East West University

Design and Development of Net Metering Through IP Based IoT

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This M.Sc. thesis report on "Design and development of net metering through IP based IoT" submitted for the partial fulfilment of the M.Sc. degree in "Telecommunication Engineering" from "Electronics and Communications Engineering," department of **East West University**. It has been carried out by the student bearing Exam: ID: 2018-2-98-002 and ID: 2018-3-98-002, under my supervision. As per knowledge and declaration of students, they complete the whole work and thesis report and have not submitted to anywhere else.

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Acceptance

This research presented to the Department of Electronics and Communications Engineering. East West University submitted to partial fulfilment to the requirements for the degree of MS in Telecommunication Engineering under the complete supervision of the undersigned.

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Declaration

We, at this moment, declare that this research thesis is an original piece of work carried out by us, under the guidance and supervision of Prof. Dr Md. Habibur Rahman. This report is the requirement for the successful completion of MS in Telecommunication Engineering under the Department of Electronics and Communication Engineering.

We state that the report, along with its literature that demonstrated in this report papers, is our work and which is complete with the masterly guidance and fruitful assistance of our supervisor for the finalization of our report successfully.

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Abstract

Energy efficiency and conservation have been a heavily focused subject in recent years. So, the importance of power meter has a significant effect. The thesis aims to develop a Net Meter though IP based IoT by using a bidirectional power meter where we were using a microcontroller (Arduino nano). Arduino nano which is used because it is cheap and has less PIN.

The thesis constitutes a microcontroller (Arduino nano), an Ethernet shield, a current sensor, voltage sensor, bulbs as load, and a display. The RMS values of voltage and current are determined in the thesis and sowed on the screen.

Then the Calibration is done inside the developed program. After that the power is Calculated and showed in the display. Then the direction of the power is determined, which is dependent on the phase difference between voltage and current coming from the grid. If there is no phase difference between the voltage and current, then the power is positive and leaving from the network. If there is a phase difference between the voltage and current, then the power is negative and entering the grid. The negative power is calculated by reversing the direction of the current sensor, but it can be also be detected by adding a power-producing device like a generator. The direction of the power flow is significant for efficiently using power.

Chapter 1: Introduction

1.1 Background

Nowadays, for enhancing and a better life, electricity is the most important thing. For that, each country is working on renewable energy and want to save energy. There are gradual changes which are going on in information and communication technology to accomplish all customers demand to safe power. Clients are asking for accurate energy measurement, time to time information, and for a satisfying service. So, we can work in a smart grid system with different communication technologies, which can be as cost-effective as the best solution. The electrical part has a bi-directional communication where electrical energy consumption is share between prosumers along with a utility for remote monitoring. This paper narrating the tracking of energy outlay with the Arduino Uno board and Ethernet shield using IP based IoT (Internet of Things) concept. The proposed design eliminates social inclusion in the conservation of electricity. The prosumers can access information about the outlay of energy by using the IP address on their devices. The web client code is upload for verifying the client whereabouts such as content, location, connection, and disconnection to the web site. The proposed system provides trustworthy and exact information regarding IP based IoT online Net Meter.

1.2 Introduction

Since the solar photovoltaic (PV) technology is being the most significant successful thesis, and it is very eye-catching in the modern power market. So, it still in the limelight. Among solar photovoltaic, net metering is one of the most essential and contemporary technology. Energy expenses are always the leading factor to meet by our community. Net metering can be the solution to mitigate this problem in our households as well as industries. In net metering, we use the idea of an Ethernet shield through IoT to encourage the prosumers with complete management. Bringing in all the equipment and sensors connected to the web, and all this equipment can share complete information through the internet. In this process, net meter analysing and controlling the devices is so easy that it can follow up from anywhere in the world.

Net metering of IoT is an essential part of the smart grid. For generating and supplying the power to clients, this intelligent grid has necessary information, including renewable energy. This procedure has an excellent effect of reducing extra cost on any particular network. A smart grid plays a vital role in the low carbon economy.

1.3 Photovoltaic system in IP base IoT

Solar power is an essential key to our clean energy future. We get unlimited energy from the sun that is more than our need to power everything on earth. Sun based vitality is limitless, accessible, plentiful and free from contamination.

As the PV system is soundless, it can be an ideal answer for modern urban life. The fundamental issue with sun-based vitality is its irregularity. Stockpiling batteries are required if there should arise an occurrence of the off framework along these lines to have uninterrupted power. It expands the general expense of a structure. On account of a matrix associate with the PV system, the interest can fulfil by utilizing sun powered vitality and the vitality drawn from the lattice without using batteries. In this framework, on the off chance that the sun-oriented PV board produces surplus power, at that point, that must provide to the matrix, and the sent out surplus power must represent. The vitality meter needs to represent imported power from the lattice to the shopper framework and the traded ability from the customer framework to the matrix. The IP address has provided to each house to connected with a smart grid solar panel through the net meter, and then consumers can check their used or produced electricity from the PV system and vice versa.

1.4 Bidirectional meter in PV system

Bidirectional meter gives the information of energy source- it can assess the stream of electricity in two fixed ways. It evaluates the delivery and receiving the quantity of power from the smart grid solar PV system. Solar power is an essential key to our clean energy future. We get unlimited energy from the sun that is more than our need to power everything on earth. Sun based vitality is limitless, accessible, plentiful and free from contamination. As the PV system is soundless, it can be an ideal answer for modern urban life. The fundamental issue with sun-based vitality is its irregularity. Stockpiling batteries are required if there should arise an occurrence of the off framework along these lines to have sustainable power. It expands the general expense of a structure. On account of a matrix associate with the PV system, the interest can fulfil by utilising sun powered vitality and the vitality drawn from the lattice without using batteries. In this framework, on the off chance that the sun-oriented PV board produces surplus power, at that point, that must be provided to the matrix, and the sent out surplus power must be represented. The vitality meter needs to represent imported power from the lattice to the shopper framework and the traded ability from the customer framework to the matrix. If the IP address is provided to each house connected with a smart grid solar panel through the net meter, then consumers can check their used or produced electricity from the PV system and vice versa. A bidirectional net meter is a measurement circuit which forms of voltage and current and can evaluate the transitory gradually. There is a new technology using Arduino UNO with an Ethernet shield through IP based IoT working as a processing unit and showing the total energy.

1.5 Net meter

Net metering has a very widely important role in the energy consumption sector. Net metering is mainly for those people who produce their electricity. In net metering, billing mechanism electricity can run in two fixed directions – from or to the customer using the bidirectional meter.

The surveyed data kept in the meter and transferred to the central grid. In this net metering procedure, the billing system of customers depends on stored data. During the billing time, prosumers can sell the extra power of electricity to the government.

1.6 Aim of this thesis

The main objective of the proposed proposal is to form a microcontroller-based a bi-directional meter though IP base IoT net meter. The consumer can see all the information from the website. The point of the venture is to take out the misuse of intensity, which is going to the lattice and storing it for more utilise. It can improve the efficiency rate of solar panels, and net metering decreases the installation and equipment cost. This smart grid system is comparatively cheaper, as well as easier to install.

• To decide the positive or negative power, the stage move between the voltage and current of the matrix is determined. If there is a stage contrast between the voltage and current, at that point, the power is negative, and if there is no stage contrast between the voltage, what is more, current, at that point, the power is sure.

• To decide the power stream, regardless of whether it is absolute or negative, so that the course can be resolved.

• Then, to decide the course of the power. If the power is sure, at that point, it is coming from the framework. Also, if the power is negative, at that point, it is entering the matrix.

• Then, the RMS estimations of voltage and current are estimated.

• Then, the power is estimated by building up a program in Arduino programming.

• Then, the progression of the power is controlled by building up a program in Arduino programming.

• The RMS voltage, current, estimation of intensity, and heading of the power have appeared in the showcase mounted on the breadboard of the undertaking.

• For deciding the negative power, the heading of the present sensor is switched, and it demonstrated the negative power on the presentation. For this, control creating a gadget like a generator can be utilised later on.

• Last however not the rundown, to dispense with the wastage of the power.

The produced electricity can be stored as a short form of another energy; at peak time, it can mitigate the pressure of power company. Thus, it can be seen as a virtual battery. For this reason, the proficiency of the power system rises.

1.7 Content of this report

The full report has been isolated into five parts. Notwithstanding the structure and execution study, some related hypothesis has likewise been joined in this report. The report contains the accompanying sections.

1) Introduction: This section is a summary of the thesis, points of the work, and theory association.

2) Related theory: The similar and foundation hypothesis required for this exploration is talked about here.
3) Net metering: Metering necessities and history for measurement are narrated in this section.
4) Design and development of the online Net Meter: The exploratory and programming arrangement of this created meter is clarified here.
5) Performance Study: Performance study and level of blunder estimation is given in this part.
6) Conclusion: In this examination, there is some future propagation, and a few barriers had likewise been to survive. These points are talked about in this section.

Chapter 2: Related Theory

2.1 Requirements of Power Study

The necessary estimation parameters of static meters generally incorporate compelling voltage, strong current, dynamic power, responsive power, evident power, control factor (PF), vibrant vitality, and receptive vitality. Among them, the powerful and responsive energies are received as the charging amounts. It is notable that the higher the exactness of the estimation results, the more exact the vitality bills. Nonetheless, in down to earth estimations, the way that the info and yield stage point between the current and voltage waveforms is challenging to keep up similar worth impacts the precision and dependability of the estimation information. The stage move edges of transformers are commonly little when they work around the ostensible qualities.

In control designing, the power-stream study, or burden stream study, is a numerical examination of the progression of electric power in an interconnected framework. Power-stream research, as a rule, utilise streamlined documentation, for example, a one-line chart and per-unit frame and spotlights on different parts of AC control parameters, for example, voltages, voltage edges, pure power, and receptive power. It breaks down the power frameworks in typical enduring state activity.

Power-stream or burden stream reads are significant for arranging the future development of intensity frameworks just as in deciding the best activity of existing structures. The foremost data acquired from the power-stream study is the greatness and stage edge of the voltage at each transport and the genuine and responsive power streaming in each line.

Business control frameworks are typically too complex to even think about allowing for the hand arrangement of the power stream. Specific reason arrange analysers were worked among 1929 and the mid-1960s to give research centre scale physical models of intensity frameworks. Massive-scale advanced PCs supplanted simple techniques with numerical arrangements.

Notwithstanding a power-stream study, PC programs perform related figures, for example, cut off examination, strength thinks about (transient and constant state), unit responsibility, and monetary dispatch. Precisely, a few theses utilise straight programming to locate the ideal power stream, the conditions which give the least cost per kilowatt-hour conveyed.

A heap stream study is particularly significant for a framework with numerous heap focuses, for example, a treatment facility complex. The power stream study is an investigation of the framework's ability to supply the associated burden sufficiently. The absolute framework misfortunes, just as individual line misfortunes, likewise are classified. Transformer tap positions are chosen to guarantee the right voltage at primary areas, for example, engine control focuses. Playing out a heap stream study on a current framework gives knowledge and suggestions with regards to the framework activity and improvement of control settings to get the most extreme limit while limiting the working expenses. The aftereffects of such an examination are regarding dynamic power, receptive power, size, and stage edge. Moreover, control stream calculations are pivotal for the ideal activities of gatherings of producing units.

The Open Energy Modeling Initiative advances open-source load-stream models and different sorts of vitality framework models.

2.2 Power Measurements

Power is the rate at which work is done (work/time). It is also the rate at which energy is generated or used. For dc systems, power is expressed in watts: **P=V DCA DC**. For ac systems, the determination of power is more complicated. The voltage and current in an AC circuit periodically change direction (alternating current). In a purely resistive circuit, the voltage and current change direction at the same time (in-phase). Power measurements are made by measuring the RMS current and voltage and applying the formula P = VrmsArms. If a reactive element is also present (either capacitive or inductive), the voltage and Current no longer change direction at the same time. The current will lag the voltage when the circuit includes inductance (see fig. A). The current will lead the voltage when the circuit consists of capacitance. The amount of lead or lag, expressed in degrees, is the phase angle (ø). The power delivered is P = VAcosø. The term cosø is the power factor. Note that for a purely reactive circuit, P = 0. A load that includes responsive elements is a complex impedance (Z). In a series circuit Z =√÷R 2, where X is inductive or capacitive

reactance in ohms and R is the resistance in ohms. In a parallel circuit Z = √RX/

÷R2. The power factor is the ratio R/Z. The power factor can also be described as the real power divided by the apparent power: PF = W/VA. For a purely resistive circuit, PF = 1. Crest Factor Another parameter used to characterise ac voltage and current waveforms is the crest factor - the ratio of peak to RMS value. The crest factor of a sine wave is. CF of a full-wave rectified sine is also √ , but a

half-wave rectified sine is 2. The CF of a square wave is 1; triangle wave √3. Low duty cycle pulse trains can have crest factors >10. The crest factor specification in a measuring instrument defines the peak signal level that can be handled, often with a de-rated accuracy.

Two factors contribute to this specification: - the dynamic range of the amplifiers and signal conditioning circuits - the bandwidth of the RMS converter used. On instruments with more than one input range, a limitation in the amplifiers can be overcome by using a higher range. The signal peaks for a particular amplitude will then fall within the maximum allowed on that range shown in **Figure 2.1 (b).** As the crest factor increases, the higher frequency components become a more significant part of the total waveform. These are usually multiples of the fundamental frequency (harmonics). Electronic speed controls, lamp dimmers, switching power supplies, and similar electronic circuits often generate waveforms with high harmonic content. A single-phase diode bridge DC power supply, with no line filtering, has current waveform harmonics well beyond the 7th shown in **Figure 2.1 (c**). A converter with bandwidth (-3db point) of 780Hz will measure 71% of the contribution of the 13th harmonic. Converter bandwidth is not a significant problem when the fundamental is 50 or 60Hz. However, when the primary is a high frequency (e.g., 20kHz in a power inverter), much higher bandwidth is required to measure a non-sinusoidal waveform accurately. Test equipment intended to measure points within a switching circuit need high bandwidth. Single Phase Circuits The most straightforward single-phase ac power connection requires two wires. In low voltage circuits, the voltage can be measured directly with an appropriately scaled ac voltmeter. The current is usually measured by inserting a current transformer in the line side and monitoring the output with a 5A full-scale ac ammeter shown in **Figure 2.1 (d**). Where the circuit cannot be broken to insert the current transformer, a split core or clamp-on current transducer can be used.

In higher voltage circuits, a potential transformer may be added to step down the source voltage to a lower level shown in **Figure 2.2 (e**). Depending on voltage levels, frequency meters can be directly connected in the same manner as the ac voltmeter or operated through a potential transformer. Some wattmeters, power factor meters, and watt-hour meters are directly related to the power source shown in **Figure 2.2 (f)**.). In higher energy circuits or situations where the meter is located far from the power circuit, a CT and PT are used, as shown in **Figure 2.2 (g)**.

