Electrical Parameter Monitoring Device

By

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Certificate

This is to certify that this thesis submitted by Aown Shah Niwaz Malik and Abdur Rehman is accepted in its present form by the department of electronics Quaid-i -Azam university Islamabad for the award degree of bachelor of science in electronics (bs-electronics). The project work is supervised by Dr. Muhammad Aqueel Ashraf.

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

Acknowledgment

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We thank our college who give us a particularly cutthroat stage to show our abilities. Most importantly, how might we fail to remember our parent's? We might want to thank our parent's for struggling for us and bringing us up on this stage. Without their endeavors, supplicates and help we would not able to be at this phase of life finally, we thank each dignitary who helped us straightforwardly and in a roundabout way through this excursion.

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Abstract

Several technological solutions, like energy management systems (ems), have been created to allow the observing of power and energy, these solutions are still very costly, generally because of the hardware cost yet in addition to their establishment and appointing exertion, which should be performed by qualified faculty only.

Early increases in the demand of cost of electricity has animated interest of monitoring power usage and developing efficiency. In electronic industry, technology is getting more and more advanced. Measurement of electrical parameters in electrical systems through paper work are difficult and time taken. The acceptance of this device is due to make the measurement of electrical parameters easy.

This research work supports development of low-cost power meter proficient of measuring rms voltages, rms current, real power, apparent power, power factor, frequency, energy, phase angle.

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Chapter 1

Introduction:

Electric power or energy have become an ultimate necessity now a days. In now a days we cannot imagine life without electricity. By looking on the importance of electricity, it is very important to discuss the means to use it sufficiently so that the user feel at ease. All electrical systems are basically consisting of two quantities. And those are **voltage**, and **current**. And the electric power is defined as the product of applied voltages and current at any instant of time.

As in early eras they don't have any device to measure any of the electrical parameters, as the time passed the device called multimeter was introduced. But this device can note measure the parameters which are used for monitoring the efficiency of loads or system. They measure basics quantities of electronics like resistance voltages current etc. They use these quantities to calculate the efficiency parameters like power, real power, apparent power, power factor. But now world is progressing at fast rate, in accordance to meet this advancement every equipment's should also be modernized technologically. That's why,

This research report presents the design of single-phase ac power meter based on only two sensors, to easily measure those electrical parameters which needs a calculation to measure. Which is difficult and also time taken. As we know electrical energy is always in a demand for industrial usage. It is on the increment for the improvement of domestic and industrial applications. Quite possibly the most economical methods to fulfill the electrical need is to further develop the system efficiency by rectifying the power factor. The power factor is defined as the ratio of the real power to apparent power.

1.1 Literature Review

1.1.1 Problem Statement

Main concern of this research report is about power. Which is based upon the fact that we are not able to utilize all energy, or the electrical power transmitted towards us. And the studies tell us that low power factor means wastage of electrical power instead of making use to it. Low power means that either current wave is leading or lagging by some angle called (phase angle) to voltage wave. More the phase angle between them means the more wastage of energy or electrical power.

There is one more perspective on it. That the less power factor implies that higher the current needed to perform out a similar amount of power factor. Low power factor in transmission lines implies that you need to expand the size of conductor to transmit similar amount of real power at steady voltages as it carries the large amount of current.

Means higher power factor can actually help us to increase the efficiency of electrical system. And also, it may help in increasing the life of electrical system. As we know the low power factor means the increase in phase difference between current and voltage wave, which have impact on the components of electrical system. And furthermore, it might help in increasing the existence of electrical system.

1.1.2 Different Nature of Loads

The major concern of power factor is with large industries as they have to deal with larger loads then home appliances where the compensation of power factor is very low concern that it can be ignored. As in real world there are three types of loads those are resistive, inductive, capacitive. All of these shows different behavior towards the distortion of power factor.

1.1.3 Resistive Loads

Generally, the resistive loads are considered to show the unity in power factor. Although we know the resistive loads are very limited in real world, but they have no impact on voltage and current distortion. Phase difference between them is ideally zero. And hence the power factor of resistive loads is unity 1.

1.1.4 Inductive Loads

Any type of load which has coil in it is generally known as inductive load. Example of inductive loads are speaker, compressor, motor, inductor, transformer.

Let's understand the basic phenomena of induction. Electromagnetic induction is the phenomena in which emf produced across an electrical conductor because of a continuously changing magnetic field.

According to faraday's law of electromagnetic induction any change in magnetic field of coil will cause an emf to induce in the coil and this called the induced emf. And the current in the circuit called the induced current. Now the concept raise here is that this phenomenon generates some kind of magnetize current which draws reactive power from source.

Generally inductive load shows the lagging in power factor behavior. When inductive load used in electrical system it starts to draw the reactive power in demand for magnetizing current along with real power. The current lags the voltage by some angle in inductive loads. That's why in inductive loads due to consumption of reactive power the power factor is less than 1. Or we say between 0.6 and 0.8.

As less the power factor higher the current will flow from load. And ultimately at some point the load start to resist it and start heat up. And it reduces the efficiency of load and finally machine will not of any use.

1.1.5 Capacitive Load

In real world the contribution of capacitive load is quite much smaller than inductive loads. But still it is necessary to understand the concept of capacitive load to overcome the problems related leading power factor.

To understand it lets consider the generators. Generator controlled its output voltage's by constantly measuring it and adjusting the current fed to the spinning electromagnet. If the load is suddenly applied to it and voltages drops and the regulator acts to slightly increase the electromagnetic current to maintain the desire output voltages. If the load has leading out of phase current this will add to the electromagnetic filed and the regulator must reduce the excitation current to the electromagnet to compensate. The voltage regulator has a limiting capacity of maintain the output voltages as the leading excitation current increase until a point appears where regulator stops delivering the supply current. At this point the leading out of phase current will be able to supply current to whole field and at this stage instability start to produce in output voltages.

As in nature power factor distortion is because of two components. The harmonic current and the excitation current. But the problem of leading power factor is neither because of harmonic current nor because of the lagging reactive current. The reason of this problem is leading reactive current that starts to supply and making the actual source of no use and causing problems. And because of the phase angle between voltage and current the wave in capacitive loads the power factor is zero.

1.1.6 Types of Electrical Power

We have three types of electrical power

- Real power: the power which is actually consumed by the load.
- Reactive power: reactive power is the power that flows back from a destination toward the grid.
- Apparent power: is the product of V_{rms} and I_{rms} .

1.2 Research Motivation:

All the studies and research that have been reviewed, show that there are many methodologies to measure efficiency parameter of electrical system. Through all these we concluded that by using hall effect sensor and high precision transformer-based sensors instead of using differential amplifier method we can measure electrical parameters like voltage, current ,real power, apparent power, power factor, frequency, phase angle and consumed energy with high efficiency rate, low cost and with low rate of power loss. Previously developed designs included the use of differential amplifier and step-down voltages that make the system very expensive, heavy weighted and non-portable, more power loss and difficult to assemble and use. These drawbacks have led the products to be unattractive for consumers.

Now days, Pakistan is facing a lot of energy crises. This resulted in increment of cost of electricity production, as this cost has direct effect on consumers' income. This factor has motivated us to develop such a system. Above all draw backs, the main factor that motivated us to remake this design of electrical parameter monitoring devise is that the due to low voltages and fluctuating current from grid station damaged the electrical system and at industrial level we cannot afford this. We presented a solution to this by designing this parameter monitoring devise at low cost and reusable. We measured dimensions of each module involved in the design very thoughtfully so that it occupies less space. We were motivated to arrange all the components of this system in such a manner that the final product must not be larger and costly often done by using the voltage and current sensor module after doing some calculation in programing. Whenever we supply the ac voltage and current to our device it will be sensed by the sensor modules. This device also has manual calibration to read the parameters accurate and efficiently. This framework is fulfilled by Atmega 328 microcontroller, it comprises of Arduino ide, voltage sensor, current sensor, lcd keypad shield

1.3 Objectives

The objectives of this research work are

- To measure the voltage and current supply from grid station
- To measure the real and apparent power
- To measure the power factor
- To measure the frequency
- To measure the usage of energy
- To measure the phase angle

1.4 Overview

This research report contains all the relevant information gathered from different sources before the start of the project. The first part provides details of the studies on the relevant theories associated with power factor meters. Then the details about zmpt101b(voltage sensor), acs712 (current sensor) and Arduino is presented together with their applications in the project. After that some determinations are presented. And the software applications used to design are also introduced here. Methodology we used for power factor meter is also explained and finally the results which we gathered after experiments are also explained in this report.

Chapter 2

Hardware Modules

Before designing this system, we reviewed each module involving in this project design. As the objective of this project was to design a device which can monitor the electrical parameters to check the efficiency of electrical systems for this purpose, modules used in this project contributed the challenges we faced during the proper

assortment of the modules. From selecting a sensor to a powering up the whole system, is discussed in this chapter.

2.1 Selection of Sensors

As a basic function, we looked-up for a technique through which we could continuously measure ac voltages with higher sensitivity and reasonable range. After a deep study and research, we came across these results that the methods like difference amplifier or voltage divider that was used to measure the voltages and current are widely used and are not efficient due to more power consumptions and difficult to use by users. Our focus is to choose a sensor that would be yet efficient, high range, higher in sensitivity and off Corse it must be low in cost. Figure 1 below shows the hall effect phenomena.

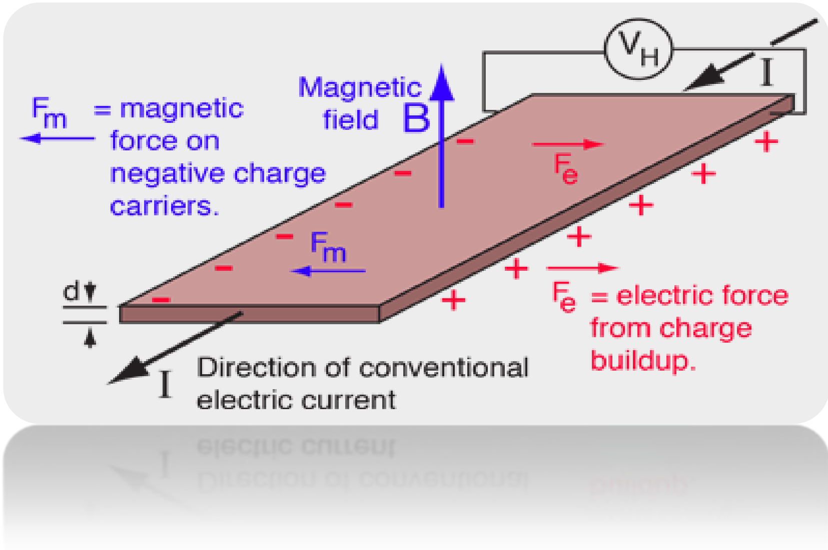


Figure 2.1

That’s why we select the hall effect-based sensor for current, and high precision voltage transformer-based sensor for voltage measurement. Because hall effect sensors worked by measuring the voltages produced across the edges of current carrying conductor called hall element when it placed in magnetic field. And note that the voltages that are generated are perpendicular to both the direction of current and magnetic field. These sensors are built to be sensitive to the slight changes in voltages or current. And the high precision voltage transformer used to step down the voltage under the range of microcontroller because most of the microcontroller measure voltage under the range of 5v. So, we need to step down the ac 220v volts. Figure shows the high precision voltage transformer.

