR_{sys} - KVAR_{new}$