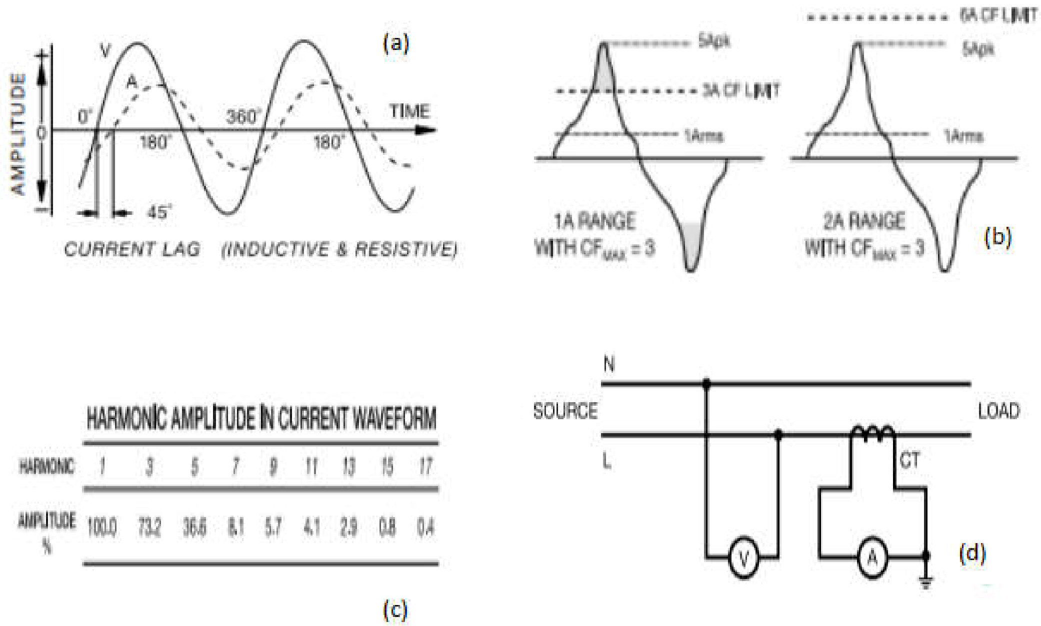


Figure 2.1: Power Measurement Process

In a single-phase three-wire system, the two hot conductors are 180° out of phase (referenced to the neutral). A single-phase three-wire system requires two single-phase wattmeters or one polyphase instrument with two measuring elements (each element measures voltage and current), which is shown in **Figure 2.2 (h)**. Care must be taken not to overload the meter when the power factor is low. With PF=0.5, a full-scale readout requires 2X full scale on either the V or A input. Polyphase Circuits While many of the loads throughout a plant are single-phase, their operating power comes from one phase of a three-phase distribution system. Heavy electrical loads, such as large motors, are generally three phases for improved efficiency. Three-phase power is configured as either wye (Y) or delta. Y connections can be either 3 or 4 wire. The voltage on each phase is displaced by

120° from the voltage on the other phases. Blondel's Theorem states that if a

The network is supplied through N conductors; the total power is measured by summing the readings of N wattmeters arranged, so a current element of a wattmeter is in each line, and the corresponding voltage element is connected between that line and a common point. If the common point is located on one of the tracks, then the power may be measured by N-1 wattmeters.

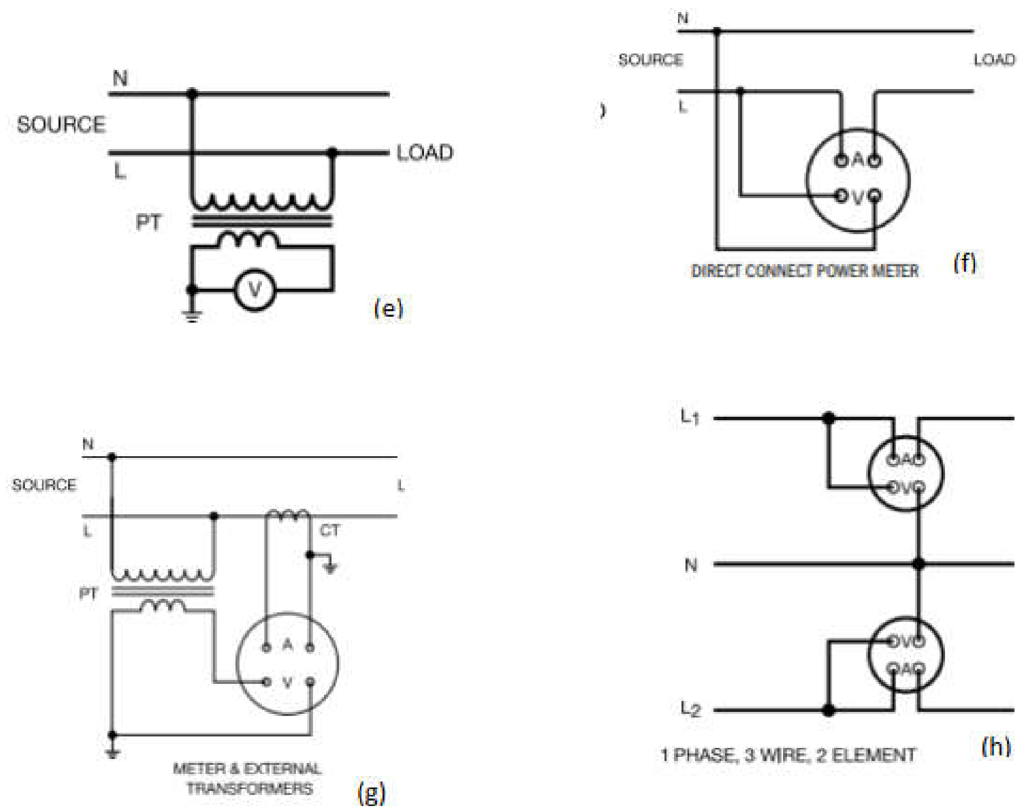


Figure 2.2: Power Measurement for 3 Phase

This allows a 3 phase, 3-wire system to be measured by two single-phase wattmeters, similar to the single-phase, three-wire system shown in **Figure 2.3 (i).** Total power is the algebraic sum of the two readings under all conditions of load and power factor. If the load is balanced, at the unity power factor, each instrument will read half the load; at 0.5 power factor, one instrument reads all the load, and the other reading is zero; at less than

0.5 power factor, one reading will be negative. While balanced loads are preferred, many systems today are unbalanced due to system modifications or the presence of non-linear loads. A 3 phase Y system with a centre neutral is the equivalent of a 4-wire system. It requires the use of three measuring elements shown in **Figure 2.3 (j).** With three wattmeters, total power is the algebraic sum of the three readings under all conditions of load and power factor. These diagrams show the use of single-phase, directly connected wattmeters. External PTs and CTs can also be used as discussed for single-phase circuits. In practice, a three-phase power meter is typically used, since it can measure all three legs and perform the algebraic sum internally. In systems where the third voltage lead is not available at the meter, an exclusive 2 1/2 element configuration can be used, as shown in **Figure 2.4 (k).**

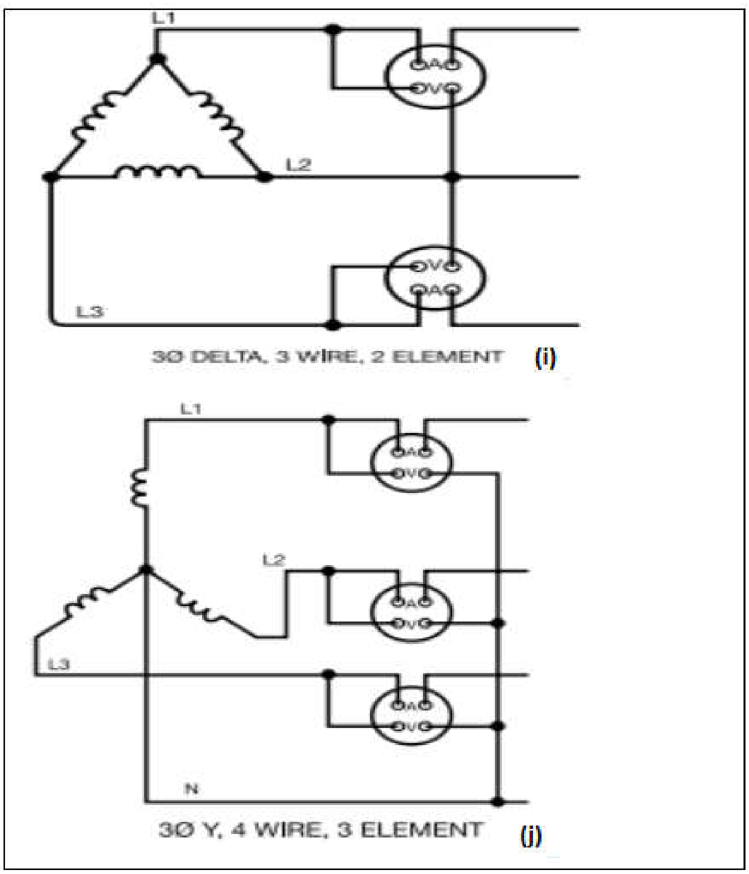


Figure 2.3

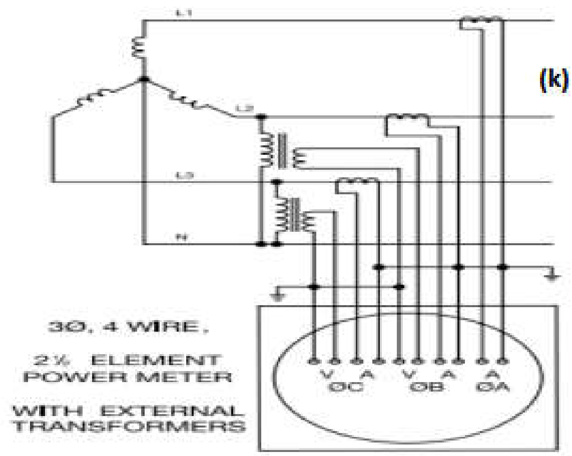


Figure 2.4

Polyphase instruments are available in both analogue and digital configurations. Some electronic 3 phase power meters cannot be used on single-phase circuits, due to the internal math function required. Energy is the power used for a particular time (P˚ t). Electrical energy is generally measured in kWh or MWh. Kilowatt-hour meters are power meters with a time base for integrating the instantaneous power over time. Electronic versions of the kWH meter often include the ability to display power and demand. Demand is the average amount of energy consumed over a specific time interval. For a utility, this interval is usually 15 or 30 minutes. The service must have sufficient capacity to supply the peak demand, so energy prices are often established based on this factor. Demand meters with adjustable set points and output relays can be used to shed low priority loads to limit demand peaks.

2.3 AC Metering Circuits

Power estimation in AC circuits can be a considerable amount more unpredictable than with DC circuits for the necessary explanation that stage move muddles the issue past, increasing the voltage by current figures acquired with meters.

What is required is an instrument ready to decide the item (increase) of quick voltage and current. Luckily, the normal electrodynamometer development with its stationary and moving curl makes an excellent showing of this.

Three-stage control estimation can be practised utilising two dynamometer developments with a typical shaft connecting the two moving curls, so a solitary pointer registers the control on a meter development scale. This makes for a somewhat costly and complicated development component; however, it is a useful arrangement.

2.4 Literature Review

A. A. Girgis *et al.* presented the testing of the performance of three-phase induction watt-hour meters in the presence of harmonic distortion. These are developed electromechanical (inductive) energy meter. But this type of meter did not have excellent efficiency and accuracy.

A. Cataliotti, V. Cosentino *et al.* developed Static meters for the reactive energy in the presence of harmonics. It is a static (electronic) type of energy meter to overcome the disadvantages of low accuracy of the electro0mechanical meters. Electricity metering plays a crucial role in all the commercial transactions on the energy market. Thus, an accurate evaluation of the performance of the electricity metering equipment is required not only in the reference operating conditions but also in the presence of disturbances affecting the power systems.

Wavelet-based reactive power and energy measurement in the presence of power quality disturbances is developed by W. G. Morsi *et al.,* which is a high accuracy electronic energy meter.

Cataliotti *et al.* presented the measurement of reactive energy in polluted distribution power systems: An analysis of the performance of commercial static meters, which is more accurate and has a dynamic range of electronic energy meter.

J. Li *et al.* developed a review of the electric energy metering system where various considerations of the latest electronic energy meters are discussed to overcome the obstacles regarding using them.

A. Cataliotti, V. Cosentino *et al.* presented the metrological characterisation of the static meters for reactive energy in the presence of harmonic distortion. The static meters are substituting the traditional inductive meters because they have better stability, many multifunctional metering facilities.

D. Gallo *et al.* developed a new methodological approach to quality assurance of energy meters under non-sinusoidal conditions. This meter has high quality with an excellent performance to measure the energy as electricity.

D. Brunelli *et al.* developed smart monitoring for sustainable and energy-efficient buildings: A case study. Steadily raising standards for indoor environmental quality in living and office spaces lead to extensive utilisation of high performance and power-demanding climate control systems. An increasing utility and energy cost for buildings operation, in turn, pushes researchers and manufacturers to explore new strategies to reduce energy waste and minimise ecological impact. The key enabler for efficient energy management is an accurate measurement and assessment of buildings operation that contributes to the total load. Electrical energy management is becoming crucial to optimise the generation and usage of power. Therefore, measurement of parameters (such as amplitude or phase shift) of electrical systems is of the utmost importance for achieving efficient control on power usage of electric loads in residential and industrial buildings also.

POVOMON: D. Brunelli et al. develops an ad-hoc wireless sensor network for indoor environmental monitoring.

The accuracy of power measurement is an essential basis for the regular operation of the power grid. At present, not only the power supply companies pay attention to the development of energy metering technology, but also electricity users, large factories and enterprises also attach great importance to their development. And all parties are protected by its accuracy, reliability, and fairness. Besides, the theft of electricity caused significant losses to our country, and we urgently need a device that can directly measure the electrical energy on the primary side. At present, the conventional measuring equipment in China consists of transformers, electric energy meters, and connecting lines. The measurement error is related to the accuracy of the current transformer, the voltage transformer, the connection mode, and the accuracy of the energy meter. The conventional electric energy meter mainly has the following problems.

A. Brush developed the measurement of microwave power, which is an RF power meter is an indispensable instrument to measure the forward and reflected power of an RF amplifier connected to an arbitrary load. The RF power can be measured using diode detectors, thermistors, and thermocouples. Hewlett-Packard Company presented the fundamentals of RF and Microwave power measurements. The forward and reflected waves are sampled on a transmission line to measure the RF power. It is generally done through a directional coupler. The directional coupler is implemented either with lumped circuits or distributed circuits based on the frequency of operation.

Chapter 3: Net Metering

3.1 INTRODUCTION

An electric meter, or vitality meter, is a gadget that estimates the measure of electrical vitality devoured by a structure, an industry, or electrically fueled gear. Electric utilities utilise electric meters introduced at clients' premises to quantify electric energy conveyed to their clients for charging purposes. They are ordinarily aligned in charging units, the most widely recognised one being the kilowatt-hour (kWh). They are typically perused once each charging period.

At the point when vitality investment funds during specific periods are wanted, a few meters may quantify request, the most extreme utilisation of intensity in particular interims. "Time of day" metering enables electric rates to be changed during a day, to record use during the top, significant expense periods and off-top, lower-cost periods. Likewise, in certain regions, meters have transfers for request reaction load shedding during top burden periods.

Metering frameworks measure and record power passed on through a point of association. Progressed metering frameworks additionally have the capacity for two-path correspondence between a meter and a remote structure.

Meters are crucial when working with electrical frameworks. Throughout the years, a wide assortment of electrical meters has been created to help with checking and investigating electrical structures.

Many meters were created utilising moving loop instruments, called D'Arsonval developments. A perpetual magnet gives a uniform, attractive field into which a spring-mounted moving curl is situated. A pointer is joined to the moving spiral. The current to be estimated goes through the coil, which is allowed to rotate. As the present goes through the curl, it creates an attractive field that communicates with the beautiful uniform area delivered by the lasting magnet. This communication makes the moving coil and pointer turn. Since these developments can be decisively adjusted, they structure the premise of numerous simple meters.

To dispense with the requirement for exact mechanical parts and to lessen the demand for alignment and alteration, advanced hardware structure the reason for much metering done today. Simple voltage and current signs are changed over to superior qualities and afterwards showed as numbers. Computerised innovation permits one metering gadget to display various attributes. Most electric meters introduced are simple meters, which show units proposed to be perused outwardly.