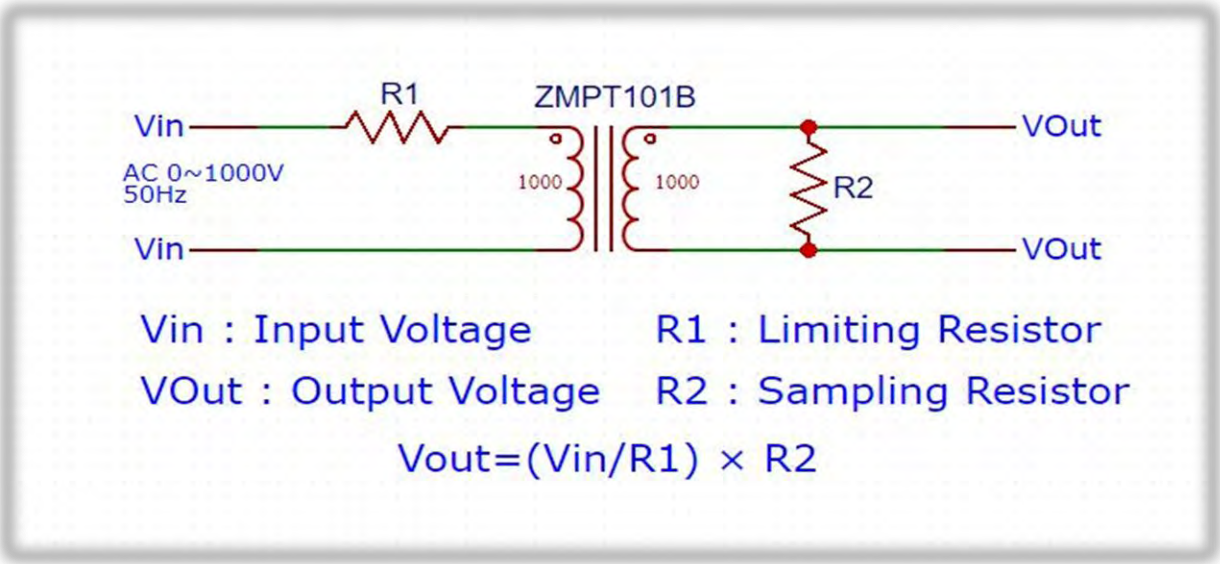


Figure 2.2

Before selecting the sensor, let's examine different type of sensor current and voltage sensor.

2.1.1 Voltage Sensors

- Dc voltage sensor module
- Zmpt101b

Dc voltage sensor module

This dc voltage sensor module based on a principle of resistive voltage divider phenomena. This sensor works in between 0v to 25v. And note that these voltages are only dc because this module is not design for ac voltages. If you are using Arduino analog input pin of 5v then the maximum input voltage will be 5v*5=25v. But if you are using the Arduino analog input pin of 3.3v the maximum input voltage is only 3.3v*5=16.5v only.

Description

Weight	4gm

Dimension	28*14*13mm(l*w*h)
Input voltage range	Dc 0 to 25
Voltage detection range	Dc0.0245 to 25v
Analog voltage resolution	0.00489v
Output interface	Red terminal + with vcc, negative with ground

Zmpt101b

This voltage sensors are designed to monitor the smallest changes in voltage signal. Among the transformer-based voltage sensors zmpt transformer sensors has a wide range with higher sensitivity. The zmpt101b was best meeting our requirements for our voltage monitoring device. So, we decided to use zmpt101b as we focused more on power factor. And the dimension of sensor also contributes. And also, this module used the good quality of amplifier to amplify the input signal step downed by transformer.

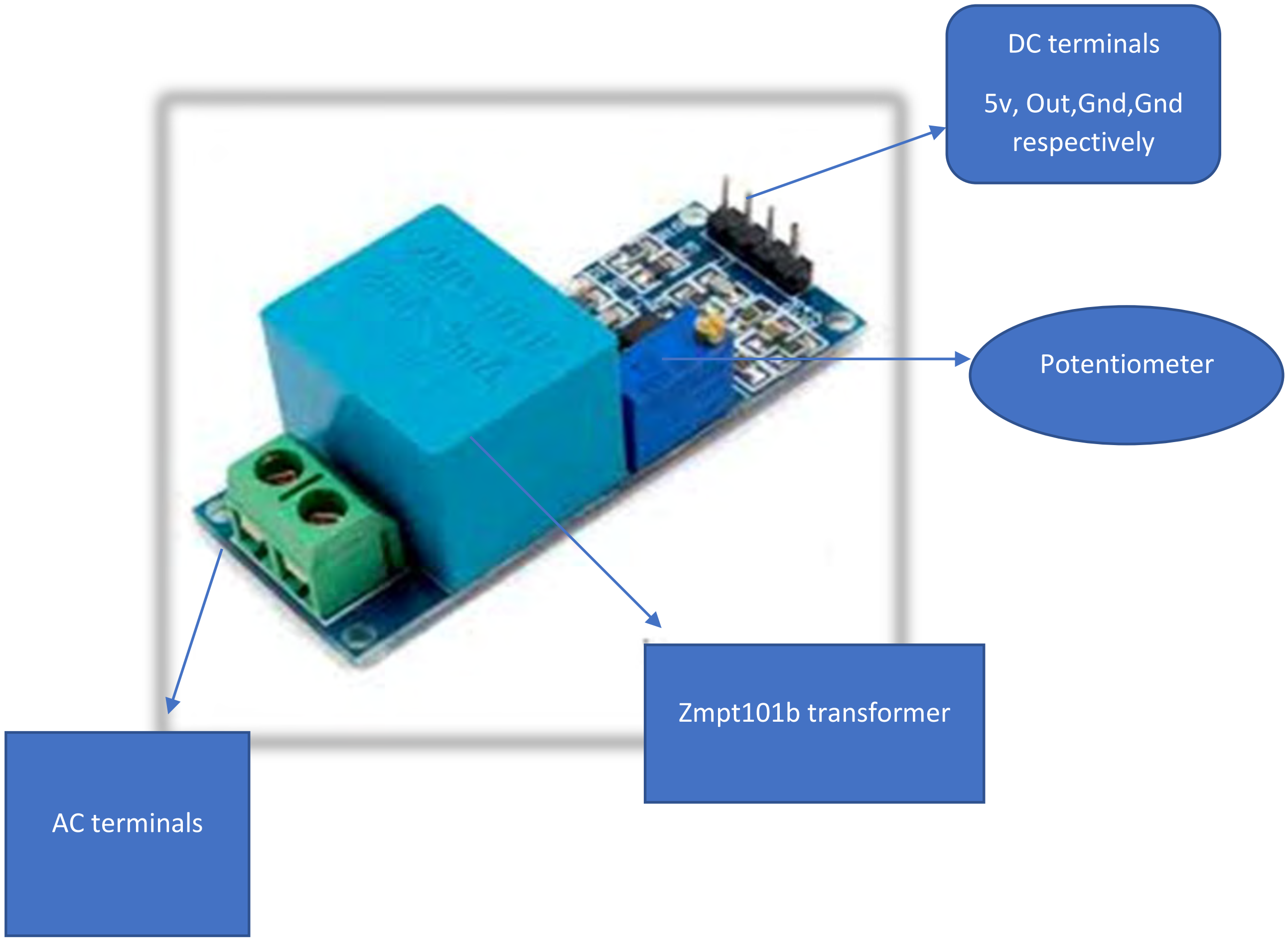


Figure 2.3

2.1.2 Current Sensors

- Acs713
- Acs712

Acs713

When we talk about the current, we focus on high sensitivity because current wave is changing continuously specially at the point where load is connected. So, we study acs713 sensor. But after study it we conclude that this sensor has not a wide range of sensitivity and also this sensor is designed only for dc supply. As our main focus is on ac supply so wo refused to use it.

Acs712

After study the different sensors we reached to this that we have to use Acs712 Hall effect based linear current sensor. Because it has wide range of sensitivity, stable output current, and this sensor consist of precise low offset. And specially that this sensor is designed for both dc and ac currents. So, we conclude that this sensor meets our project requirements. Figure below shows the acs712 current sensor.

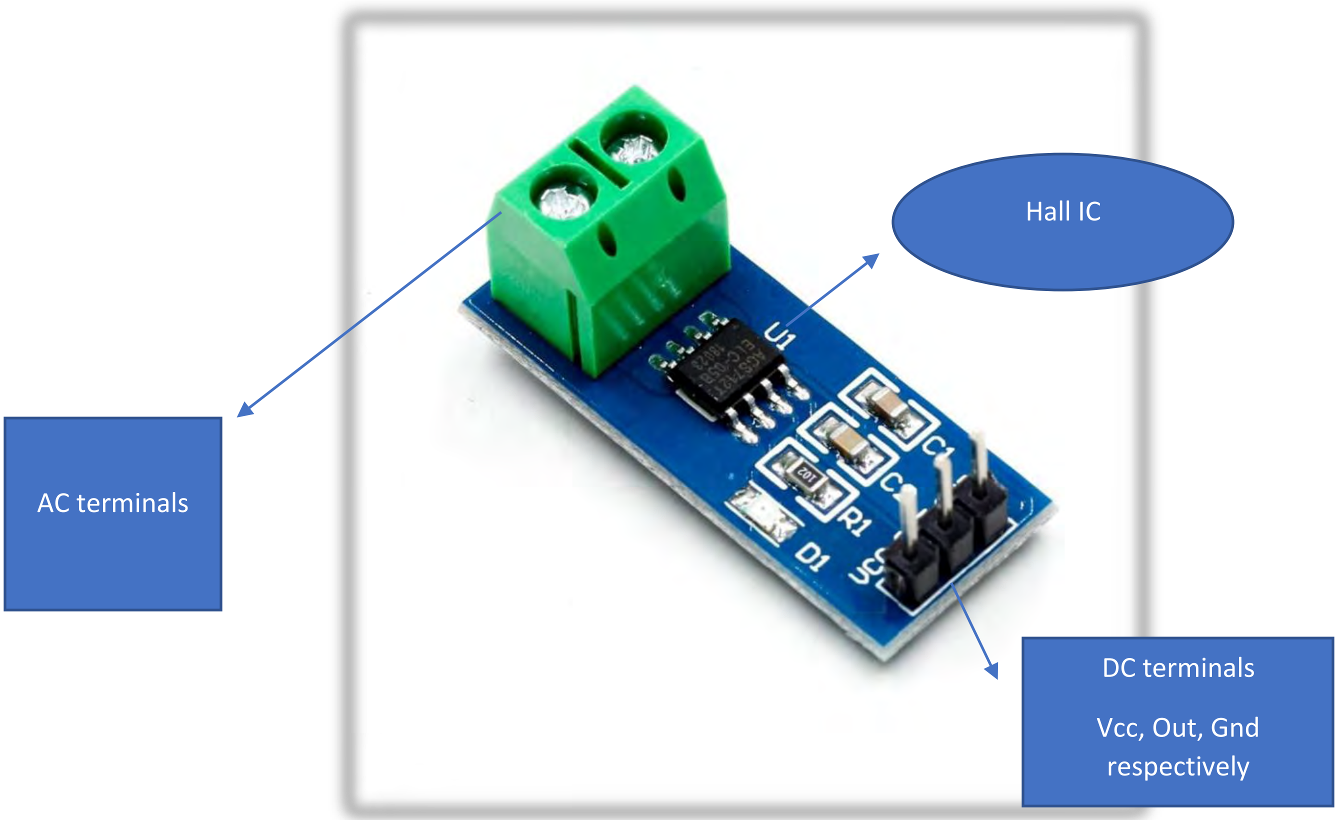


Figure 2.4

2.2 Detailed Explanation of Sensors

2.2.1 Zmpt101b Voltage Sensor

This zmpt101b voltage sensor is made by zmpt101b voltage transformer. It changes the ac mains voltages signal into appropriate signal which is understandable by our programing board. This module has good consistency for power and voltage and has a high accuracy. This module is designed for both ac and dc voltages. It can measure up to 250v ac. The internal circuit of this module is shown below.