Figure 3.1: Analogue Electric Meter.

3.2. Timeline of the History of Electric Meters

Here is a shortlist of significant occasions in history with time.

1800 The electric age starts with Volta's battery, which flashes numerous innovators and researchers around the globe to begin to explore different avenues regarding power. There are no guidelines of estimation or meters to gauge this power. Nobody yet comprehends what power is, and accordingly, it takes an additional 90 years before progressively logical clarifications help to separate power into its components, which at that point are doled out principles by the IEC in Chicago and Paris during the 1880s-1890s.

1866 Transatlantic broadcast was finished. Essential galvanometer-type meters were utilised to set up broadcast frameworks.

1879 Thomas Edison frantically needs an approach to gauge the power his clients would Use. The built-up a substance meter with two bars of copper in an answer, as power was utilised. One of the terminals broke down, appearing by mass how much power had been utilised. This creation was not prepared for use when the Pearl Street Station began working with clients, so early clients got power for nothing. Following a year, Edison started to utilising the synthetic meter, yet it was not precise, and clients were despondent. Interesting Fact: JP Morgan ran 106 lights from 3 pm-6 am nevertheless never paid more for this utilisation since he just paid by the number of light attachments and for the physical bulb buys

1880s Elihu Thomson builds up a synthetic meter like Edison's, except for it utilised a zinc sulfate shower, which worked much better. Edison's organisations promptly began using Thomson's meter as they were edgy to take care of the issue of metering.

1880s Edison versus the gas business: Thomas Edison embraced Thomson's meters and changed to a model that charged clients for power use, anyway this maddened numerous clients. They had been persuaded to change over from gas lights as a result of the way that the progression of power was free. Edison doesn't get enough kudos for his taking the brunt of the gas versus power fight. We need to express gratitude toward Edison for keeping it together and working at a misfortune for a considerable length of time before getting benefits.

1886 Edward Weston builds up a moving curl galvanometer type meter with a steady changeless magnet, which turns into the premise of Amp, Volt, and Watt meters for the following 100+ years.

1880s Edward Weston refined a watt-hour dependent on Thomson's work.

1887 Oliver Shallenberger builds up the first exact voltmeter at Westinghouse with Philip Lange.

1888 Oliver Shallenberger at Westinghouse builds up a meter that is near the cutting-edge watt

hour meter and sets the new standard.

1890 Only 5% of US homes were outfitted with power. Bend lights for open road lighting and trolleys were the most productive work of the innovation. The AC upset of the1890s would change that.

1892 J.A. Fleming begins to take a shot at what might turn into the vacuum tube during the 1900s.

1890s Elihu Thomson keeps on improving electric meters. Thomson has been working with AC control since the 1870s and has more involvement with the territory than a great many people around at the time.

The 1890s The IEC - International Electrical Congress makes models for estimation of power The 1890s The IEC - International Electrical Congress makes models for the estimation of power.

1896 William Stanley builds up a static ground location meter. This technique is as yet utilized today to help ground vehicles and offices as a proportion of wellbeing. This course of events was made by the Edison Tech Center, report copyright encroachment by content strippers who target timetables like this.

1916 High Voltage Measurement: Chubb and others create meters that utilisation forerunners to vacuum cylinders and make the primary to some degree exact approaches to gauge this hazardous and troublesome type of intensity. Before this point, they utilised the unrefined strategy for estimating the separation. An electric curve could go through the air or a cylinder to make sense of the high voltage.

1922 E.B. Moullin makes the first genuine vacuum tube voltmeters utilising improved triodes.

1930 The IEC sets up increasingly standard electrical units, including Hertz, Oersted, Gauss, Maxell, Gilbert, Var, and Weber.
1957 Rosewell Gilbert (of Weston) built up the double slant simple to-computerized change circuit was created and took into consideration stable clamour decreased estimation by advanced methods.

1970s Digital multimeters start to show up as the expense of sharp state gadgets drops.

1970s Vacuum tube meters, at last, execute off moving loop galvanometers, which were still being used by large organisations. Numerous representatives take the more established meters home, and these enter assortments, including the Edison Tech Center's variety later on.

1990s Digital multimeters dwarf tube-based or attractive multimeters.
Numerous organisations deliver 2000s Digital multimeters, and some arrive at costs as low as 90 pennies for every meter. In contrast, others made by Fluke or Milwaukee have a better quality of value and unwavering quality and bring costs in the many dollars.

Figure 3.2: Digital Electric Meter

3.3 What can be metered?

Both computerised and straightforward metering techniques can quantify numerous helpful electrical amounts, counting the accompanying:

3.3.1 Voltage

A voltmeter is put in parallel with a circuit element to measure the potential difference across that element. To minimise the current flow through the voltmeter, it often designed with internal impedances on the order of many megohms per volt. Voltmeters can determine relay contact and switch states while the circuit is energised, easing the troubleshooting process. A zero voltage reading across the connections indicates the contacts are closed, and a non-zero voltage indicates they're open.

3.3.2 Current

Ammeters are placed in arrangement with a circuit component to gauge the present moving through that piece of the circuit. Ammeters are planned with exceptionally low interior impedance to limit the voltage drop over the meter. Due to this low inside impedance, inappropriately associating an ammeter can bring about an extremely high current course through the meter, which could harm the meter loop or hardware. Along these lines, ammeters are ordinarily intertwined to shield the meter from the unreasonable current. A few ammeters, known as cinch on ammeters, utilise an implicit current transformer, which can be clipped around a conductor to encourage a quick and straightforward estimation.

3.3.3 power

Since control is the result of voltage and current, you can meter control utilising a voltage or potential component and a presentation component. On the off chance that genuine power is to be estimated, the RMS extents of the voltage and current waveforms are increased together. That item is duplicated by the cosine of the point distinction between the voltage and current waveforms, which is the power factor. On the off chance that receptive power is to be estimated, the power factor is supplanted by the sine of the edge distinction between the voltage and current waveforms.

3.3.4 Energy

Incorporating control after some time yields vitality; in this way, acquainting a period standard with a power meter makes it conceivable to quantify watt/hours, VAR-hours, and volt-ampere-hours. This is done electromechanically with an enlistment plate meter, which is basically an acceptance engine that pivots at a speed relative to the power estimated by the potential and current curls. A mechanical register or odometer tallies the circle upsets. At the point when the quantity of unrest is scaled by the fitting constants — in light of the meter plan — it's conceivable to decide the measure of vitality going through the meter. The fundamental standards of metering can be utilized to quantify different amounts like recurrence, control factor, and synchronism (voltage size and edge correlation) over an open electrical switch. While a portion of these metering strategies might be very perplexing, the essentials of metering continue as before.

3.4. Types of electric meters

Watt-hour meter or vitality meter is an instrument that estimates the measure of electrical vitality utilised by the purchasers. Utilities introduce these instruments at each spot like homes, ventures, associations to charge power utilisation by burdens, for example, lights, fans, and different apparatuses. Most fascinating sorts are utilized as prepaid power meters.

The essential unit of intensity is in watts. One thousand watts is one kilowatt. On the off chance that we utilise one kilowatt in 60 minutes, it is considered as one unit of vitality devoured. These meters measure the quick voltage and flow, figure its item, and give immediate power. This power is incorporated over a period, which offers the vitality used over that timeframe.

These might be single or three-stage meters relying upon the inventory used by local or business establishments. For little help estimations like household clients, these can be legitimately associated with line and burden. Be that as it may, for more significant responsibilities, step down current transformers must be put to confine vitality meters from higher flows.

Vitality meter or watt-hour meter is arranged as per a few factors, for example,

• Type of show like simple or advanced electric meter.

• Type of metering points like a lattice, auxiliary transmission, and essential and nearby dissemination

• End applications like household, business, and modern.

• Technical like three stages, single-stage, HT, LT, and precision class meters.

Three Basic Types of Energy Meters

Electromechanical induction type Energy meter

Figure 3.3: Induction Type Energy Meter

It is the prominently known and most ordinary sort of age-old watt-hour meter. It comprises of pivoting aluminium circles mounted on an axle between two electromagnets. The speed of turn of the plate is corresponding to the power, and this power is coordinated by the utilisation of counter instruments and rigging trains. It involves two silicon steel overlaid electromagnets, i.e., arrangement and shunt magnets.

Arrangement magnet conveys a curl, which is of hardly any turns of thick wire associated in arrangement with the line. However, shunt magnet sends curl with numerous turns of slender wire associated over the stock.

The breaking magnet is a perpetual magnet that applies the power inverse to a typical plate pivot to move that circle at the adjusted position and to stop the plate while control is off.

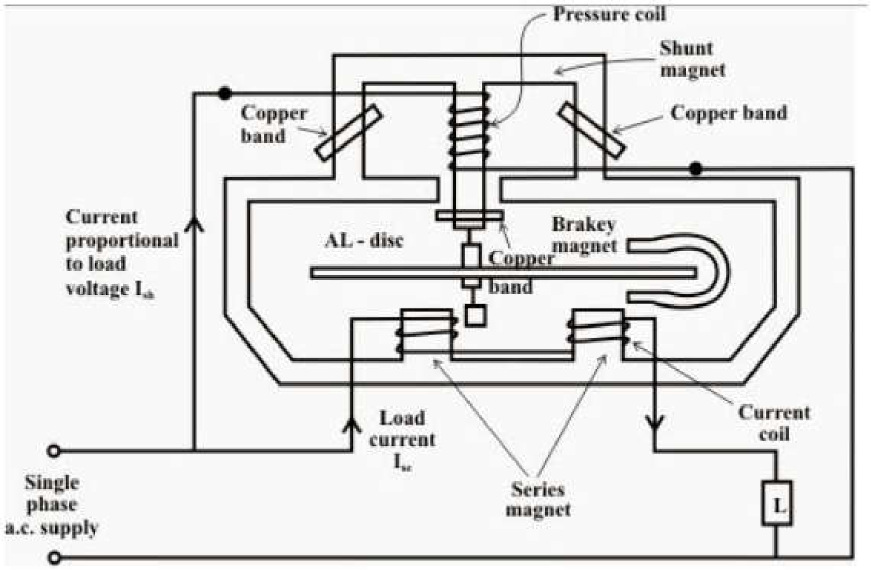


Figure 3.4: Working of Induction Type Energy Meter

Figure 3.4: Working of Induction Type Energy Meter

An arrangement magnet delivers the transition, which is corresponding to the present streaming, and the shunt magnet creates the motion relative to the voltage. These two transitions slack by 90 degrees because of inductive nature. The collaboration of these two fields produces vortex current in the circle, applying a power, which is relative to the result of immediate voltage, current, and stage edge between them.

Vertical axle or shaft of the aluminium plate is associated with gear course of action, which records a number relative to the number of insurgencies of the circle. This rigging course of action sets the number in a progression of dials and shows vitality devoured after some time. This sort of meter is essential in development, and precision is, to some degree, less because of crawling and other outside fields. A significant issue with these sorts of meters is their simple inclined to altering, prompting a necessity of an electrical vitality checking framework. These are generally utilized in household and modern applications.

3.5 Electronic Energy meters

These are of the precise, high parade and dependable sorts of estimating instruments when contrasted with customary mechanical meters. It devours less power and starts evaluating when it is associated with the load. These meters may be simple or computerised. In simple meters, control is changed over to relative recurrence or heartbeat rate, and it is incorporated by counters put inside it. In advanced electric meter, control is legitimately estimated by an excellent quality processor. The power is coordinated by rationale circuits to get the vitality and for testing and adjustment purposes. It is then changed over to a recurrence or heartbeat rate.

3.5.1 Analog Electronic Energy Meters

In simple sort meters, voltage and current estimations of each stage are acquired by the voltage divider, and current transformers individually, which are legitimately associated with the heap as appeared in the figure underneath.

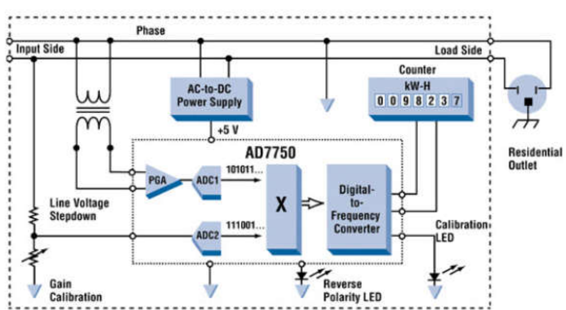


Figure 3.5: Analog Electronic Meters

Analogue to digital converter changes over these analogue qualities to digitised tests, and it is then changed over to relating recurrence flag by recurrence converter. This recurrence beats at that point drive a counter component where these examples are incorporated after some time to create power utilisation.

3.5.2 Digital Electronic Energy Meters

Digital sign processors or elite chips are utilized in digital electric meters. Like the analogue meters, voltage and current transducers are associated with a high-goals ADC. When it changes over the analogue sign to digital examples, voltage and current samples are increased and incorporated by digital circuits to quantify the vitality devoured.

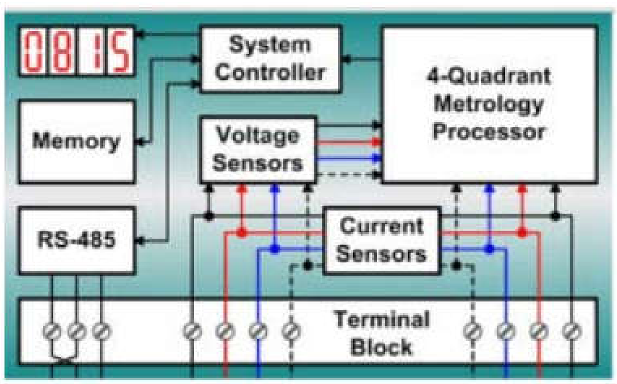


Figure 3.6: Digital Electronic Energy Meters

The microprocessor additionally computes stage edge among voltage and current, with the goal that it likewise quantifies and demonstrates receptive power. It is customised so that it figures vitality as indicated by the duty and different parameters like power factor, most extreme interest, and so forth and stores every one of these qualities in a nonvolatile memory EEPROM.

It contains an ongoing clock (RTC) for ascertaining the ideal opportunity for control mix, most extreme interest counts, and the date and time stamps for specific parameters. Besides, it collaborates with fluid gem show (LCD), specialised gadgets, and other meter yields. The battery is accommodated RTC and other critical peripherals for reinforcement control.

3.5.3 Smart Energy Meters

It is a progressed metering innovation, including putting wise meters to peruse, procedure, and input the information to clients. It estimates vitality utilisation, remotely changes the stockpile to clients, and remotely controls the most extreme power utilisation. The intelligent metering framework utilises the progressed metering foundation framework innovation for better execution.

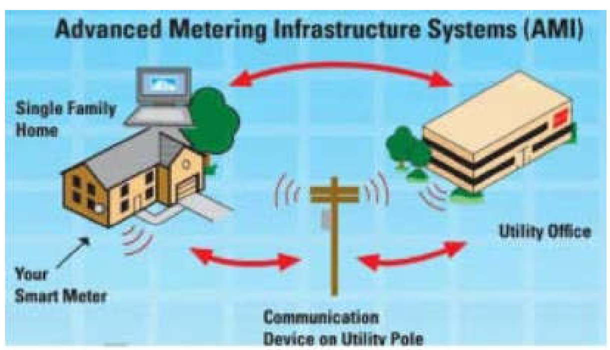


Figure 3.7: Smart Electric Meters

These are equipped for imparting in the two bearings. They can transmit the information to the utilities like vitality utilisation, parameter esteems, cautions, and so on and can get data from utilities, for example, programmed meter understanding framework, reconnect/detach directions, updating of meter programming and other significant messages. These meters lessen the need to visit while taking or perusing a month to month bill. Modems are utilised in these brilliant meters to encourage correspondence frameworks, for example, phone, remote, fibre link, control line interchanges. Another bit of leeway of intelligent metering is finished evasion of altering of vitality meter where there is the extent of utilising power illicitly.

3.6. Types of Electric Meter concerning Current Direction

3.6.1 Unidirectional Energy Meter

These Energy meters are fundamental sorts of vitality meters that you see each day. They simply measure the present, which is streaming side inwards or towards the customer side. On the off chance that the current is flowing towards outside, at that point, it doesn't tally or nullify those units. In this way, these meters name of these meters is unidirectional meters.

3.6.2 Bi-directional Energy Meters

These are the uncommon sorts of Energy Meters that measure flows in the two bearings. It implies if the Current is streaming internal, at that point, it will include the units in its aggregated register and on the off chance that the Current is flowing outwards; at that point, it will discredit units from the register. With the headway in sun-based innovation, Electric purchasers are moving their heaps towards the sunlight-based side. If somebody has more sun powered boards than its heap prerequisites, at that point, they can sell extra Energy units (which are going to squander in any case) to the service organisations. This procedure is called Net Metering. Service organisations can satisfy their vitality lacks through this strategy. In Net Metering, Bidirectional Energy Meters are the main answer for include or invalidate the vitality units as for the present heading.

Analogue meters, otherwise called electromechanical, are the most well-known; the basic meter turns forward when you're utilising power. If the analogue meter is bidirectional, it will turn in reverse when your sunlight based electric framework is driving additional power once more into the lattice. The occasions the plate turns forward or, in reverse, decides how much power you are utilising or adding to the electric matrix. The service organisation must dispatch a meter per user consistently to make sense of how a lot of vitality your structure is utilising.

Digital meters or robust state meters have no moving parts and work like analogue meters. Yet, they show the information on a digital screen versus the dials on an analogue meter. The utility will have the option to peruse the data from the meter at regular intervals without the need of sending a meter per user to your property since it's associated with the utility system. Digital meters enable your service organisation to screen your utilisation remotely and are generally bidirectional.

3.7 Accuracy

Power metering precision is critical in guaranteeing the uprightness of a charging framework. The accuracy relies upon the plan and constructs nature of the meter's information channels - a more magnificent estimating meter will give better exactness yet will build the cost of the item. Some significant parameters that influence the precision estimation of a vitality meter are:

a) The fluctuation of the reading value, which is represented in percentage % from the actual value (reading)

b) A fixed error (noises) commonly represented as a percentage from full scale (FS) as its constant value.

c) For power and energy measurements, the phase shift between the voltage and the current also affects the accuracy since the power equals voltage multiplied by current multiplied by the cosine of the phase angle.

d) The phase angle accuracy is represented in degrees in current transformers creating

Additional errors to energy/power meters.

3.8 Net Meter in Smart Grid

A net meter is one of the most significant gadgets utilised in the matrix scheme or smart grid (SG). Mainly grid is embodied in generation, transmission, consumption, and distribution of power. Generally, in the control grid, electricity is carried from a few focal generators to a considerable number of load centres with consumers. This control grid turns to a smart grid which tills now under development. It works as a two-way data stream and anomalistic power stream, also creates an independent and spread out power delivery network.

Here we can see the differences between the smart grid and the existing grid in Figure 3.8.

Existing Grid	**Smart Grid**
Electromechanical	Digital
One way communication	Two-way communication
Centralised generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-heating

Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

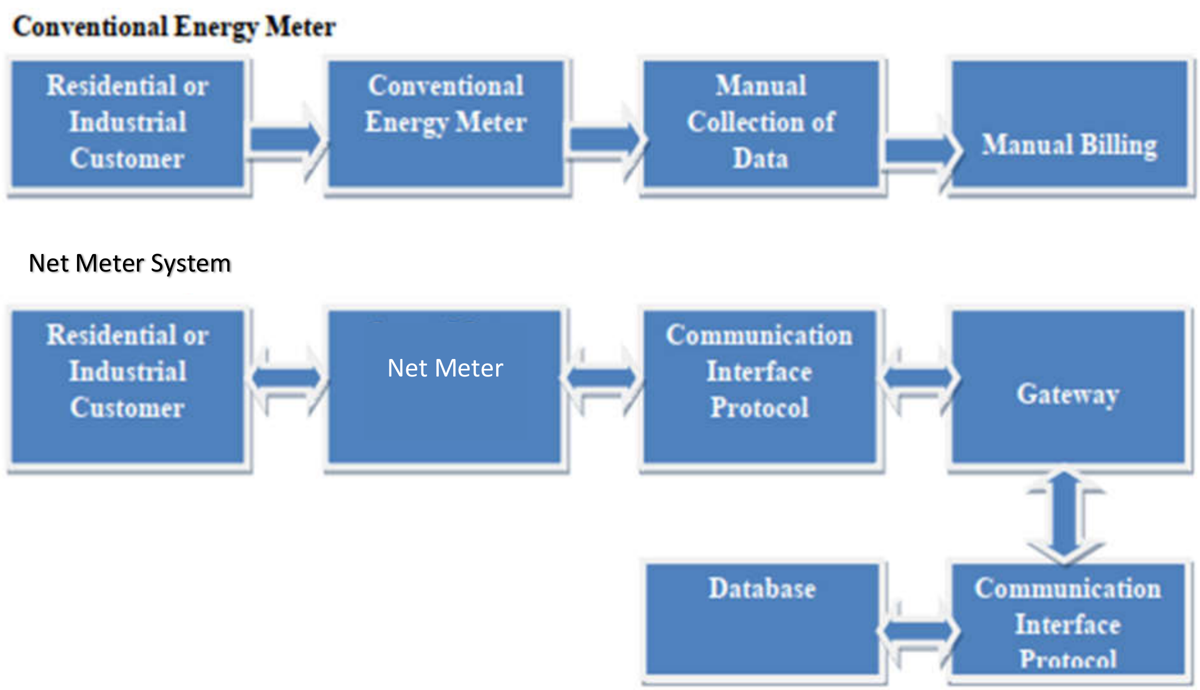


Figure 3.8: Architectures of conventional energy and a net meter.

3.9 The typical function of the net meter

The net meter has the following characters:

» It works as a two-way communication system

» It can accumulate, record, and store data.

» The load control system

» The programming function

» The security system

» The display system

» The billing system

3.9.1 Net metering system benefits

The advantages of introducing net meters have a wide range of varieties of partners in different spheres of scheme matrix framework. Net Metering Value Proposition for the utilities:

» It sets aside a great deal of cash by improving the remote region perusing and charging framework.

» It enables the utility to oversee during peak hours more readily.

» It makes more utilisation of vitality and grid resources.

» It offers another duty model in the power advertises.

» It develops the transformer load management for the transmission line.

3.9.2 Net Metering Value Proposition to User

» It shows client information about their power utilisation tendencies.

» It gives the client progressively exact and convenient electrical charging.

» It supports the client to utilize electrical machinery during peak hours more readily.

» During peak hour, it helps customers to change/postpone their electrical appliances.

3.9.3 Net Metering Value Proposition for Governments

» It energised the economy by putting resources into net metering systems.

» It improves the natural condition by lessening CO2 emanation.

» It prompts a decrease in utilisation by expanding the familiarity with utilisation designs.

» It assists better with stacking determining for the power network and counteracts enormous scale power outages.

» It gives information for improving productivity and unwavering quality of administration.

3.10 Net meter technologies

The net meter operates straightforwardly. It collects data from the end consumers and transmits this information through Wi-Fi to the data collector. It can read data continuously. This process executed at a regular interval or once a day based on the requirement of client demand. Collect data and then transmits it. Through the Wide Area Network (WAN), the further procedure regarding data performed by the utility focal accumulation.

It is a two-way communication process. Where signal and commands directly go to the meter or client premise. A net meter is a smart billing technology, which consists of an Ethernet shield, Arduino Nano board, Wi-Fi. And the voltage sensor and current sensor are aggregating with the smart grid through the transformer. And they are interconnected with Arduino Nano. All the information auto-updated and stored on the website. Here it is to be remembered this is a read-only file, and nothing can be added or subtracted.

3.11 Measurement Errors in Energy Meters

During the ongoing years, the power organise has been influenced by a few electrical aggravations because of the expansion of non-straight loads. These non-straight loads present high consonant substance in the present waveforms required from the AC net, bringing about mutilation in the voltage control framework waveform, control factor decrease, over the top removal of current and voltage, the significant level of the third symphonious substance in the unbiased current, and EMI (electromagnetic obstructions). Electrical vitality estimations assume a substantial job in business vitality exchanges, and in the electrical dissemination arrange assessing the vitality adjusts for soundness purposes. Along these lines, the effects of no sinusoidal and unequal states of intensity organise on meter precision must be dissected because these impacts can speak to generous financial implications for the utility and the customer.

The Net Energy Meter (NEM) is a very outstretched concept. No matter how much we -brainstorm about net energy meter (NEM) it is nothing but only one thing, that procedure occupies solar energy system owners sent back electricity to the grid, and get a credit for the contributed electricity. After installing the solar panel, it can produce more electricity than the demand, the spared electricity will add to the grid, which helps to balance the utility bill between the owner and the power company. It assures that owner is being paid the right charge.

Chapter 4: Design and Development of Our Proposed Device

4.1 Introduction

The net meter mainly helps to reduce the electricity billing cost, and our proposed is to make a new meter which can be made quickly as well as at a low price. So, we are going to use open-source hardware and software.

System Block Diagram

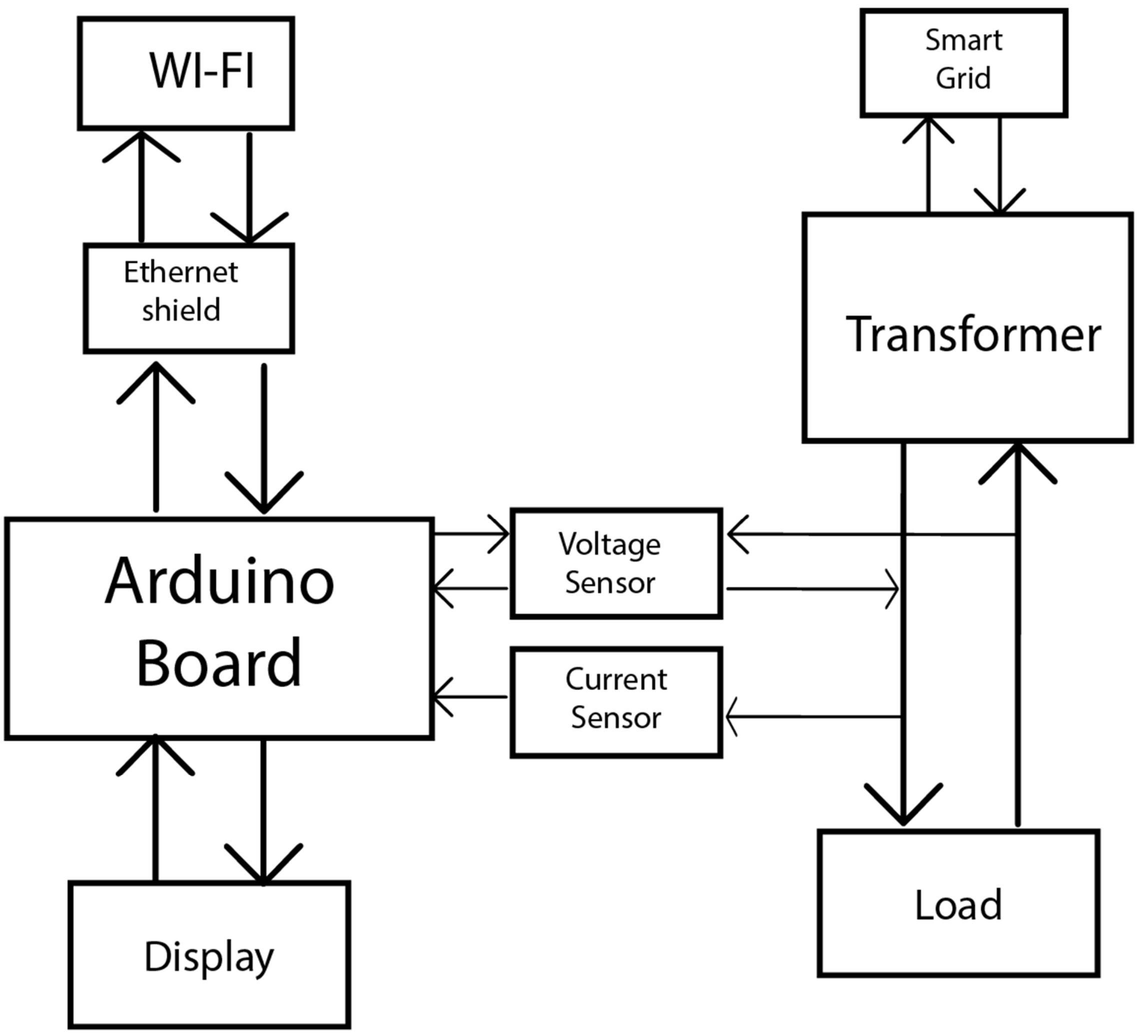


Figure 4.1: Block Diagram online net metering system

In this section, a block diagram of the online Net Metering system id depicted. This proposed system demands some appliances which are available to get at a low cost. This device consists of an Arduino board, Ethernet shield along with Voltage & Current sensor.

Where Arduino Uno board is connected with an Ethernet shield and Ethernet shield connected with Wi-Fi, here voltage & current sensor are working as a bridge/medium between the Arduino board and smart grid through the transformer. Which load is consumed by a consumer that comes from the grid through the transformer, Arduino delivers the data using Wi-Fi via an Ethernet shield for updating on a website. This website displays the result when any users log into the site with a valid and particular IP address.

4.1.1 Arduino Uno

Arduino refers to an open-source electronics platform or board and the software used to program it. Arduino is designed to make electronics more accessible to artists, designers, hobbyists and anyone interested in creating interactive objects or environments. An Arduino board can be purchased pre-assembled or because the hardware design is open source, built by hand. Either way, users can adapt the boards to their needs, as well as update and distribute their own versions.

The word "UNO" means "one" in Italian and was chosen to mark the initial release of Arduino Software. The Uno board is the first in a series of USB-based Arduino boards.

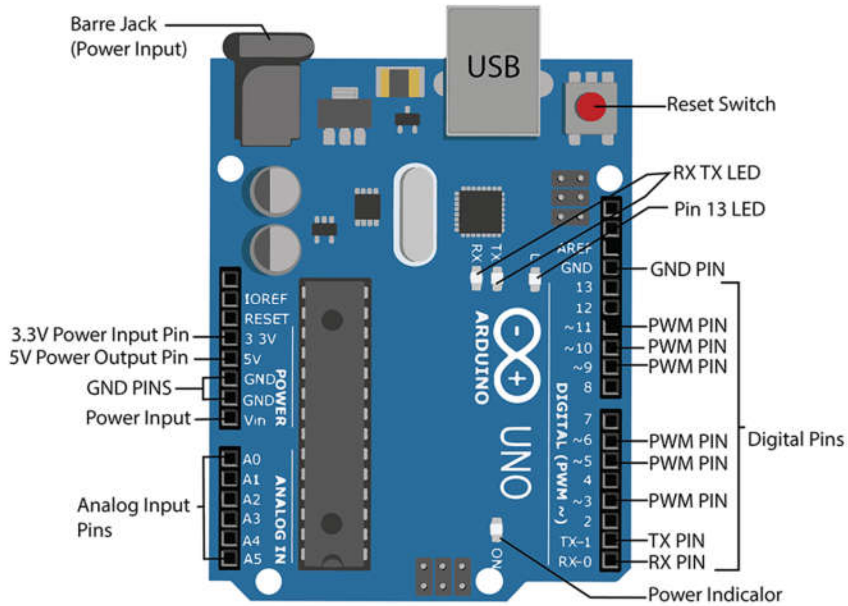


Figure 4.2 : An Arduino board

Pin description

Pin category	Pin name	details
Power	V_{in}, 3.3 V,5V, GND	**V_{in}**: Input voltage to Arduino when using an external power source. **5V**: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by the onboard voltage regulator. Maximum current draw is 50mA. **GND**: ground pins.
Reset	Reset	Resets the microcontroller.
Analog pins	A0-A5	Used to provide analog input in the range of 0-5V
Input/ Output pins	Digital pins 0-13	Can be used as an input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data
External interrupts	2,3	To trigger an interrupt.