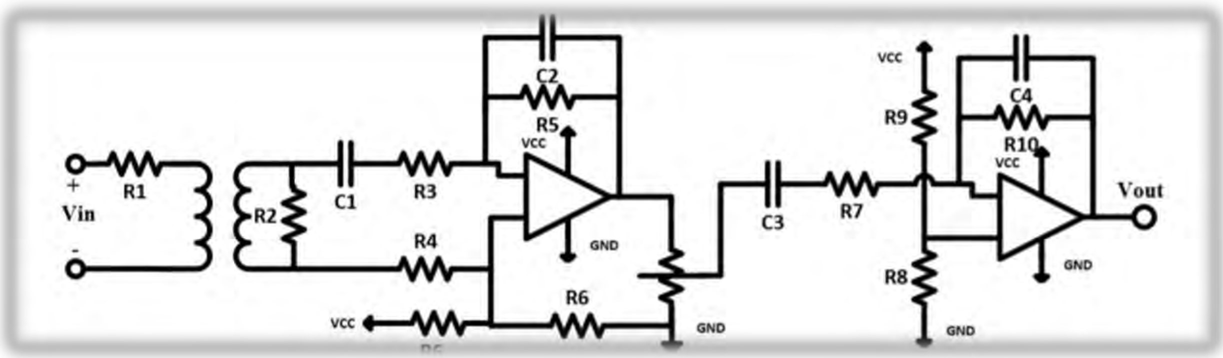


Figure 2.5

This module used the attenuator after the ac supply with the tolerance of less the 5Vacpp. The output wave of this circuit is changing(riding) on dc voltages as an offset voltage of about 2.5v. This module also has a potentiometer to adjust the amplitude of output wave. But this output voltages amplitude should not be greater the 5v.

This voltage sensor module has zmpt101b current transformer with low load of impedance. This zmpt101b module is small in size and it has good quality of isolation with good consistency for measuring the voltages.

2.2.2 Basic Statistics

Shape	**Rectanguler**
Price	380rs
Output	0 to 5v
Sensitivity	0 to 250v ac
Power supply	5v
Frequency	50hz and 60hz both

2.2.3 Arrangements Of Zmpt101b Sensor

For our project we use 1-zmpt101b module. It's ac two terminals are directly connected with ac source or supply. We connect fuse between ac supply and sensor module to protect our device from fluctuating current. The pins on the other side are for dc connections. Pin 1 is Vcc pin directly connected with 5v dc. You may connect it with 3.3v dc but at these low voltage's sensor will not work properly even it is also possible that sensor may damage. Because this module is designed as 5v dc against 250v ac. The second pin is for output connect it with analog pins of Arduino. And the third pin is connected with ground to complete the circuit.

2.2.4 Working Of Zmpt101b

Basically, the zmpt101b is a transformer in this module. And through the transformer the power remains same but the voltage and current will change.

Transformer

Is a passive component use to transform electrical energy from one point to another. As we know it has two types.

1. Step up
2. Step down

Here in this project, we used step down transformer-based module because we need voltages under the readable range of Arduino. And the step up or step-down phenomena primarily based on the primary and secondary winding of the transformer. If primary side winding has more turns the secondary side winding, then this transformer is step down transformer.

A zmpt101b transformer does this with voltages. This sensor module also equipped an op amp circuit with that high precision transformer. It can measure up to 250v ac. The output signal against the given input can be adjustable by trimmer potentiometer. It measures the analog values from 0 to 1023 from the instantaneous voltage wave form. Voltage analog signal needs to be calibrated because the amplitude of voltage wave form is adjustable.

Calibration of voltage sensor

In order to calibrate the voltage sensor module, we need any other meter which can measure the ac voltage as reference. But the meter you take as refence has ability to measure rms voltages. Which can be regular voltmeter or a simple multimeter. Because the voltage that voltage module can measure are rms voltages. And technically the sensor measures the waveform in peak voltages.

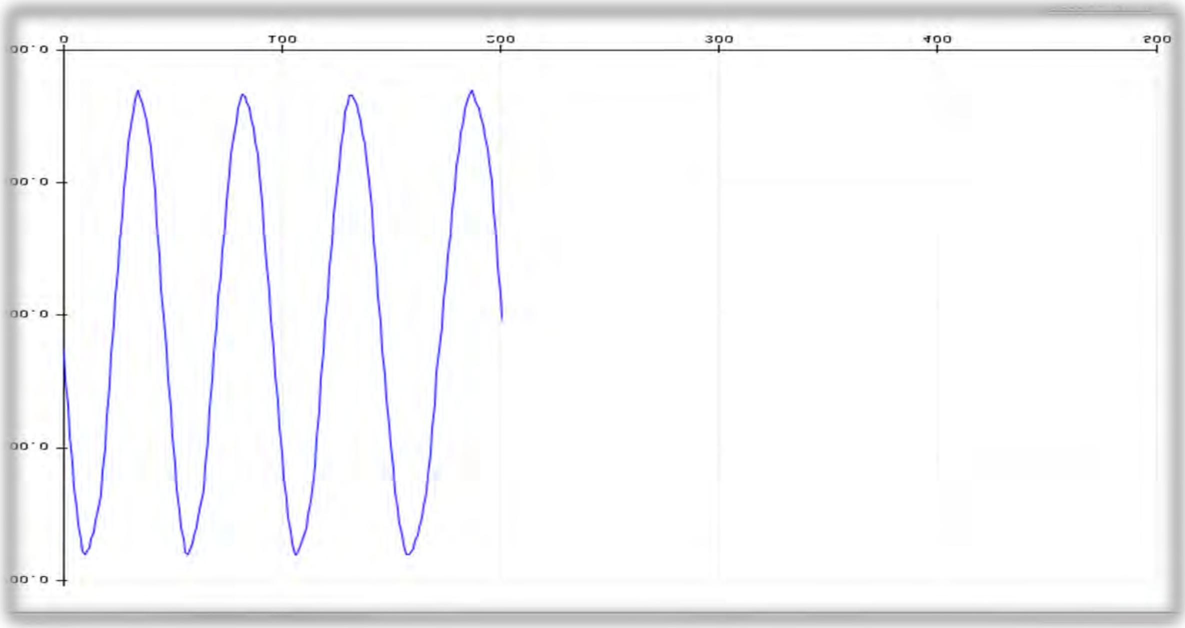


Figure 2.6

To calibrate this sensor module, we have two methods.

1. First, we have to determine the peak value of voltages given by module, using serial monitor or serial plotter. Then we have to convert these peak values into rms values. Then compare the value of those rms voltage with any other rms voltage reader like multimeter or any other energy meter.
2. Upload the code for sensor module in controller. Now adjust the voltage waveform using trim pot potentiometer given in module and compare the voltage display on lcd or serial monitor with any other rms voltage reader taken as reference.

Now after the calibration the sensor module is ready for use.

2.2.5 Lm358

The operational amplifier ic. It has two operational amplifiers with high gain, and both are powered by single power supply from 3v to 32v. But it can also work with two different power supplies with ±1.5v to ±16v. These two operational amplifiers will work as a comparator. The differential input range of this IC is equal to the supply voltages. The magnitude of input offset voltage is very low, which is about to 2mv. The supply current is in between 500_{ua} to $700_{ua,}$ and it is independent of supply voltages. This IC has large dc voltage gain of 100db. This IC has one output pin and two input pins. One of the input pin is positive and other one is negative. Positive pin used for positive feedback and negative pin for negative feedback. It will increase and provide the output voltages when voltages at positive pin is higher than the negative pin.

2.3 Acs712 Current Sensor

Acs712 current sensor module is one of the widely used sensor for Arduino. This module utilizes the phenomena of hall effect to measure the ac current. With the help of the voltage which are generated due to the movement of current with in the region of magnetic field. And now these generated voltages are directly proportional to the applied current and make it suitable to measure the applied ac current through the sensed voltages. This sensor has three variants 5a,20a,30a., consist of precise low off set circuit with coper conduction path near surface of die. As acs712 is provided in a small surface mount soic8 package.

2.3.1 Arrangements

For our project we use 1-acs712 module. One of its ac two terminals are directly connected with ac source or supply and other one is connected in series with the load to measure the current across the load. We connect fuse between ac supply and sensor module to protect our device from fluctuating current. The pins on the other side are for dc connections. Pin 1 is Vcc pin directly connected with 5v dc. You cannot connect it with 3.3v dc like voltage sensor module because at these low voltage's sensor will not work. Because this module is designed for 4.4v dc to 5v dc. The second pin is for output connect it with analog pins of Arduino. And the third pin is connected with ground to complete the circuit.

2.3.2 Working of Sensor

As we know it worked on the base of hall effect, so there will be a presence of Lorentz force, and due to the presence of Lorentz force, the distribution of current in sensor is no more uniform across the current carrying conductor or hall element that's why the voltage generated across the edges of hall element is perpendicular to the direction of both the current and the magnetic field. These generate voltages are in few microvolts.

When we apply the current through the coper conductor, then the built-in hall element sensed the magnetic field generated by the current and the hall transducer convert this magnetic field into the voltages. The flip chip technology allows the transducer to be placed over the portion of the loop where the magnetic field is strongest. The flip chip technology also allows for the connection of the signal leaves of the ic to the package leaves on the other side of the package. There is an insulating layer of plastic between the two terminals. This insolating layer provides high voltage isolation which allows the sensor IC to be used in ac lines.

now according to literatures there is a linear relationship between the input conduction current and the output hall voltages. Because the strength of magnetic field is directly proportional to the current through conduction path. The induced hall voltages are stabilized and enhanced by the on-chip signal conditioner and filter circuit to an appropriate level to measure it through ADC channel of microcontroller.

There is an internal resistance r_f connected between output buffer stage and the output of on chip signal amplifier and the other end of the resistor can be controlled externally through pin 6(filter pin). And this resistance is very low in this module which is about to 1_{mohm} due to which the power loss in this circuit is very low

This sensor module can sense in two direction.

1. Current flow (current enter from positive and out from negative)
2. Reverse current flow (current enters from negative and out from positive)

In reverse current flow the produced voltage will be reduced, but it will not damage the sensor. The analog pin of Arduino only reads the positive integer value, that's why to measure in both directions, your zero point should be half of the total voltage range and that is 2.5v dc because this sensor module works on 5vv dc.

2.3.3 Basic Statistics

Shape	Rectanguler
Price	350rs
Output	4.4v to 5v dc
Sensitivity	185mv/amp for 5a 100mv/amp for 20a 66mv/amp for 30a
Power supply	5v
Frequency	50hz and 60hz both

2.4 Arduino Uno:

In our project, one of the main components is Arduino uno. This is the main controller, or we say the master device in our project which is controlling the whole system. It has various parts which helps in proper functioning.

2.4.1: Overview:

Arduino uno is an open-source microcontroller board containing its main microchip Atmega 328p. In our project we use complete board of Arduino uno instead of using the atmega328p chip.

1. In our project, Arduino uno is used to run the program code.
2. It is used to power up the lcd keypad shield and the voltage and current sensor to operate the circuit.

Following figure shows the Arduino uno:

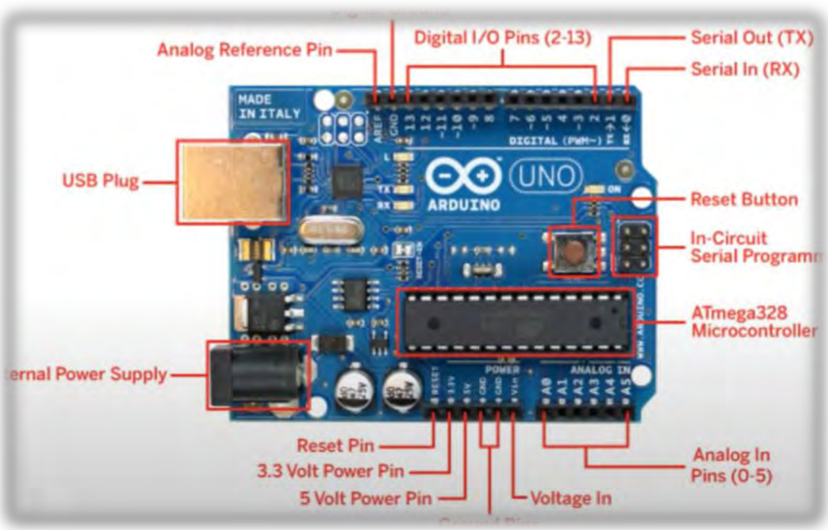


figure 2.7Arduino uno

2.4.2: Arrangement of Arduino Uno:

Arduino uno consists of both a physical programmable circuit board and a piece of software. The major components of Arduino uno are usb connector, power port, microcontroller, analogue input pins, digital pins, reset switch, crystal oscillator, usb interface chip and tx rx led's.