PWM	3,5,6,9,11	Provides 8-bit PWM output.
SPI	10(SS), 11(MOSI), 12(MISO) & 13(SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED
PWI	A4 (SDA), A5 (SCA)	They are used for TWI communication.
AREF	AREF	To provide a reference voltage for input voltage.

Arduino Uno Technical Specifications

Microcontroller	ATmega328P – 8-bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	7-20V
Analog Input Pins	6 (A0-A5)
Digital I/O Pins	14(Out of which 6 provide PWM output)
DC Current on I/O pins	40mA
DC Current on 3.3 Volt pin	50mA
Flash Memory	32 KB (0.5 KB Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16MHz

4.1.2 Ethernet shield

An Ethernet shield is a computer component commonly used with Arduino technologies. These components allow a device to connect to the Internet through the use of an Ethernet cable and a local access network (LAN). They may be used to both receive and send information over the Internet.

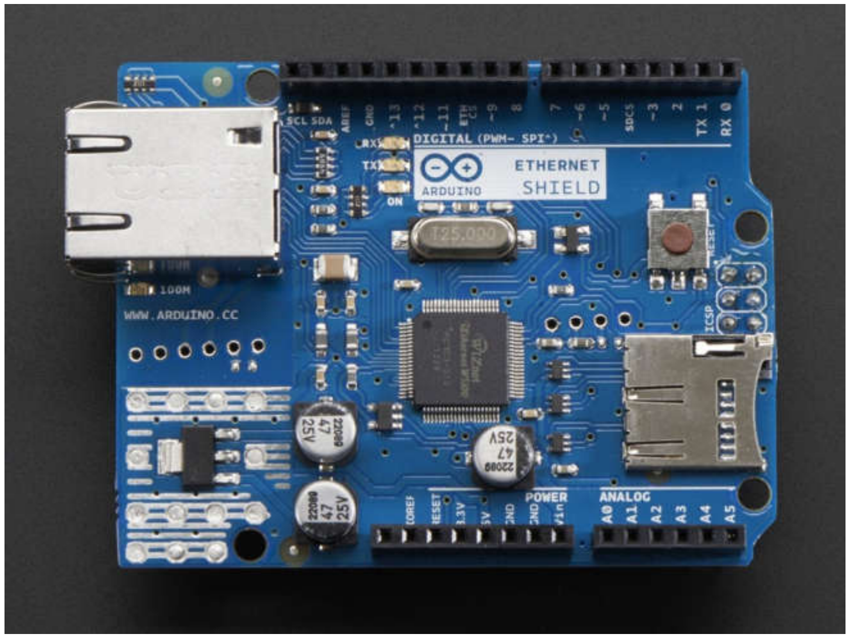


Figure 4.3: Ethernet Shield

4.1.3 Voltage sensor

The Voltage Sensor is a simple module that can be used with Arduino (or any other microcontroller with input tolerance of 5V) to measure external voltages that are greater than its maximum acceptable value, i.e. 5V in case of Arduino. Following is the image of the Voltage Sensor Module used in this device.

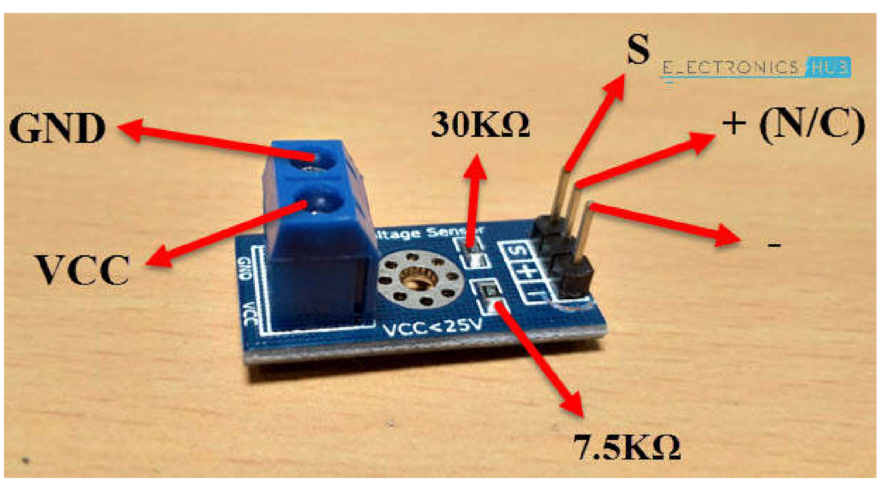


Figure 4.4: A Voltage sensor

- **VCC** is the Positive terminal of the voltage to be measured (0-25V).
- GND: Negative terminal of the voltage to be measured
- S: Analog Input of Arduino
- +: Not connected (N/C)
- –: GND of Arduino

4.1.4 Current sensor

A Current Sensor is an important device in power calculation and management applications. It measures the current through a device or a circuit and generates an appropriate signal that is proportional to the current measured. Usually, the output signal is an analog voltage.

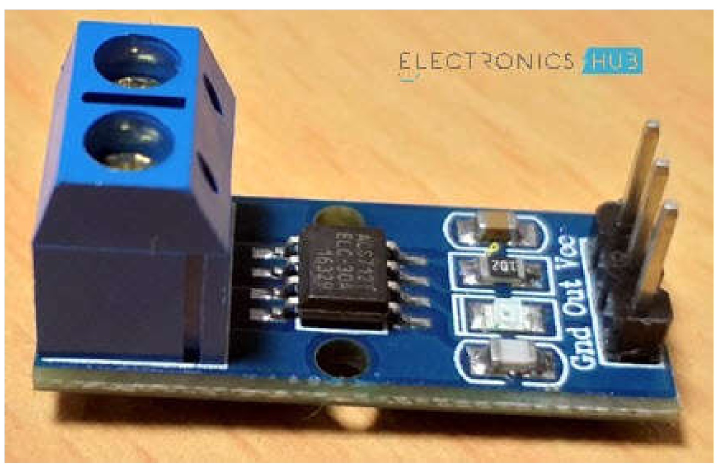


Figure 4.5 : A Current sensor

It is fairly a simple board with only a few components including the ASC712 IC, few passive components and connectors.

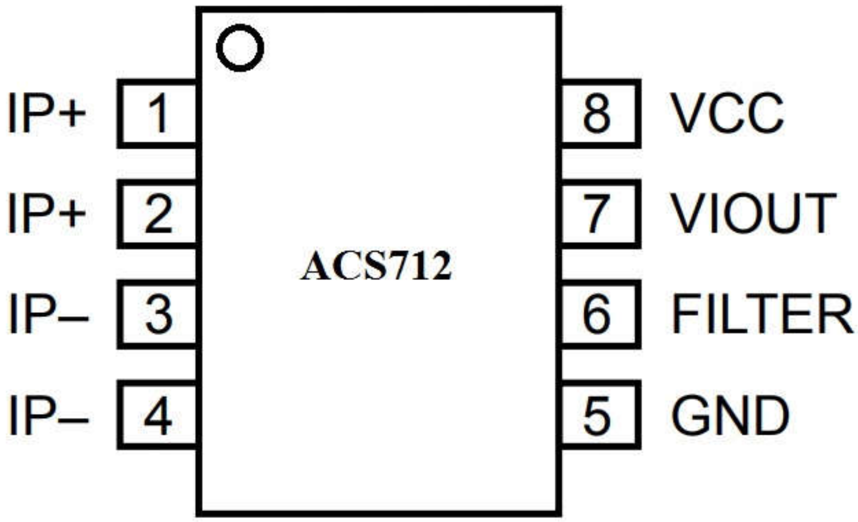


Figure 4.6: A PIN diagram of the current sensor

Description of pin diagram.

Pin number	Pin name	Pin description
1&2	IP+	+ve terminal for sensing current
3&4	IP-	-ve terminal for sensing current
5	GND	Signal ground
6	Filter	External capacitor(to set the bandwidth)
7	VIOUT	Analog output
8	VCC	Power supply

4.2 Design Concept

Our proposed device is being made to fulfil the following requirements-

1. It requires low cost
2. Comprises less hardware
3. It will be accessible worldwide.

Here are proposed device requirements are to cope with the SCADA system. This system has two parts.

i) Data acquisition system

ii) Supervisory control system

4.3 Data Acquisition System

4.3.1 Component of the data acquisition system

a) Data acquisition server

A data acquisition server is a software service that uses standard protocols to access data. This server maintains industrial protocols to connect software services. It works through field devices such as RTU and MCU.

These days, so many companies help clients by giving web servers with unlimited space along with demanding a low annual cost.

b) Telemetry service

SCADA system is a new and eye-catching system, works for remote monitoring and controlling. It is an automatic process that sends sensor data to remote data acquisition. Eventually, it is diminishing the necessity of staying or frequently visiting for the operator.There are so many telemetry services, yet Ethernet is one of the most reliable and cheap of all those, and it is the most popular in Local Area Network (LAN) technology.So, we are using Ethernet for our proposed device.

c) Main Controller Unit

For our proposed device, we need inexpensive and less hardware. Though Programmable Logic Circuit (PLC) is cheap, it requires many hardware equipments rather then MCU. Therefore, we can use here Arduino Uno board. This Arduino is an excellent replacement for PLC, specifically designed to use a microcontroller chip as well as other input and output. Arduino was a control system when it connected with sensors, actuators, lights, speakers, shields, and other integrated circuits. It is open-source and very cheap too. This Arduino can be modified and used at any time whenever clients want. That's why for our proposed device, we used the Arduino Uno board.

D) Remote Terminal Unit (RTU)

In this proposed device, we used Arduino Uno as MCU and Ethernet shield as telemetry. After connecting both hardware, this will be used as RTU.

Hence RTU is capable of sending data to the data acquisition server. And Arduino is capable of connecting to the internet because of the Ethernet shield.

e) Sensor

The sensor is a kind of transducer. It is used to detect events and variations of the environment and gives us a resembling output. Sensors usually use for electrical or optical signals. For our proposed system, we are using the register as a sensor.

F) Human Machine Interface (HMI)

One of the primary and essential purposes of our proposed system can access from anywhere in the world. We intend to use a website as HMI. Hypertext preprocessor (PHP) programing language is being used to develop this HMI where PHP is open source and free of cost too.

It can be used in two ways. Firstly, HMI works itself as a client, request data from the data acquisition server. Secondly, HMI acts as the graphical user interface for the operator. After performing all the processes, it sends notifications.

g) Historian Software

We need a historian software as a server that can preserve all the time-stamped data in a store. This software is developed by a free of cost open-source database management system referred to as MySQL. This software as a client and request a data acquisition server for data, and it can be queried in the HMI.

4.3.2 Supervisory Control System

SCADA is mainly a supervisory control system that made of various software and hardware elements, where it permits industrial clients for interaction and control machines. And it is connected with HMI software.

a) Controlled Device

There are many types of relays, magnetic contractor or any other voltage control switch are used to manage the function of the power plant. They are used to detect electrical faults and to alarm, disconnect, or shut down a faulted device to provide for personal safety and equipment protection.

Types of relays we use for protection scheme are-

1. Overcurrent

2. Overcurrent with voltage restraint
3. Different relays
4. Distance relays
5. Frequency relays
6. Neutral connected ground fault relays
7. Overvoltage, under-voltage, voltage valance, and reverse face relays
8. Synchronism check relays
9. Temperature and pressure relays
10. Directional power, directional overcurrent

The reasons for using relays

i) To detect electrical faults

ii) To alarm disconnect or shut down a faulted device

iii) To provide for personal safety

iv) To ensure the equipment protection

v) To make or break contact with the help of a signal without any human.

Three basic types of relay electromechanical, solid-state, and digital are generally used in the power plant. We used electromechanical relay as a protection relay in this controlled supervisory device.

b) Controlling Device

An Arduino GSM module will be utilized to control the assurance hand-off. It plays out the fundamental control task as got utilizing an instant message from the HMI programming.

c) Human Machine Interface (HMI)

A cell phone with a functioning SIM card will be utilized as the HMI of the proposed supervisory control framework. The working framework (OS) of the cell phone fills in as the HMI programming. The administrator sends instant messages with the essential directions from it to the Arduino GSM module.

4.4 Development of the proposed system

The proposed SCADA system consists of three system-

a) An embedded system

b) An online system

c) A GSM system

4.4.1 Embedded system

The designed embedded system will calculate the full power through a sensor. The relation between the PV array and the power across the sensor is simple and directly proportional. When the PV array is not working, the power across the sensor is zero.

PV array $\propto$ current sensor. After collecting all the data, it sends it to the online system. This system consists of five components

a) Arduino Uno

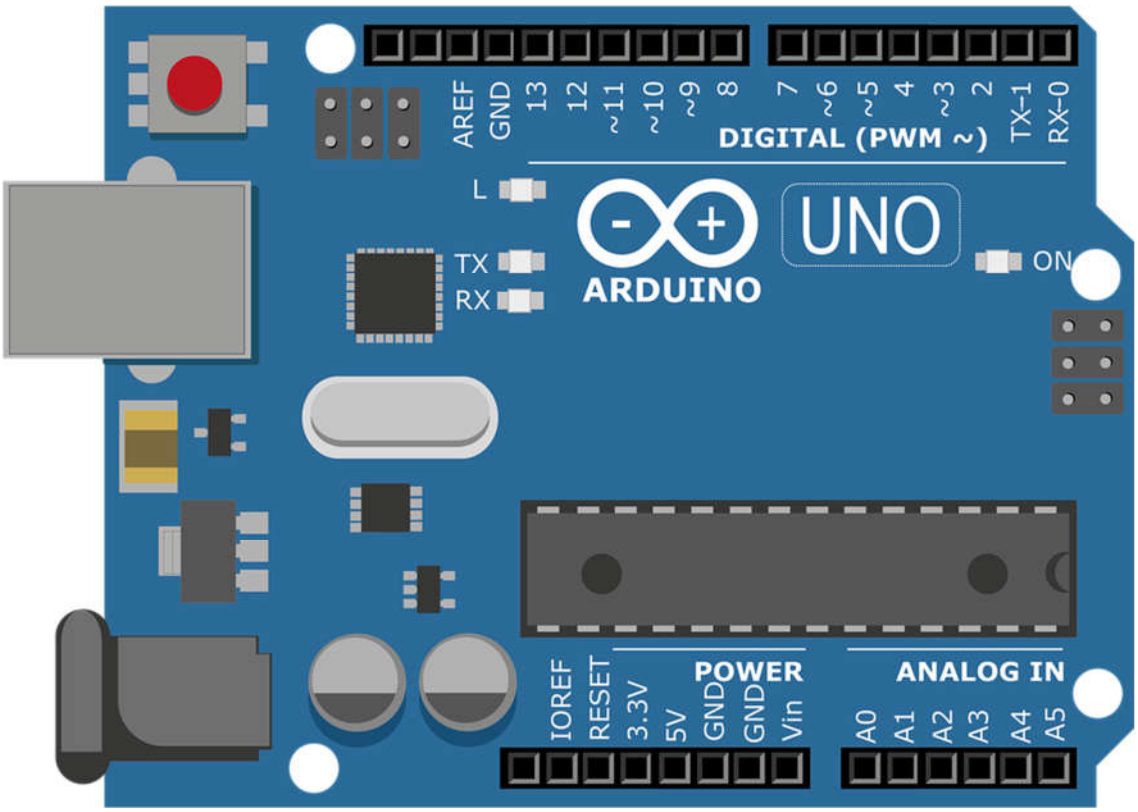


Figure 4.2: Arduino Unio

1. Measuring Voltage Across the Sensor

To get analogue info, Arduino Uno utilises ATmega328 microcontroller's analogue to digital converter, typically called an A/D converter or ADC. The ADC changes over a persistent analogue voltage applied to one of the analogue pins of Arduino Uno into a number worth relative to the measure of voltage at that pin. This is a particular piece of equipment that is associated with 6 of Arduino's general I/O pins, set apart on the board as A0 – A5. The Arduino ADC has a 10-piece goal, implying that it will restore a whole number an incentive from 0 to 1023 relating to 0 volt and +5 volts separately. Presently, an Arduino analogue pin can accept 5 volts most extreme as its information. Yet, it can without much of a stretch be utilised as a voltmeter to gauge higher voltages than that. This is accomplished by utilizing two resistors to make a voltage divider. The voltage divider diminishes the voltage being estimated to inside the scope of the Arduino analogue data sources. The code in the Arduino sketch is then used to figure the genuine voltage being estimated. The accompanying qualities have been considered, to assemble the voltage divider for this installed framework.

Maximum output voltage of PV array, $V = 300$ V.

Voltage across the second resistor, $V_1 = 5$ V.

Second resistor value, $R_1 = 5$ kΩ.

Now, the voltage divider rule states that,

$$\frac{V_1}{V} = \frac{R_1}{R + R_1}$$

Using this rule, the sensor value,

$$R \approx 300 \text{ k}\Omega.$$

As a result, when measuring 300 volts, the Arduino analog pin will be at its maximum voltage of 5 volts. This will change simultaneously with the change in the PV array output voltage.

Now, the voltage on the Arduino analog pin is,

$$V_{pin\_2} = Integer\ value \times (5/1024)\ (\text{V})$$

$V = Vpin\_2 \times (R + R1\ /R1)$ (V)

By using this simple equation n in the Arduino sketch, the voltage across the sensor can easily be measured.

2. Measuring Current Through the Sensor

A powerful device to quantify the current through a sensor is the Hall impact current sensor. It is exceptionally simple to utilise the bi-directional current sensor. It comes in 5, 20, and 30 amperes adaptations. The 5 amperes rendition (ACS714) will be utilized to structure this implanted framework. The present sensor peruses the present worth and changes over it into applicable voltage esteem. The worth that connections the two estimations is affectability, which – for 5A model – has a commonplace evaluation of 185 mV/A. The present sensor can gauge positive and negative flows inside the range - 5 amperes to 5 amperes. The power supply for the present sensor is 5 volts, and the centre detecting voltage is 2.5 volts when no current. The present sensor appears in Figure 3.2.

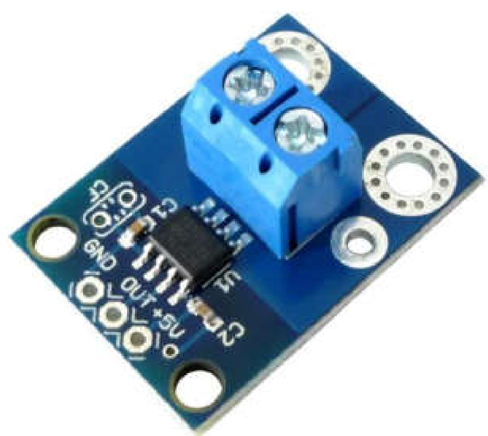


Figure 4.3: ACS714 Hall Current Sensor Module

The present sensor is to be put in an arrangement with the framework sensor. The OUT port of the current sensor is associated with another analogue pin of Arduino Uno. The voltage on this analogue pin can be estimated by,

V $pin\_4 = Integer\ value \times$	5
1024	

(V) (3.3)

The current through the load can be found out by the following equation,

$I = [Vpin\_4 - 2.5]/0.185$ (A) (3.4)

By using this calculation in the Arduino sketch, the Current through the PV load is measured.

3. Measuring Power Across the Sensor

The power across the sensor can be measured by, $P = V \times I$ (W) (3.5) This equation is put inside the Arduino sketch to calculate the power across the sensor.

4. Powering Arduino Uno

The Arduino Uno needs some capacity to work. It tends to be effectively given by utilising an extremely regular 12 volts 1 ampere AC to DC divider mole control connector. The connector will be connected to the power port of Arduino Uno. In the wake of turning on the switch of the attachment, the Arduino Uno will begin to work.

b) Sensor

The range of the output value of a PV array is 0-300 volts as a load film resistor creates a direct PV system. It works only under solar radiation so that in the absence of solar energy, we get less amount of power and get maximum when the PV array reaches its peak, 300 volts. The output of the resistor is analogue.

c) Arduino Ethernet shield

The ATmega328 microcontroller of the Arduino Uno will finish the information preparation. Be that as it may, it can't send it to the webserver by itself.

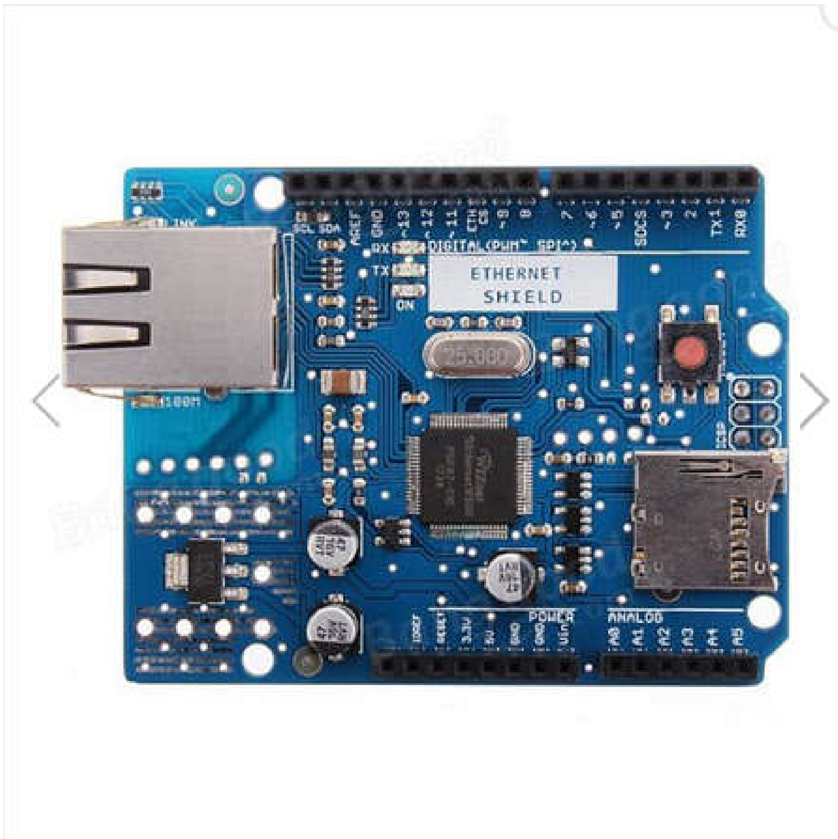


Figure 4.4: Ethernet Shield

.Therefore, an Arduino Ethernet shield, will be joined with the Arduino Uno. An Ethernet association is to be embedded in the Ethernet port of the Ethernet shield. The shield will take the Arduino Uno prepared information and send them to the webserver utilizing Ethernet.

d) Arduino GSM Module

A hand-off is a switch, which can control gadgets by turning ON and OFF. The exchanging of the condition of the transfer can be remotely constrained by utilising an

Arduino GSM SIM808 module. It can get instant messages with directions and move the directions to the ATmega328 microcontroller. The microcontroller will, at that point, turn the transfer ON or OFF according to necessity.

4.4.2 Online system

After receiving the data from the embedded system, the online system

make those accessible.

1) Web Server
2) Historian Server
3) Website

we are going to give a short description of these three portions

Web Server

This one gives us a significant advantage, which has unlimited storage capacity. It works as a data acquisition server and collects data from the embedded system, and then stored to the server.

Historian Software

This historian's software will actuate the time-stamped data. Using MySQL, this software is being developed.

Website

A website is being created by using PHP. Here the time-stamped data from the historian software will be shown. This website will be worked as the HMI of the data acquisition system. Anyone can observe of operation of a PV array on this website at any time.

4.4.3 GSM System

An active SIM card inserted into a working mobile phone, this how the GSM system is being structured. This phone text message with the necessary commands will be sent to the GSM module.

4.5 RMS Value Calculation

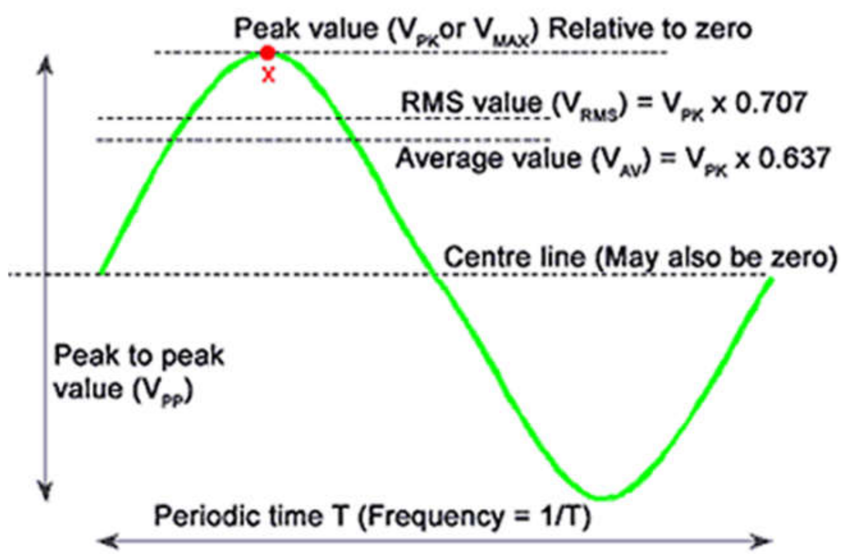


Figure 4.5: **Characteristics of a Sine Wave**

A waveform is a graph showing the variation, usually of voltage or Current, against time. The horizontal axis shows the passing of time, progressing from left to right. The vertical axis shows the quantity measured (this is a voltage in Figure 4.5).

Six of the essential characteristics of a sine wave are;

- PEAK TO PEAK value.
- INSTANTANEOUS value.

- AMPLITUDE.
- PEAK value.
- PERIODIC TIME.
- AVERAGE value.
- RMS value.

These characteristics are illustrated in figure 4.5

4.5.1 Peak to Peak Value

The PEAK TO PEAK value is the vertical distance between the top and bottom of the wave. It will be measured in volts on a voltage waveform and may be labelled V_{PP} or V_{PK-PK}. In a current waveform, it would be labelled I_{PP} or I_{PK-PK} as I (not C) is used to represent current.

4.5.2 Instantaneous Value

This is the value (voltage or current) of a wave at any particular instant. We have often chosen to coincide with some other event. E.g. The instantaneous value of a sine wave one-quarter of the way through the cycle will be equal to the peak value. See point X in Figure 4.5.

4.5.3 Amplitude

The AMPLITUDE of a sine wave is the maximum vertical distance reached, in either direction from the centerline of the wave. As a sine wave is symmetrical about its centerline, the amplitude of the wave is half the peak to peak value, as shown in Figure 4.5 (a).

Peak Value

The PEAK value of the wave is the highest value. The wave reaches above a reference value. The reference value commonly used is zero. In a voltage waveform, the peak value may be labelled V_{PK} or V_{MAX} (I_{PK} or I_{MAX} in a current waveform).

If the sine wave being measured is symmetrical either side of zero volts (or zero amperes), meaning that the dc level or dc component of the wave is zero volts, then the peak value must be the same as the amplitude, that is half of the peak to peak value.

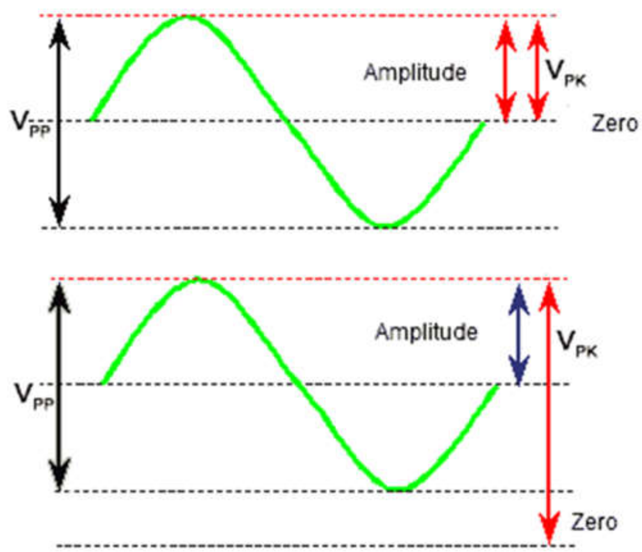


Figure 4.5 (a): **Defining the Peak value V_{PK}**

However, this is not always the case; if a dc component other than zero volts is also present, the sine wave will be symmetrical about this level rather than zero. The bottom waveform in Figure 4.5(a) shows that the peak value can now be even more significant than the peak to peak value, (the amplitude of the wave, however, remains the same, and is the difference between the peak value and the "Centreline" of the waveform).

4.5.3 Periodic Time & Frequency

The PERIODIC TIME (given the symbol T) is the time, in seconds milliseconds, etc. taken for one complete cycle of the wave. It can be used to find the FREQUENCY of the wave f using the formula $T = 1/f$

Thus if the periodic time of a wave is 20ms (or 1/50th of a second), then there must be 50 complete cycles of the wave in one second. A frequency of 50 Hz. Note that when you use this formula, if the periodic time is in seconds, then the frequency will be in Hz.

4.5.4 Average Value

The AVERAGE value. This is normally taken to mean the average value of only half a cycle of the wave. If the average of the full cycle was taken, it would, of course, be zero, as in a sine wave symmetrical about zero, there are equal excursions above and below the zero line.

Using only half a cycle, [as illustrated in figure 4.5 (b)], The average value (voltage or current) is always 0.637 of the peak value of the wave.

$V_{AV} = V_{PK} \times 0.637$

Or $I_{AV} = I_{PK} \times 0.637$

The average value is the value that usually determines the voltage or current indicated on a test meter. There are, however, some meters that will read the RMS value; these are called "True RMS meters."

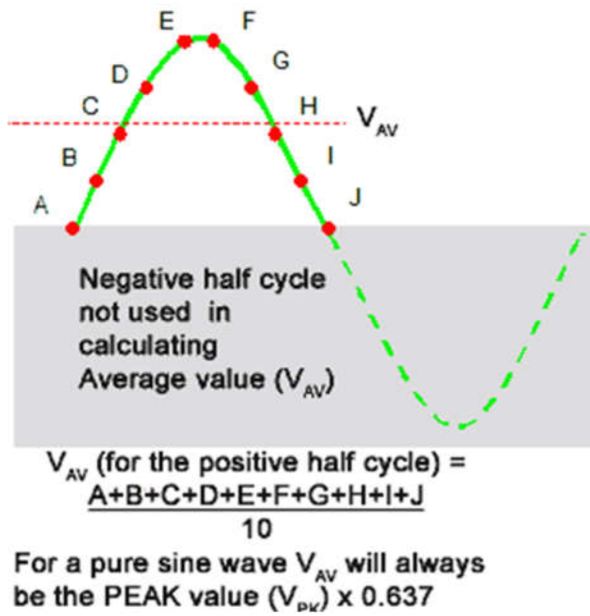


Figure 4.5(b): The Average Value of the Sine Wave

4.5.5 The RMS Value.

The RMS or ROOT MEAN SQUARED value is the value of the equivalent direct (non-varying) voltage or current, which would provide the same energy to a circuit as the sine wave measured. That is, if an AC sine wave has an RMS value of 240 volts, it will provide the same energy to a circuit as a DC supply of 240 volts.