In our project we used only the analogue channels of Arduino uno, because we have only analogue outputs from both voltage and current sensor circuit. And, we use 5v dc and ground to supply the sensors circuit.

2.4.3 Atmega 328p:

This microchip plays a vital role in programming the whole project. The program is loaded to the Arduino using this microchip. It controls everything that goes on the device. It fetches the program instructions from flash memory and run it with the help of ram. It consists of 28 pins.

Following figure shows the Atmega 328p

Figure 2.8

Pin description of Atmega 328p is shown below in figure:

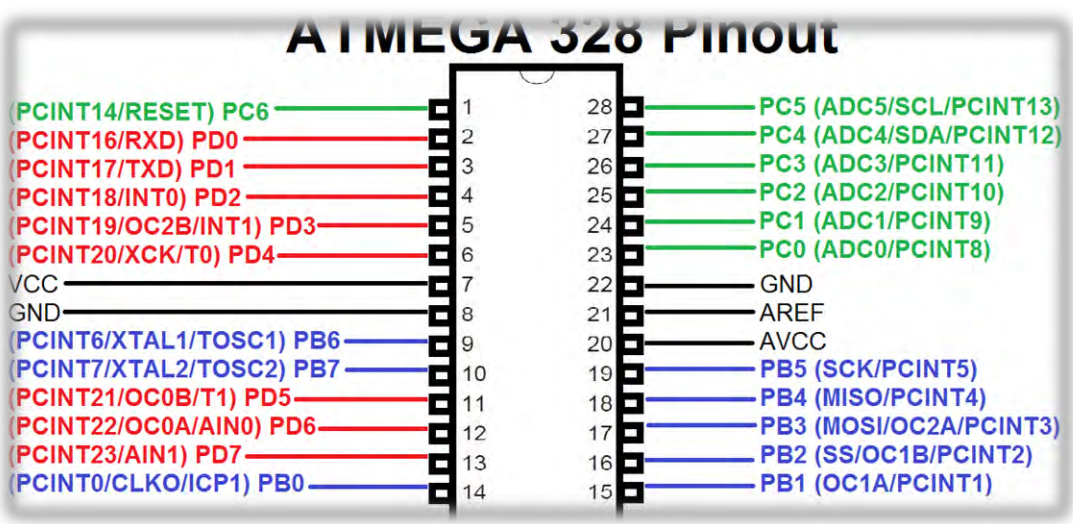


Figure 2.9

In our project, we load our programming code into this microchip to measure the electrical parameters.

2.5 Lcd Keypad Shield

We found two type of display that meets our project requirements.

1. Lcd display
2. Lcd keypad shield

We can also use lcd display to show our output results. But during project we are facing a technical issue that after the experiment, lcd is continuously show some values even after we off the circuit. It is because of lcd calibration we don't have method to calibrate the lcd. So, it becomes at zero reading.

Because of this issue we decide to use lcd having keypad shield. In this lcd we have switches to perform some work. And it is easy to use, because by using this you don't need to use the i2c communication because it is made to fix on Arduino without wires, so all the pins are connected directly and working properly. Also, it connects the analog and digital channels of Arduino board with your analog outputs of different sensors. It also has a potentiometer to adjust the contrast of lcd. By using the keypad shield module, i can calibrate my lcd easily by use of the button present on it.

Shape	**Rectangular**
Price	300rs
Columns	16
Rows	2
Supply	5v dc

2.6 Fuse

In our devise we also use fuse to protect the components from fluctuating current. We use two fuses. One is of 5a and other one is of 3a. 5a fuse is connect in series with voltage sensor module. And other one the 3a fuse is connect in series with the current sensor module.

Chapter 3

Determination of Electrical Parameters

In this chapter we discussed in detail the important terminologies that was used in our project, or we say on which our project is based. Like V_{rms}, I_{rms}, real power, apparent power, power factor, phase angle. We also in this chapter we discuss the theoretical calculation of these calculation.

3.1 Rms Voltages

Rms stands for root mean square and these voltages also called the (effective voltages). This is a method that is used to denoting the voltage sine wave or we say ac wave as its equivalent voltages. Also, these voltages represent the dc values that produce the same amount of heating effect, and power dissipation in circuits.

Voltage can be representing by both ac and dc waveform but they are in different forms. As we know dc voltage is one-way just constant voltage, they don't have cycles. But the ac waveform will be fluctuating between positive and negative cycle. That's why the rms values are important. It allows us to compare the power that an dc wave form and in ac waveform can give to circuit.

Note that rms voltages are not an average voltage. It is a method which follows three steps, root, mean and the square. It means it is the square root of the mean(averages) value of squared function of instantaneous value.

3.1.1 Calculation

For calculating the rms, we need to know about the peak voltages.

Peak voltages are the values at the highest point of the voltage wave form.

Peak to peak is the difference between the positive and the negative point of waveform.

Now to calculate the rms voltage value we use the peak value factor which is.

$Vrms = Vpeak * 0.707$

Or

$Vrms = Vpeak/\sqrt{2}$

3.2 Rms Current

As we know that ac is an alternating current, it will change its magnitude and direction periodically. There for the average value for alternating current will always zero. Because when we take the average value then positive values will cancel the negative value. This the reason of using the rms value for defining the alternating current. Because rms provides the same amount of heat in the time interval in a circuit. And it is equal to the values that dc current provides in same interval.

3.2.1 Calculation

$$Irms = \frac{Ipeak}{\sqrt{2}}$$

Or

$Irms = Ipeak * 0.707$

3.3 Real Power

Also known as true power, active power. Defines as the power used or consumed by the resistive component of machine to do useful works. The real power is measure in **watts(w)**. It signifies the power that will be drawn by the internal resistance of circuit. Real power in ac circuits is same as the power is dc circuits for single phase electrical system the real power is

$\boldsymbol{P = VICos\theta}$

Here:

- V is the rms voltages
- I is the rms current

- θ is the phase difference between the applied voltage and applied current. And it is also known as phase angle.

there is zero phase difference between the voltage waveform and current waveform. They are in phase.

There is an alternate calculation for real power. That is by taking the average instantaneous value of power over a cycle. Means the average value of voltage multiplied with the average value of current from each of the discrete points measured in a cycle.

3.4 Apparent Power

It defines as the product of rms value of voltage with the rms value of current. It measured in **volt-amp** (**Va**). The apparent power is made by two parts, one is the power by resistive part known as real power which is in phase and the reactive power which is the out phase. Apparent power represents two types of load, one is inductive and other one is resistive. We can use the vector diagram to represent the relationship. It represents by s.

$AP = V * I$

Or

$S = V * I$

3.5 Reactive Power

Reactive power is known for imaginary power also called non-real power from inductive loads and capacitive loads. It is represented by **Q**. Reactive power generally measured in VARS (vol-ampere reactive). In electrical systems, reactive power I defined as the power that flaw back from load towards the AC source. As in DC the load and voltage are static, but in AC current there are different phases having to do with elements of the system like capacitors and inductors.

We have two types of reactive power

1. Positive Reactive Power: is caused by inductive loads such as motors and transformers (especially at low loads).
2. Negative Reactive Power: power is caused by capacitive loads. This can include lighting ballasts, variable speed drives for motors, computer equipment, and inverters (especially when idle).
3. $Q = V * Ir(Kvar)$

3.6 Power and Power Factor

Power which consumed by the resistive components of circuits and dissipated in the form of heat and not returned back to the source called true power. Also defines as the rate at which energy is consumed. In ac circuits current is rises to peak values and diminish to zero many times in a second. In ac circuits power is the vector sum of two powers. In purely resistive circuits true power is equal to the apparent power because phase difference in voltage and current is equal to zero in purely resistive circuits. But in purely capacitive and purely inductive circuits the current and voltages are 90' out of phase. Now the power factor, it measures that how efficiently the ac current is converted into useful works, in easy words we can say that power factor tells us about the efficiency of electrical system.

Now as we know that the power factor is define as the ratio of true power (real power) and the apparent power. But power factor can also be defined by using the formulas of true power and apparent power. That's why power factor expressed as

$$PF = \frac{RP}{AP}$$

Or

$$PF = \frac{VIcos\theta}{VI}$$

In purely resistive circuits there is no phase difference between voltage and current wave form. That's why the angle between them is zero. And the cosine of 0 is equal to 1. It means power factor is 1. Which means the total energy that is delivered to electrical system is consumed without any loss. But in purely reactive and inductive circuits the phase angle is 90 between voltage and current wave form, and the cosine of 90 is zero (0). It means 0 power factor. Which means the system return all the energy back to source. There is another important point, which is that in a circuit where resistance and reactance are equal the current and voltage waveform are displaced by 45 degrees. And the cosine of 45 is 0.7071. This means the circuit returns the 30% of energy back to source and consumed 70% of energy delivered by source. It means we can say that the load with power factor of 1.0 is the most efficient load. And the load with 0.5 power factor is not efficient yet. In practice we have two types of power factor, which are as follows.

3.6.1 Leading and Lagging Power Factor

As we know the voltage lags by the current in capacitive circuits, due to this power factor considered as leading power factor, but if we have more capacitive reactance then inductive reactance. But as we know voltages leads in inductive circuits that's why power factor is considered as lagging power factor, but if there is more inductive reactance than capacitive reactance.

3.6.2 Power Factor Problems

We can conclude from previous that the power factor will be decrease if there is an increase in reactive power. It means the power distribution in electrical system is not efficiently because all current is not performing the work.

3.6.3 Power Factor Correction

It is method to overcome the problems related the poor power factor. It is not the aim of our project but yet it is the solution if you are looking the poor power factor. There are some methods as follows.

1. **Bulk correction**

We can monitor the power factor of total current supplied to the system by a controller which then switches capacitor banks, to maintain the power factor better than the preset limit. Ideally the power factor is unity which means power factor should be closed to unity.

2. **Static correction**

For the supply there is a large proportion of lagging current is due to magnetizing current in inductive loads. By connecting the capacitors, we can easily correct each individual load. For inductive loads it is important that the inductive magnetizing current should be greater than the capacitive current in static correction. In static correction the correction capacitor is connected directly with the loads parallelly. When no supply to the load, no supply from correction capacitor. And when load is connected with the supply the capacitors are also connected and providing correction all the time till the supply is connected.

3.7 Phase Angle

In electrical systems, when the values are oscillating with the time then the wave forms are involved. Now in this portion we would cover the concepts related with phase angle or phase shift. The phase shift defines as the small difference in the oscillation time of two waveforms, or we say the delay between the two waveforms having the same frequency or period. And the phase difference is defined as the positive and the negative angle within the -180 to 180 degree, we also called it as phase angle.

Phase shift can be applied for an electrical system between the current and voltage waveform. Also, it is applied to obtain the quality of loads. We can define the previous terms like, real power, apparent power and power factor by using the phase angle between the current and voltage waveforms. We can also use the phase shift in 3-phase system between voltage and voltage waveforms. For three phase system it is an important electrical parameter to determining the phase sequence. According to right rotation angle each phase of voltage is co-relate with adjacent phases by the angle of 120 degree. For the comparison of phase angle, we can take the first wave as a reference wave. And the wave that taken as reference should be voltage wave. Because the current wave is always altered based on the load.

$\theta = \cos^{1} PF$

Chapter 4

Complete working

As our electrical parameter monitoring devise displays important electrical parameters. And those are ac rms current, ac rms voltages, rms power, real power, apparent power, power factor, energy consumption. Our devise can used in ac energy generation centers as well as in all household loads measurements. You can also use it in ac side of solar system. In order to measure all above parameters we need two sensors. One is ac voltage sensor, and other one is ac current sensor.

Let's start working step by step.