It can be shown that the RMS value of a sine wave is 0.707 of the peak value.

$V_{RMS} = V_{PK} \times 0.707$ and $I_{RMS} = I_{PK} \times 0.707$

Also, the peak value of a sine wave is equal to 1.414 x the RMS value.

4.5.6 The Form Factor

If V_{AV} (0.637) is multiplied by 1.11, the answer is 0.707, which is the RMS value. This difference is called the Form Factor of the wave, and the relationship of 1.11 is only valid for a perfect sine wave. If the wave is some other shape, either the RMS or the average value (or both) will change, and so will the relationship between them. This is important when measuring AC voltages with a meter, as it is the average value that most meters actually measure. However, they display the RMS value simply by multiplying the voltage by 1.11. Therefore, if the AC wave being measured is not a perfect sine wave, the reading will be slightly wrong. If you pay enough money, however, you can buy an accurate RMS meter that calculates the RMS value of non-sine waves.

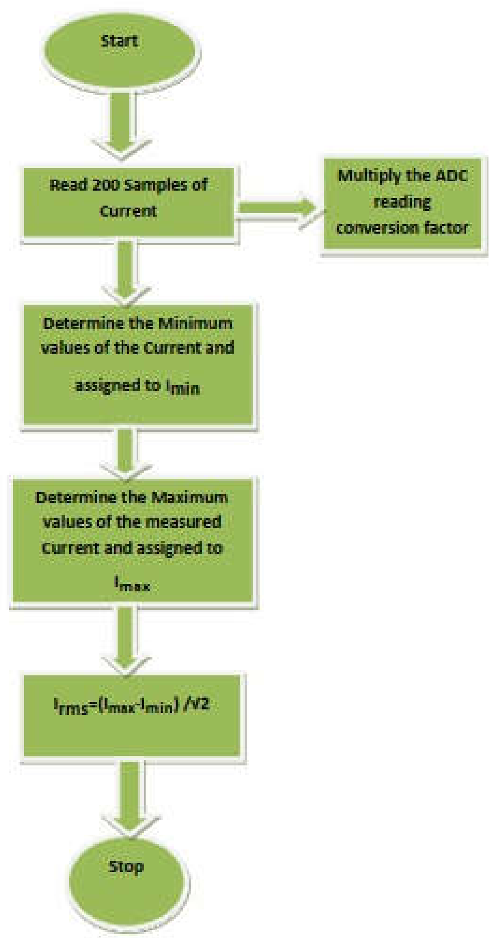


Figure 4.6: Flow Chart for Measuring Rms Current

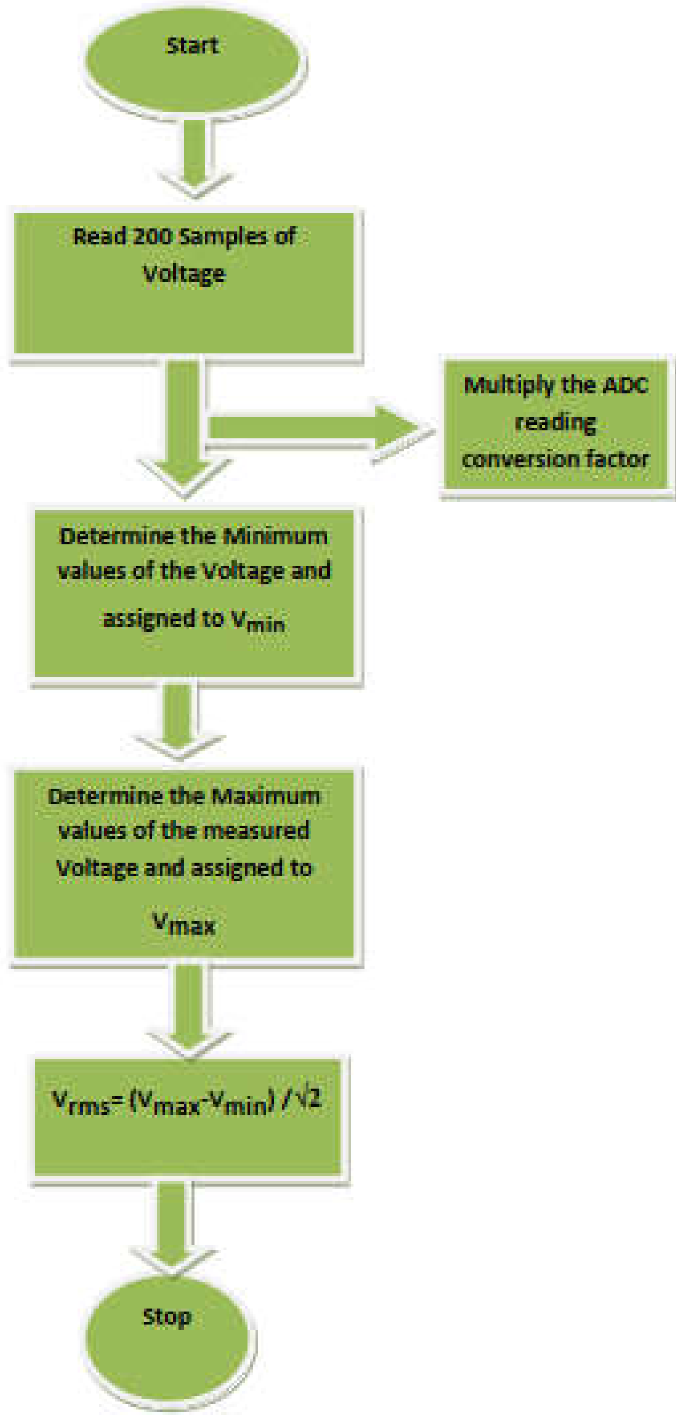


Figure 4.7: The same procedure or algorithm can be applied for measuring RMS current

4.6 Operation of the working procedure

As Arduino speed is limited, it is difficult to switch between voltage and current again and again. If voltage and current are switched repeatedly, then the data will be lost during this period. That is why a sample of voltage and current are taken t a time for measuring the RMS value of voltage and current. Data will not be changed for this short time. The voltage will be read by the Current Sensor, and the Current will be read by the Voltage Conditioning Circuit. After getting the value of voltage and current power will be calculated using this formula

P=V X I.

The simultaneous value of voltage and current has been determined for calculating the positive and negative power.

4.7 How is it Bidirectional

A bi-directional meter works by measuring energy in two directions; how much energy consumption can consume from the grid, and how much excess energy consumer export back to the grid. It is the piece of equipment that allows consumers to receive feed-in tariffs or payments through the Renewable Energy Buyback Scheme (REBS).

Chapter 5: Performance Study

5.1 Introduction

In system testing, the behaviour of the whole system/product is tested as defined by the scope of the development thesis or product. It may include tests based on risks and requirement specifications, business process, use cases, or other high-level descriptions of system behaviour, interactions with the operating systems, and system resources. System testing is most often the final test to verify that the system to be delivered meets the specification and its purpose. System testing is carried out by specialist testers or independent testers. System testing should investigate both functional and non- technical requirements of the examination.

This chapter includes the system testing as well as its results of the proposed Online-net metering system.

5.2 Modification of the Designed Embedded System

Solar power plants are still to be introduced in Bangladesh. Therefore, a PV array capable of producing 0 – 300 volts output is not available.

Nonetheless, a DC power source capable of producing 0 – 30 volts output is available in laboratories of the Department of "Electronics and Communications Engineering," of "East West University." So, instead of a PV array, such a DC power source is used as the voltage source for system testing.

With the change in the range of voltage output, the difference in the value of the sensor is also necessary. As a result, the following calculation is performed.

The maximum output voltage of power source = 30 V.

Second resistor value, 1 = 5 kΩ.

The voltage across the second resistor,1 = 5 V.

According to the voltage divider rule,

$$\frac{V_1}{V} = \frac{R_1}{R_1+R}$$

As a result, when measuring 30 volts, the Arduino analogue pin will be at its maximum voltage of 5 volts. This will change simultaneously with the change in the power source output voltage

5.3 Calibration of the System

5.3.1 Why Calibration is needed for this system?

The line voltage of 220 V is lowered using a step-down transformer to 12 V. Again, 12 V has been stepped down using a voltage divider circuit. Then this value is applied as the input of the Arduino analogue pin. So, the Arduino output will be in the same range as the input of Arduino. Calibration of voltage is needed to make this value appropriate for 220 V line voltage.

Similarly, the Current Sensor used for this system ranges between -30 Amp to 30 Amp, so Calibration or scaling factor is also needed for current measurement.

5.3.2 Calculation of Calibration

The power consumed by the load:

For Calibration mode 0:

The measured voltage from line = 226.7V

Measured current = 0.27

For Calibration mode 1:

Unscaled_voltage = 64.35A

Unscaled_current = 30.1A

Float Vscale = original_voltage/unscaled_voltage ;

Float Iscale = original_current/unscaled_current ;

For Calibration mode 0:

Scaled Voltage (calibrated) = 215.94V

Scaled Current (calibrated) = 0.26Ar

When the calibration mode is zero, the measured value from the line can be calculated by using a Multimeter and Clamp meter. This value of voltage and Current have to be calibrated with the scaling factor. While running the mode 1 of Arduino code, Unscaled voltage and current will be

The calibrated value can be determined for the following formula used in Arduino code:

1. **For Voltage:**

Vscale=
original_voltage/unscaled_voltage =
226/64.35

= 3.51

Here the unscaled voltage is the line voltage, but it is needed to be calibrated, and then the calibrated voltage will become scaled voltage. The line voltage is too high to run the microcontroller (Arduino nano). For running an Arduino nano, very small dc voltage (like 2 to 3 volts) is needed. The line voltage is 220 volts, and it is made 12 volts by using a 220 to 12 volts step down transformer. Then by a voltage controlling circuit and with the help of a battery, Arduino input is given. The output of the Arduino nano is in terms of very low voltage, but 220 volts were given, so the unscaled voltage is calibrated with the calibration factor, and then it is called the scaled voltage.

2. For Current:

I_{scale}=
original_current/unscaled_current
=0.27/30.1
=0.0089

Here the un-called current is the line current, but it is needed to be calibrated, and then the calibrated voltage will become called current. The line current is too high to run the microcontroller (Arduino nano). For running an Arduino nano, a very little dc current is needed. The line voltage is 220 volts, and it is made 12 volts by using a 220 to 12 volts step down transformer. Then by a current sensor, the grid current is measured and converted into a voltage. With the help of a battery, Arduino's input is given. The output of the Arduino nano is in terms of very low, but the grid current was very high, so the descending current is calibrated with the calibration factor, and then it is called the scaled current.

5.4 Electrical Power in Circuits

Electrical Power, (P) in a circuit is the rate at which energy is absorbed or produced within a circuit. A source of energy such as a voltage will produce or deliver power while the connected load absorbs it. Light bulbs and heaters, for example, consume electrical power and convert it into either heat, or light, or both. The higher their value or rating in watts, the more electrical power they are likely to consume.

The quantity symbol for power is P and is the product of voltage multiplied by the current with the unit of measurement is the **watt** (W). Prefixes are used to denote the various multiples or sub-multiples of a watt, such as **milliwatts** (mW = 10^{-3}W) or **kilowatts** (kW = 10^{3}W).

Then by using Ohm's law and substituting for the values of V, I and R the formula for electrical power can be found as:

To find the Power (P)

[P = V x I]   P (watts) = V (volts) x I (amps)

Also:

[P = V^2 ÷ R]   P (watts) = V^2 (volts) ÷ R (Ω)

Also:

[P = I^2 x R]   P (watts) = I^2 (amps) x R (Ω)

Again, the three quantities have been superimposed into a triangle this time called a **Power Triangle** with power at the top and current and voltage at the bottom. Again, this arrangement represents the actual position of each quantity within the Ohms law power formulas.

Arduino UNO Power Supply:

only by adding a resistor in series with an I/O pin, you get increased input voltage protection for that pin. Ex: a 10k resistor provides voltage with enough protection to allow input voltages between -10.5V and +15.5V. A 100k resistor allows DC input voltages from -100.5V to +105.5V.

Voltage Input Limits:

Input power: to power the Arduino, we can either plug it into a USB port or input a voltage source to it either it is 2.1mm x 5.5mm DC power jack or via jumpers going to its “VIN” and “GND” pins. When powering the Arduino via the power jack or VIN and GND pins, it has the following input voltage limitations:

Recommended input voltage limits: 7~12V [1&2]

- These input voltages can be sustained indefinitely

Absolute voltage limits for powering the Arduino: 6~20V [1&2]

- Below 7V may cause the 5V levels on the board to waver, fluctuate, or sag, causing board instability and less accurate analogue readings when using analogRead().
- Sustained voltage levels above 12V will cause additional heating on the linear voltage regulator of the Arduino, which could cause it to overheat. Short periods, however, are excellent. Feel the voltage regulator with your finger. If it feels too hot to touch comfortably, you need to use a voltage source within the recommended limits to reduce heat buildup. In the picture below, the black device at the left side of the Arduino, circled in yellow, is the voltage regulator.

Voltage limits on input/output pins: -0.5 – +5.5V max. [3]

If you need to read in a voltage on an Arduino digital or analogue input pin, ensure it is between 0 and 5V. If it is outside these limits, you can bring down the voltage using a voltage divider. This scales the input voltage to allow for analogue or digital readings of voltages otherwise outside the permitted range. If your input signal is digital, and you don't need to take scaled analogue readings, another technique is to clip (cut the top off of) the input voltage, rather than scale it. Since AVR microcontrollers (ex: the Atmel ATmega328) have internal clipping diodes (note that Atmel, mistakenly I believe, calls them "clamping diodes"), this can be done by simply adding a single resistor in series with the pin. Ex: adding a 10k resistor in series with the input pin permits input voltages as low as -10.5V or as high as +15.5V.

Current Output Limits:

- Total maximum current draw from the Arduino when powered from a USB port: 500mA [1]
    - The Uno has a "resettable poly-fuse that protects your computer's USB ports from shorts and overcurrent."
- Total maximum current draw when powered via external power supply:
    - Arduino Uno: 1A
    - Arduino Nano: 500mA

Note: If not powered by USB, the total 5V current limit coming out of the Arduino is limited by the voltage regulator on your particular board, and your input power supply, whichever provides less power. Let's assume your power supply going to the Arduino can provide 7~12V and >= 1A. If this is the case, the 5V power is limited strictly by your Arduino board's voltage regulator.

- The output current limit from the "5V" pin will be according to the info just above.Total max current per input/output pin: 40mA
- Sum of currents out of all input/output pins combined: 200mA

5.4 Performance Study

The performance study of the system can be measured by comparing the measured value by meter and value given by the Arduino. When a 100 Watt bulb is connected as load the percentage of error can be calculated as:

Power measured by Meter = 101.6 Watt

The real power of the load =98.6 Watt

Percentage of Error = (101.6-98.6) /101.6*100=2.95%

The efficiency of the developed meter = 97.25%

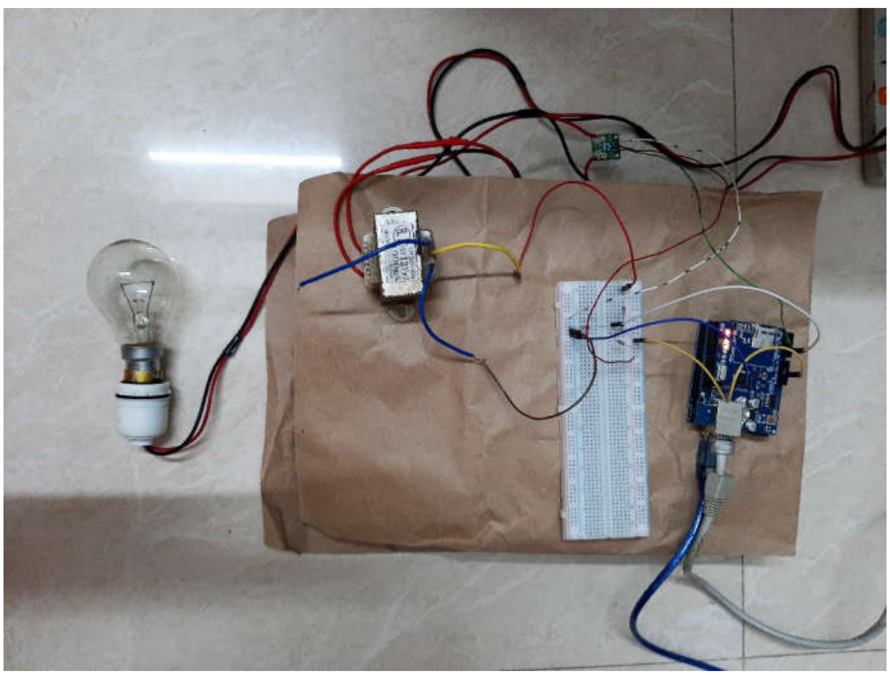


Figure 6.1 Complete arrangement of the testing system

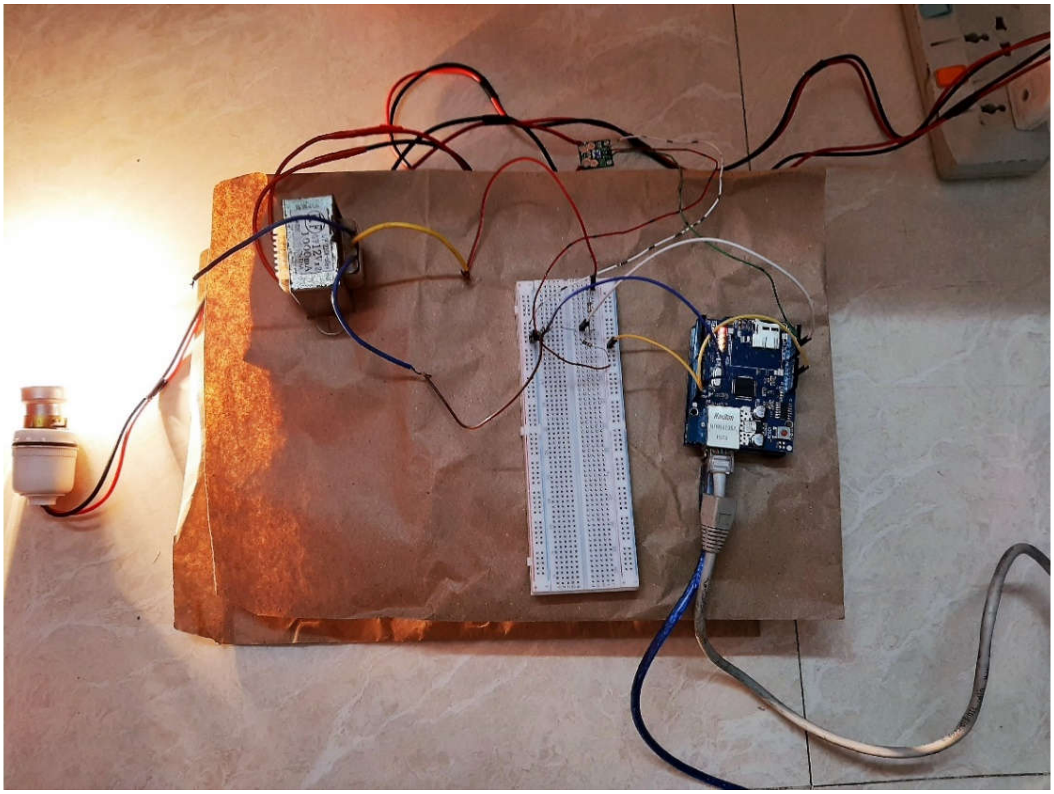


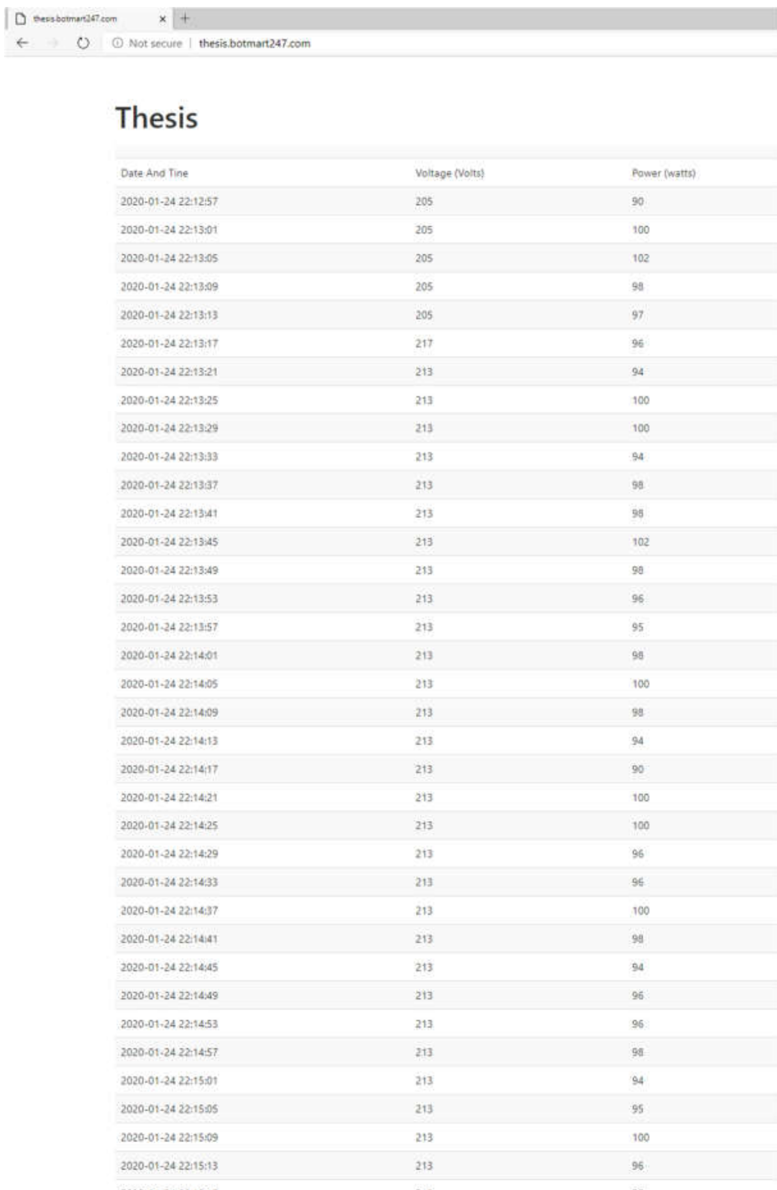
Figure 6.2 Complete arrangement of the testing system

Figure: 6.3 Complete arrangement of testing System

Description:

In this circuit, we have used 10KΩ and two 1KΩ registers. We have used the Current sensor (ACS 714 Current Sensor Carrier -5A to +5A), 12V transformer, and 100 W bulb as a load. Now the Out point of the current sensor is connected to the A2 pin of the Arduino UNO, Vcc is connected to 5v of the Arduino, and the GND point is connected to Arduino GND Point.

Please go through the link to watch the demo work of the circuit. **https://youtu.be/pGnAdtY05wE**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Thesis

Date And Tine	Voltage (Volts)	Power (watts)
2020-01-24 22:12:57	205	90
2020-01-24 22:13:01	205	100
2020-01-24 22:13:05	205	102
2020-01-24 22:13:09	205	98
2020-01-24 22:13:13	205	97
2020-01-24 22:13:17	217	96
2020-01-24 22:13:21	213	94
2020-01-24 22:13:25	213	100
2020-01-24 22:13:29	213	100
2020-01-24 22:13:33	213	94
2020-01-24 22:13:37	213	98
2020-01-24 22:13:41	213	98
2020-01-24 22:13:45	213	102
2020-01-24 22:13:49	213	98
2020-01-24 22:13:53	213	96
2020-01-24 22:13:57	213	95
2020-01-24 22:14:01	213	98
2020-01-24 22:14:05	213	100
2020-01-24 22:14:09	213	98
2020-01-24 22:14:13	213	94
2020-01-24 22:14:17	213	90
2020-01-24 22:14:21	213	100
2020-01-24 22:14:25	213	100
2020-01-24 22:14:29	213	96
2020-01-24 22:14:33	213	96
2020-01-24 22:14:37	213	100
2020-01-24 22:14:41	213	98
2020-01-24 22:14:45	213	94
2020-01-24 22:14:49	213	96
2020-01-24 22:14:53	213	96
2020-01-24 22:14:57	213	98
2020-01-24 22:15:01	213	94
2020-01-24 22:15:05	213	95
2020-01-24 22:15:09	213	100
2020-01-24 22:15:13	213	96
2020-01-24 22:15:17	213	98

Figure: Data on online

Calculation of energy consumption

The first step in calculating your energy consumption is to figure out how many watts each device uses per day. Just multiply your appliance's wattage by the number of hours you use it in a day. This will give you the number of watt-hours consumed each day.

Calculate Watt-hours Per Day

Device Wattage (watts) x Hours Used Per Day = Watt-hours (Wh) per Day

Example: A 125-watt television used three hours per day

125 watts x 3 hours = 375 Wh/Day

However, electricity on your bill is measured in kilowatt-hours (kWh), not watt-hours. One kilowatt is equal to 1000 watts, so to calculate how many kWh a device uses, divide the watt-hours from the previous step by 1000.

Convert Watt-Hours to Kilowatts

Device Usage (Wh) / 1000 (Wh/kWh) = Device Usage in kWh

Example: A television using 375 Wh of electricity per day

375 / 100 = 0.375 kWh

Now that we know how many kilowatt-hours the appliance uses per day, we have to estimate that usage over a month. Let's multiply by 30 days to simulate an average month.

Find Your Usage Over a Month

Daily Usage (kWh) x 30 (Days) = Approximate Monthly Usage (kWh/Month)

Example: A television using 0.375 kWh of electricity per day

0.375 kWh x 30 Days = 11.25 kWh/Month

So, a 125-watt television that we use for three hours per day adds up to 11.25 kilowatt-hours of energy per month.

Chapter 6: Conclusion and Future Scope

6.1 Conclusion

Day by day, society brings lots of changes in their lifestyle, which depends on their needs. Most of the important impact of these changes as well as in technologies too. For a modern comfort life, electricity is the main and important part. We can't imagine a day without electricity. Electricity makes our life so easy and comfortable. The development of society, technology, and changes in consumer behaviour have led to changes in the techniques and technologies used for measuring electricity. And everyone is so concerned about the benefit of using an electric meter. There are many studies concerning the benefit related to the use of Net meter, where it is a billing system that allows consumers to sell the extra electricity to the government.

Under the process of net metering, electricity can flow in both directions by using the bi-directional meter so that the consumer can adjust the quantity of electricity which consumed from the grid and after self-consumption of electricity consumer can spillover the electricity which produced by rooftop solar system or from any other renewable energy. All the information can be stored in the meter or transferred to the website. So, the customer bills procedure depends on the net energy they used, which recorded on the meter. If the total volume of electricity used from the grid is higher than the produced electricity which sold to the grid, the consumer has to pay the bill for net consumption. On the other side, if the total volume of generated electricity which exported to the grid is higher than the imported electricity from the grid, then the distribution utility shall allow all the credit of the consumer to roll over the next billing period. This meter mainly helped customers to pay what they use. So customers are only billed for their net energy use.

The net meter can read time-stamped data, and it is a continuous process. It can communicate remotely with a server and a smart electric apparatus. This meter helps to increase awareness of using electricity and leads to consumption reduction. This meter also helps to decrease the transmission and distribution losses and can improve energy efficiency by managing the consumption patterns of the users.

Our proposed device can be used by all types of consumers, such as domestic/residential consumers, commercial consumers, or industrial consumers.

The proposed device, the Net meter, will be a single three-phase bi-directional smart meter. Which will efficient in recording import, export, and net energy consumption. And if there any need to reprograming, the existing meter can accomplish the requirements. Then there is no need to be installed a new meter.

6.2 Advantages

Our proposed device will be a great favour for consumers. This meter is capable of reducing the money spent each year on energy. And it also can help to make money if consumers can produce more power than consume. That's why the utility company pays you for the extra power at the retail rate. This device is so easy to make and inexpensive too. It can help customers to find out the real value. It can help to take some of the clots of the grid, especially at peak consumption hours. This meter will play a vital character in alternative energy production. Thus, it helps to maintain the environment and preserve natural energy resources. In this system, it can help to save utility companies money on installing a new meter, reading, and billing cost too. And there no battery storage system needed.

6.3 Disadvantages

This proposed device has very few drawbacks. It requires the installation of additional precautions that have to be taken in the operation and maintenance of the system. Furthermore, all the cost of this device has to be borne by the consumers.

6.4 Future scope

Progressing of technologies is a gradual and continuous process. Hopefully, Wi-Fi will become more effective in open places. Bangladesh's government takes a step, which is to bring all the people within reach of electricity access, according to vision 2021. Moreover, the renewable policy of Bangladesh's government target has been set to generate 10% of the total electricity from renewable energy sources by the year 2020.

Appendix

```
// to the pins used:*/


int sensorValue = 0;        // value read from the pot

int i,volt[60],cur[60], maxv,minv,maxc,minc,avgv,avgc,power,index;

void setup() {

  // initialize serial communications at 9600 bps:

  pinMode(A1, INPUT);

  pinMode(A2, INPUT);

  Serial.begin(9600);

}


void loop() {

  for(i=0;i<60;i++)

  {

  volt[i] = analogRead(A1);

  delayMicroseconds(5);

  volt[i] = analogRead(A1);

  //for(i=0;i<300;i++)

  cur[i] = analogRead(A2);

  delayMicroseconds(5);

  cur[i] = analogRead(A2);

  }

maxv=maxc=0;

minv=minc=1100;

for(i=0;i<60;i++)
```

```
{
  if(maxv<volt[i]) { maxv=volt[i]; index=i;}
  if(maxc<cur[i]) maxc=cur[i];
  if(minv>volt[i]) minv=volt[i];
  if(minc>cur[i]) minc=cur[i];
 }
// code to get wave form of AC current
 // Serial.print(maxv);
// Serial.print("\t");
//  Serial.println(maxc);
//  Serial.print(minv);
//  Serial.print("\t");
//  Serial.println(minc);
//  Serial.println(index);
   if(cur[index]>((maxc+minc)/2))
  Serial.println("+");
  if(cur[index]<((maxc+minc)/2))
  Serial.println("-");
  avgv=(maxv-minv)/1.34;
  power=((maxc-minc)*(maxv-minv))/140;
  Serial.print("Power");
  Serial.print("\t");
  Serial.println(power);
  Serial.print("Voltage");
  Serial.print("\t");
  Serial.println(avgv);
   delay(4000);}
```

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