4.1 Testing

First of all, we need to check our both sensors, that as they are working properly or not. To check them, connect both the sensor with Arduino and main supply. To check the sensors, don't turn on the supply. Only provide them dc 5v volts from Arduino. Now by using the reference rms voltmeter or multimeter check the voltages between the dc out pin and ground. If the voltages are 2.5v dc it means your sensors are working and in good condition. Now you need to calibrate the voltage sensor. The calibration of voltage sensor is given in the portion of zmpt101b voltage sensor in **second chapter**.

4.2 Connection, Working

Let's first we connect the voltage sensor module. The two ac pins at the side of transformer labeled as l (live) and n (neutral) will directly connect with source one is directly and other one is with the fuse of 5a to protect the sensor. Now from the remaining three pins on the other side the two pins labeled with Vcc and Gnd are connected with the 5v dc and ground pin of Arduino, and the middle pin labeled as out will connect with the analog channel of Arduino pin a2.

Now connect the current sensor module. From the two-ac pin on one side of sensor one pin is directly connected with ac main supply with 3a ampere fuse. And the other pin is connected with the wire of load. And the other wire of load is connected with neutral of main supply. The remain three pins on other side are connected same as voltage sensor. One is with 5v and other one is with ground. And the out pin is connected with analog channel of Arduino labeled as a3. You can connect as many loads as you want in parallel connection but within the current limit of current sensor.

Now let's connect the power supply. When we supply the voltage and current to the circuit in a voltage sensor module the provided transformer step down the ac mains voltages because these sensor works on 5v so they cannot afford the 220v directly, after stepping down the voltage the voltage signal will be amplified by the operation amplifier lm358 provided in the sensor module into a readable range of Arduino and these voltages are provided on the out pin and built-in adc channel of Arduino convert these voltages in analogue numbers from 0 to 1023. Now in current sensor when the supply is connected the magnetic field generation will started in the circuit and due to this magnetic field around the hall element the voltage will generated across the edges of hall element and these voltages are directly proportional to the applied current and making it suitable to estimate the applied current from sensed voltages. Now let's see how the signal is being proceed through Arduino.

As we know root mean square current and the root mean square voltages are the square rooted average value which is derived from the summation of squared of each raw value. When Arduino received the analog signal from the sensor. It will draw the wave form in between the 0 to 1023 using the built in adc channel. And Arduino will collect these values and calculate it after every second. After taking the samples the sampled analog values will be squared. After squaring these sampled values, we took the average by dividing the sampled values with the number of total samples taken in that time interval. After that we take the square root of that averaged value. Here we found the rms value of voltage. Same process we did for ac current. Only at the last step we just convert the values in milliampere. After this we multiplied rms voltages and rms current to obtain the rms power.

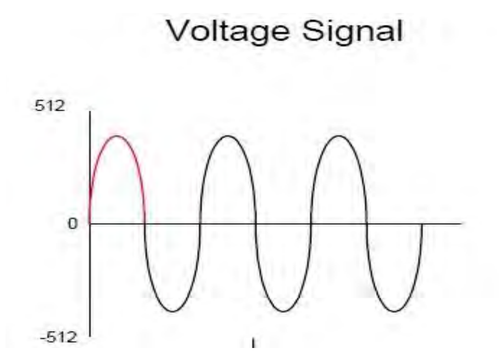
Now for the instantaneous power, as we know that the instantaneous power is the averaged value derived from summation of instantaneous current times voltage. For this purpose, after taking the analog samples from wave form of voltage signal, we multiplied them by the factor of two 2 because when we monitored the applied voltage signal the measured values are high and we need to reduce it. The amplitude of full wave is (*1) which is get distorted when near to 250. That's why we use it to overcome this distortion problem. Now these voltages are the instantaneous voltages. And for instantaneous current after taking the analogue sample we directly convert them in milli amperes and here we have the instantaneous current. After calculating both instantaneous voltage and instantaneous current we multiply each value of voltage with each value of current. After that we take the average of these values. After that we multiplied them to get active power. Now for power factor we just divide the instantaneous power over the rms power. And for energy we referring to instantons power over an extension of time.

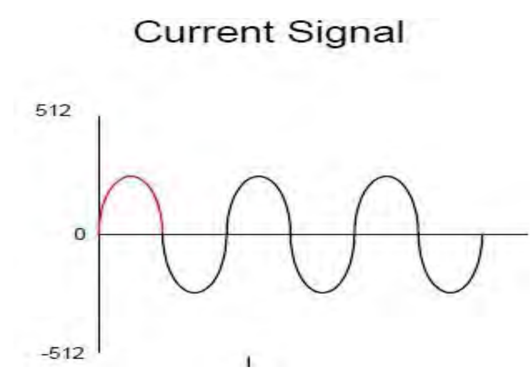
Now for phase angle here is the method to obtain the phase angle. First is by measuring the time difference to reach the 0 value or the to reach the peak value between both the voltage and the current waveform while using same start time. This is simple and direct method for obtaining the phase angle. This method is based on two reference point, the starting point and the peak value point only. We have no concern with the magnitude of voltage and current here because we need to measure the wave difference only with respect to time.

In our code we use the variable named analoginput1(wave a) as reference. Firstly, it determines the entry point to start the time recording. Starting time is same for all parameter's measurements and for all waves. When the wave a is more the 0 it continuous recording and checking the current time. The recording of the time is based on whether the recorded analog value is larger than previous measured value. If at the peak point when current recording values are no longer larger than the previous measured values, it stops the recording time. The same method is applied for the wave b which stops at peak value and separate's the time recording. The time recorded between the starting point to the peak value for wave a is the 75% of whole period of wave. But this simple estimation is not used in our project. The time difference between a and b wave to reach the peak value point is actually the phase shift through which phase angle can be calculates. When wave a is back to 0 point it will stop the time recording for period (time difference between starting point and end point) and frequency. And at the same time, it sets the current time as the starting time for next cycle of reading and this process is repeated for next 50(50hz) or 60(60hz) cycles

Now let's turn on the power supply and see the results on lcd keypad shield and compare the voltages with refence meter if they are change use the small size screwdriver to turn the potentiometer of voltage sensor module to set the voltage same as reference rms multimeter. And now congratulations the working is completed, and the readings are accurate, and devise is ready to use. Here is the flow chart

4.3 Flow Chart





Analog values

0	**10**	**16**	**18**	**16**	**10**	**0**

Squared

0	**100**	**256**	**324**	**256**	**100**	**0**

Analog values

0	**5**	**8**	**9**	**8**	**5**	**0**

Squared

0	**25**	**64**	**81**	**64**	**25**	**0**

Averaged

(0,100,256,324,256,100,0)/7

Square root

$\sqrt{148}\ \boldsymbol{RMS(ANALOG)}$

Convert

$\sqrt{148} * 2$

Rms voltages

Averaged

(0,25,64,81,64,25,0)/7

Square root

$\sqrt{37}$ RMS(analog)

Convert

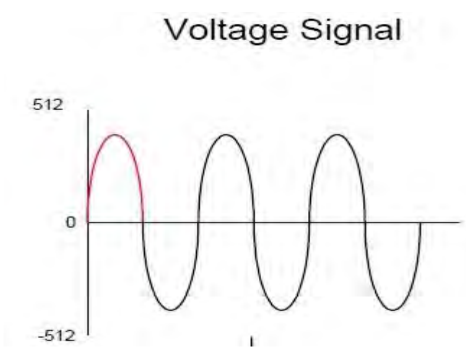
$\sqrt{37}$ (5000/1023)(mv/a)

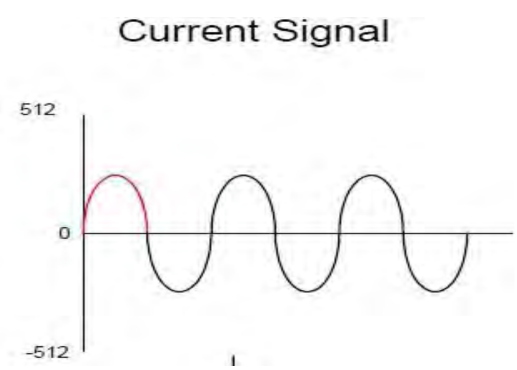
Rms current

For RMS power

RMS power =RMS voltages * RMS current

Now for instantanious power





Analog values

0	**10**	**16**	**18**	**16**	**10**	**0**

Convert

(0,10,16,18,16,10,0)*2

(0,20,32,36,32,20.0) (instantaneous voltages)

Analog values

5	**8**	**9**	**8**	**5**	**0**	**-5**

Convert

(0,5,8,9,8,5,0)*(5000/1023)(mv/a)

(24.438,39.100,43.98,39.100,24.438,0,-24.438)(Instantaneous current)

Multiply each other

(0,782,1407,606,1407.6,782.016,0,0)(mv/a)

Averaged

(0+782+1407.606+1407.6+782.016+0+0)/7(mv/a)

Active power = instantaneous voltages*instantaneous current

Power factor = ins: power/rms power

here are the figures of working after setting all issues

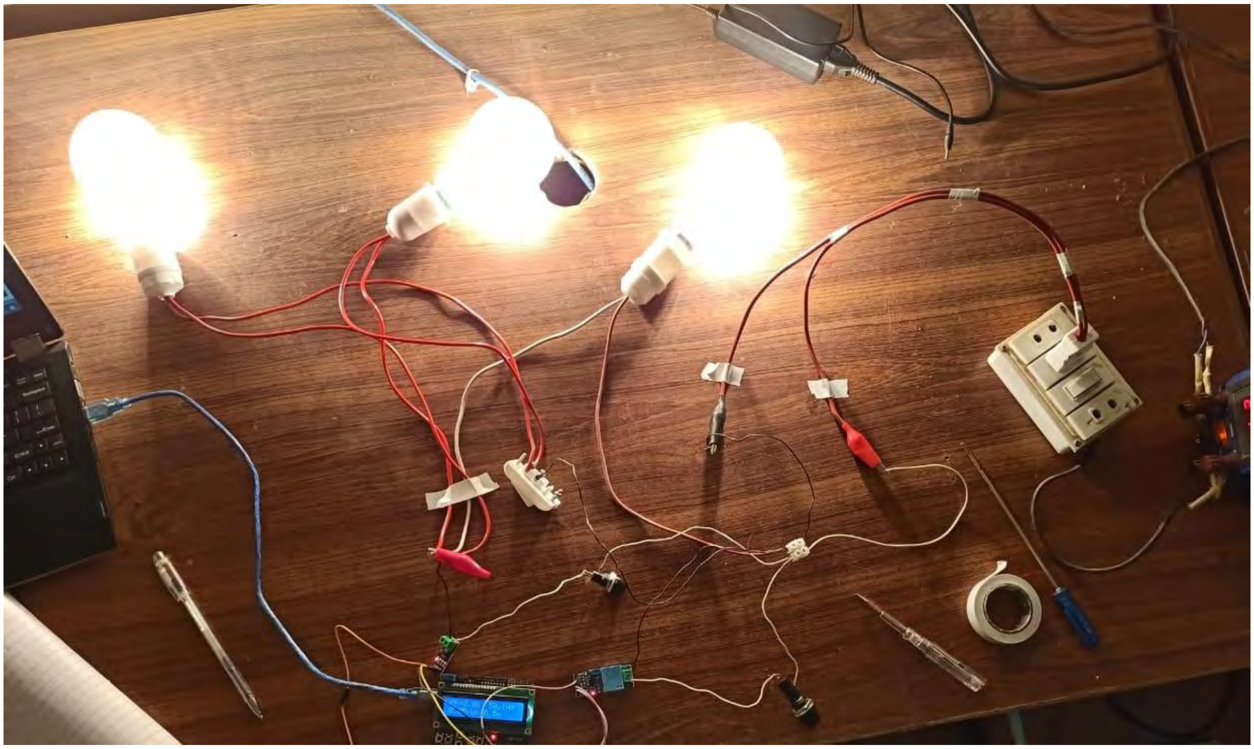
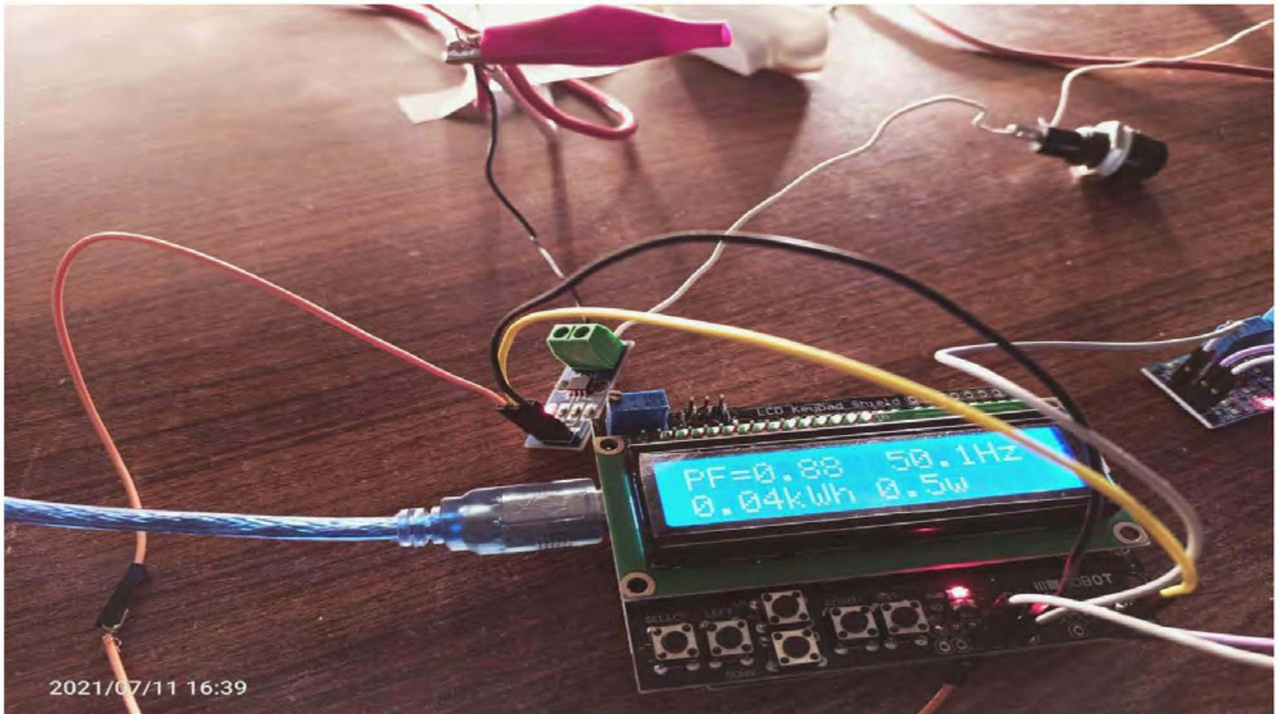


Figure 4.1


PF=0.88 50.1Hz
0.04kWh 0.5W
LCD Keypad Shield
2021/07/11 16:39

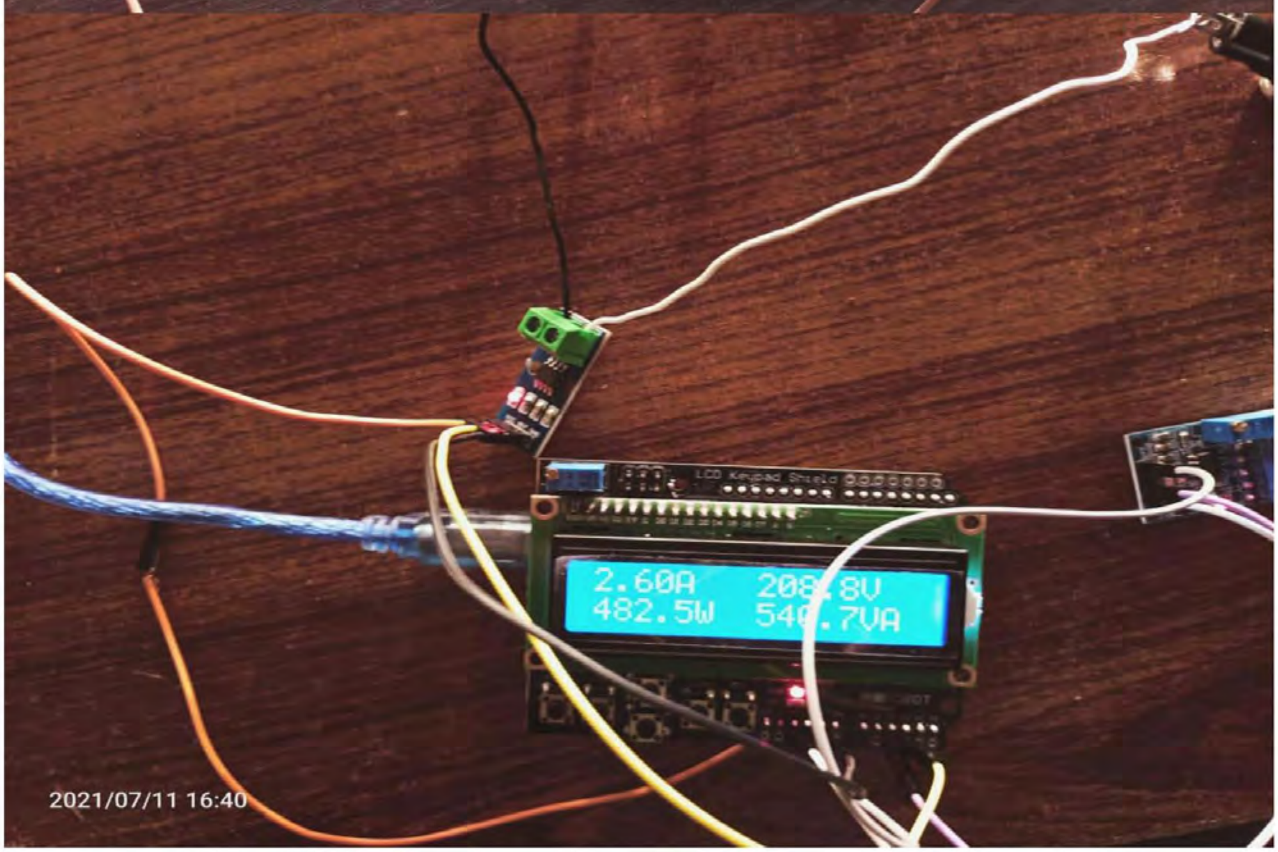

2.60A
482.5W
LCD Keypad Shield
2021/07/11 16:40

Figure 4.2 & 4.3

4.4 Experiments

Electrical parameter monitoring devise is an efficient and easy to handle devise. Results and efficiency of this project can also be improved by using the excellent code and more efficient modules. And before implementation of this devise and before introducing it at public level it required some test to check it's working.

Figures below will show experimentation at each level:

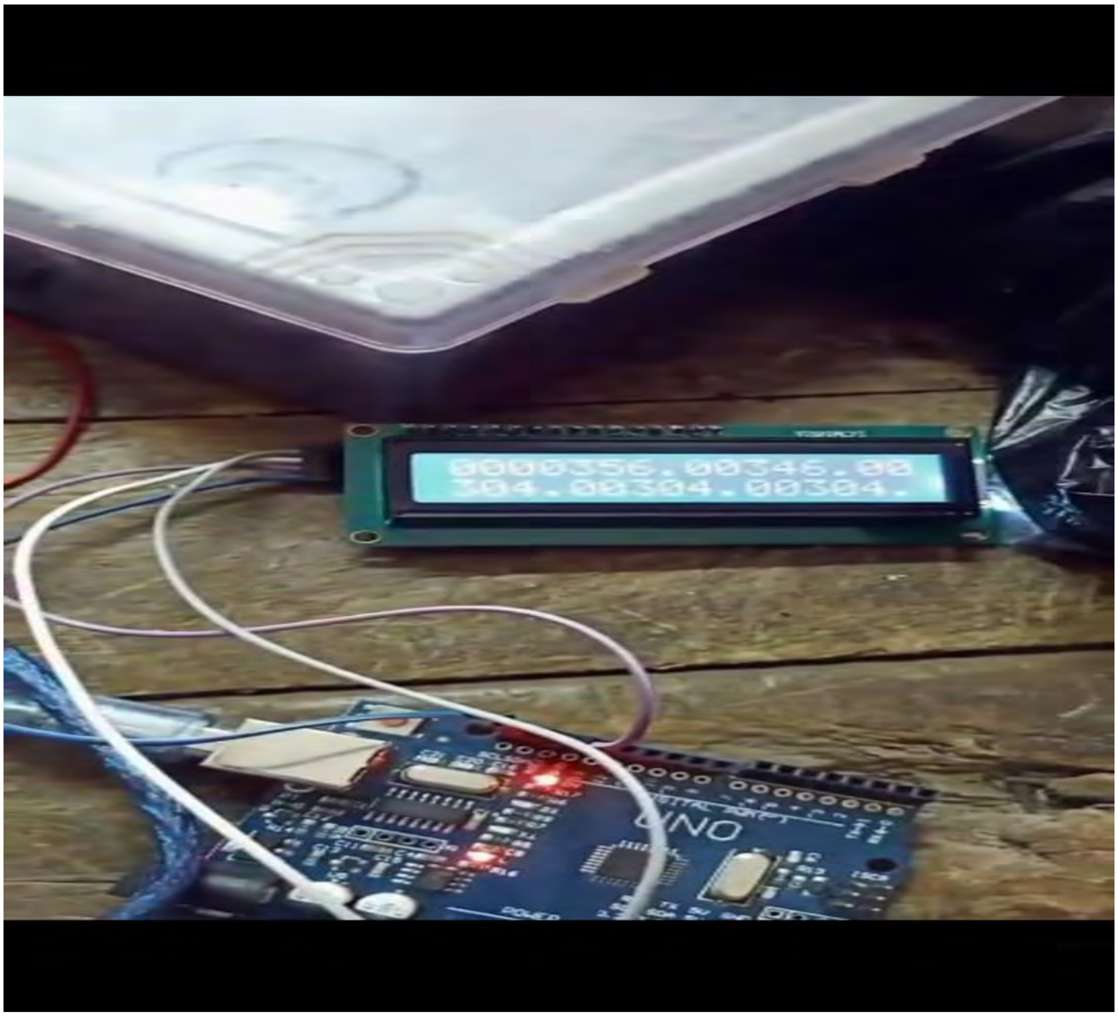


Figure 4.4

Figure shows the first experiment of the system, but it did not work well and did not monitor the voltages accurately. As we don't calibrate the sensor properly and we experienced a sudden failure in system. After that we are facing that the voltage, we are getting through the devise are very low. Then after study we found the solution that it can be set by using the potentiometer

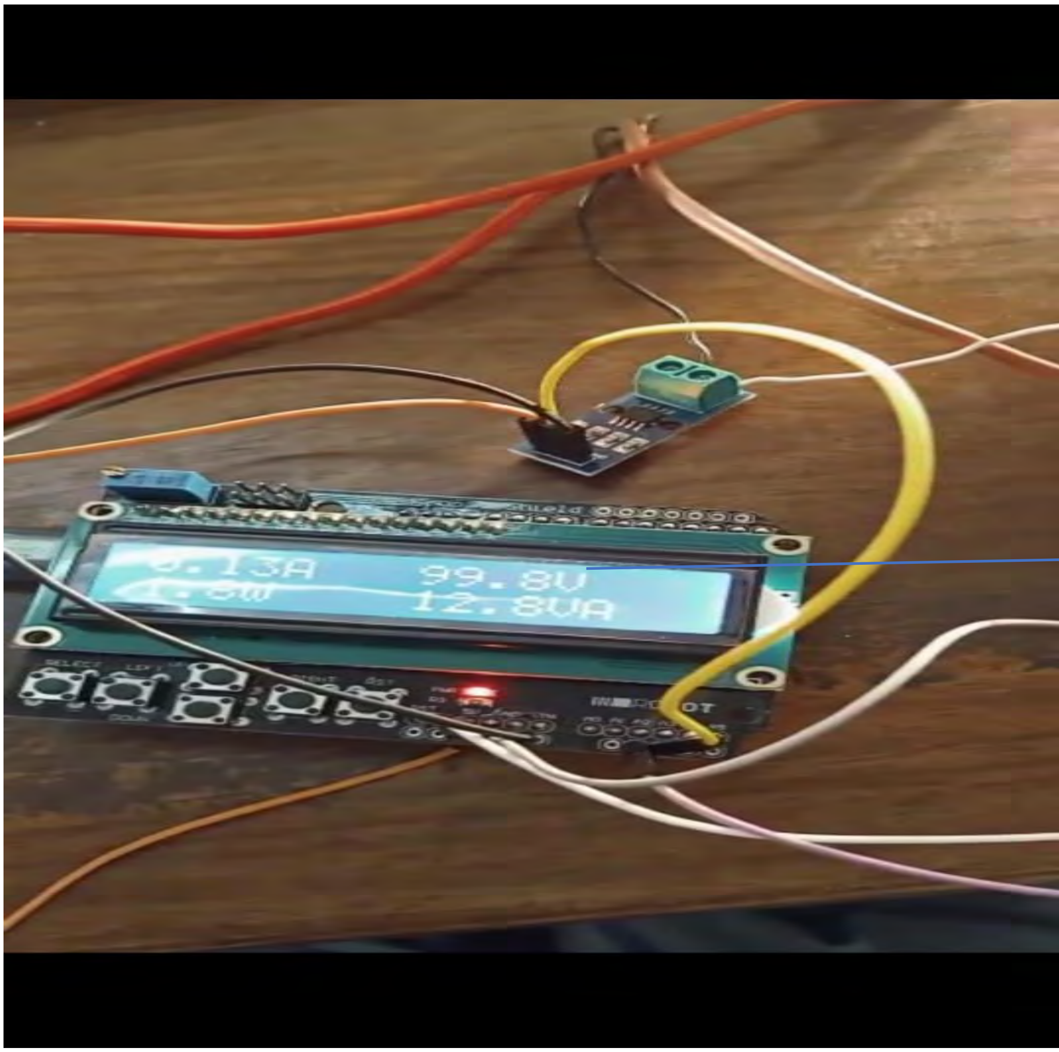


Figure 4.5

After that when we connect the acs712 sensor we see that that current measure by the devise is not accurate. To overcome this, we set the sensitivity of sensor using Arduino code.

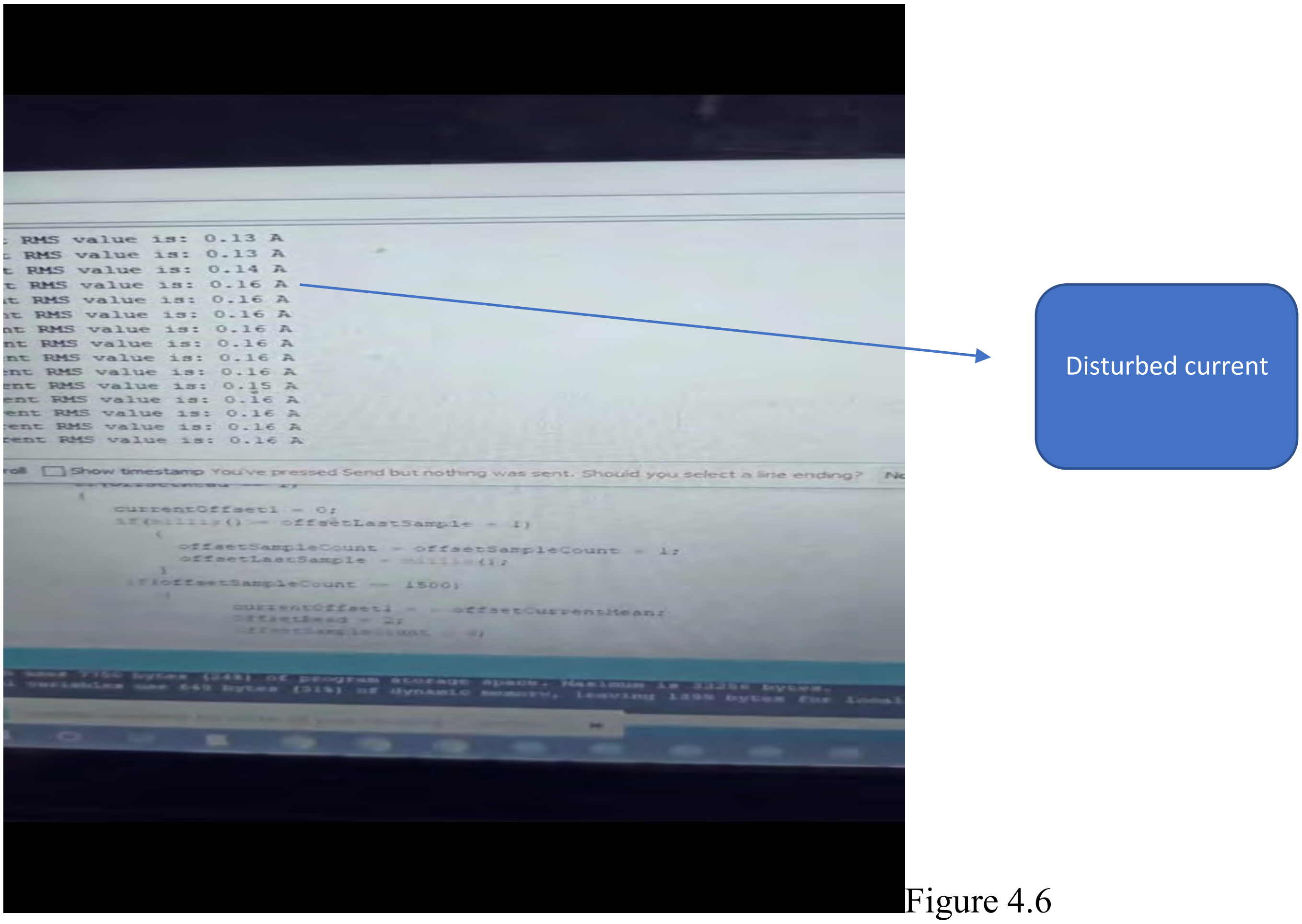


Figure 4.6

After all of above issue we have an issue that after checking the parameters our display shield is not going back to zero. It is displaying some values in decimal or some time high like 5v which is not good so to make it zero we set the select button available on lcd keypad shield to calibrate it.

Chapter 5

Software's

Electrical parameter monitoring devise based on the two software. First software is used to design the circuit simulations for testing and to design the printed circuit board layout on which all the components are electronically connected. Second software is Arduino used for programming. To monitor and measure the parameters, and to displaying the information to the user we have to program the Atmega 328p. This two software are:

1. Proteus 8 professional version 8.11
2. Arduino compiler 1.8

5.1 Proteus Professional:

In this project we designed many complex circuits which were impossible to test on breadboard. Breadboard can be a good option, but it requires a lot of time and effort. One can easily get confused specially when we are designing a complex circuit and results can be disappointing. To avoid this problem in our project we used software, proteus 8 professional. It is developed by lab center electronic ltd. Proteus 8 professional is a simulation software that is used to simulate the components of a circuit. Additionally, it can draw any desired circuit. It helped us to create schematics and electronics prints called a printed circuit board (pcb).

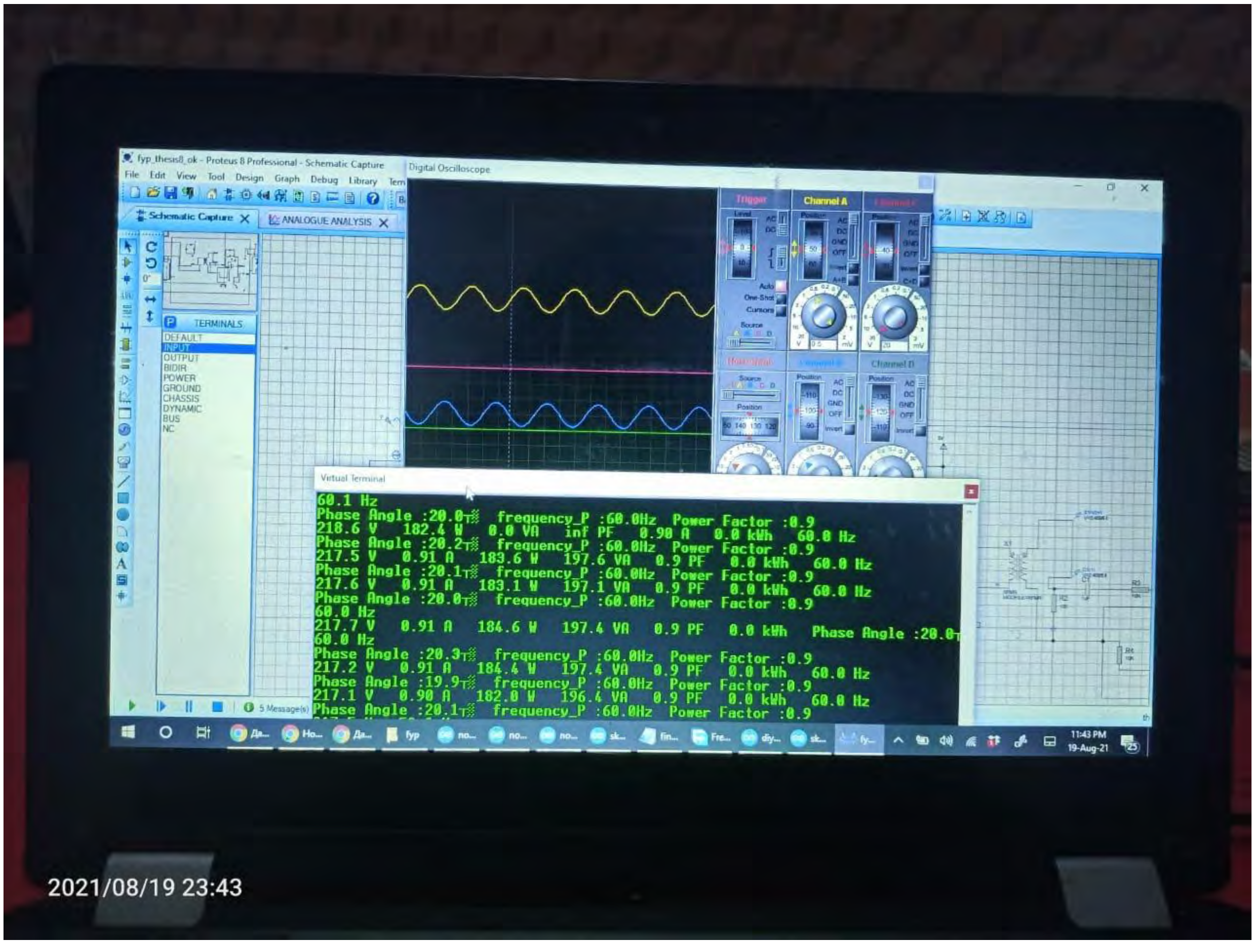


Figure 5.1

We started with design of Arduino uno board connections to lcd. We tested and simulated through many angles in this project. After testing and simulations, once we got satisfactory result at this stage, we move to next step which is to simulate the whole circuit. As we don’t have any package of zmpt101b module, so we have to design whole its internal circuit diagram. Another good point of using software is in physical testing we have to do lots of efforts to test our module on its peak ranges like, testing it on 60hz, while we have 50hz supply in ac line. So long story short it helps us in all the stages of our project.

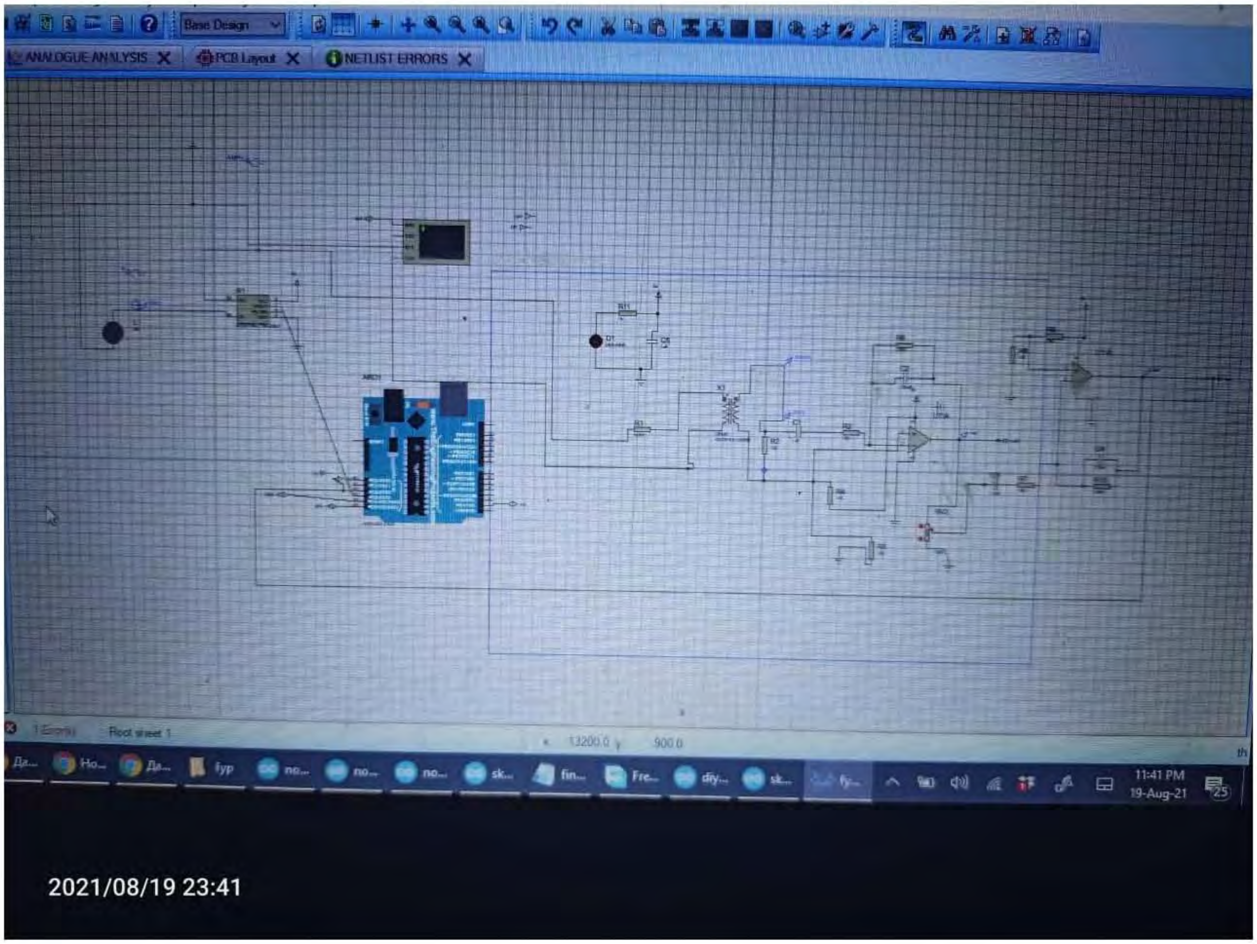

ANALOGUE ANALYSIS
PCB Layout
NETLIST ERRORS
2021/08/19 23:41

Figure 5.2

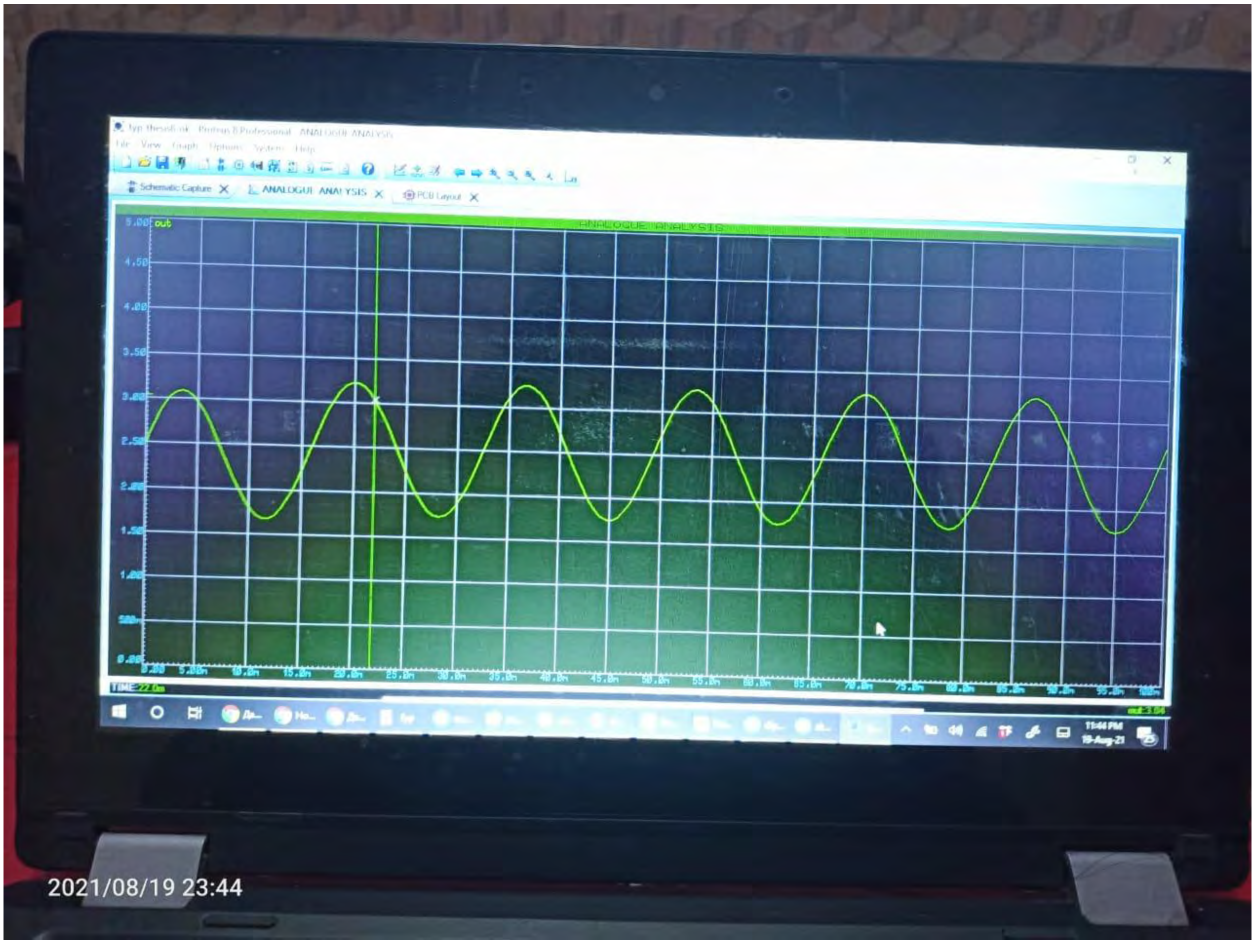


Figure 5.3

5.2 Arduino Compiler:

In our project, in order to program the atmega328 or we say the Arduino board we use Arduino ide compiler.

First, we installed an Arduino port in our system. We connected Atmega 328p to system using Arduino uno board. Arduino compiler is based on the C and C++ language. So, it was the time to implement the studied course “problem solving and programming. We added libraries for lcd in language. We coded for serial communication. First message after pushing calibration button (select button) “wait for 5 seconds” was programmed in lcd. All calculation for power and phase angle was added in Atmega using Arduino compiler.

This software helped us to configure the lcd keypad shield, to read the values from sensors and for calculation, to fulfil our aim in project. The programming code is stored in Atmega 328p and can be read on Arduino software by connecting Arduino board to system.

And here our project is designed, simulated, soldered and whole project is ready for use to monitor any electrical devise.

Chapter 6

Discussion and Conclusion

6.1 Discussion

The practice of using different types of ac meters for home appliances as well as for industry, which are easy to assembled and easy to use and are cheap are becoming more and more popular in Pakistan and many other countries. One of the suggesting selling points of such devise is the beneficial effect on the users which means reduction in damages of electrical system. This encourages the user and industries to use such devise.

This project is economical and reliable. No different meters are required to used and no calculation needed after using this devise. In the immediate future, it is estimated that inflation is increased day by day and making the machineries expensive for people. It indicates that people are taking cautions while using machineries and they are afraid of getting worse. Use of this devise let them know before something goes

Wrong with the machines, or appliances. If we analyses this system on community level, it supports and eases each induvial of our community and as well as for industries. In this project, our design of parameter monitoring devise provides ease on induvial level and is very cost approachable.

As we know that the power factor is the ratio between the real power and the apparent power, and it will be changed by the load. That's why it is important to monitor it because the variation of load cause the low power factor, which leads the penalty charge for the user and energy loss in the grid station system. The utility companies have always concerned about the low power factor on the side of consumer. Because the low power factor increases the loss of current and generates a huge equipment cost for these utility companies. For this reason, a charge has been considered for users due to low power factor.

There for the user must take the responsibility for monitor the power factor and to improving the power factor to the desired level through its own. In order to prevent from the energy loss and the penalty charge power factor should be monitored and maintained at unity. Today's industrial competitive factors are the main focusing points for any system designer. These factors include efficiency, cost effectiveness, and easy in installation or use. In our project we have focused on these factors as our number one priority. Users demands are primary factor and that are being preferred while we are designing our project. Continues monitoring of electrical parameters of any electrical system or electrical equipment's are of great importance of today's industrial race.

The large number of research have been carried out by the researchers towards new emerging technologies of to monitor electrical parameters that are technologically feasible. We have no doubt that there are many devises or systems to continuously monitor power factor with the use of different technologies till now, we have reviewed these technologies one by one. By comparing our design with the already developed technologies, we noticed that different factors that the previous technologies focused on. These factors included the monitoring the basic electrical parameters without any measurements of efficiency parameters, without any preference of cost effectiveness, ease for every individual, non-complex designs, simple handling, simple installation of the final product and easy repairable. But our project focuses on all these factors one by one. In this project the final product is extremely simple, portable, cost effective, easy to use for every individual, and can be installed at any time and most importantly in case of serious damage it can be repaired within no time.

6.2 Conclusion

This project undertaken is effectively tried and actualized which is the best conservative and reasonable vitality answer for average citizens of our country.

After designing, developing and testing this devise for verification. We were able to use this system in our daily life. This system is easy to use at any place.

Results of this system show that we can improve this design by applying small changes in hardware as well as in software of the system. We concluded that our project was successful and is fulfilling the requirements of people now a days. In comparison with previous technologies of electrical parameter monitoring devise. Our devise outnumbers all the previous minor and major draw backs. However, there is always a room for improvement.

6.3 Future Work

As i say, it doesn't matter how efficient your system is, there is always a room for improvement. Here are some points which we want to suggest for upcoming researchers.

1. At industrial level we need relaxation as much as we can. We don't have time to go to machine and check parameters all day. I suggest adding a wireless technology in this project for industrial level.
2. As we know when we have some issue in any electrical machine it starts getting hot more than its suggested level. So, add temperature sensor or temperature indication in this project.
3. I suggest that there should be a room for memory in this devise, so if we forgot to take reading or want to check the previous reading so we can. To compare the previous efficiency with the current efficiency.

Chapter 7

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Electrical Parameter Monitoring Device

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