Designing Of Bi-directional Energy Meter For Measuring Reverse Power Flow

Session: 2019 – 2023

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Undertaking

It is declared that the work entitled **"Designing of bi-directional energy meter for measuring reverse power flow"** presented in this report is an original piece of our own work, except where otherwise acknowledged in text and references. This work has not been submitted in any form for another degree or diploma at any university or other institution for tertiary education and shall not be submitted by us in future for obtaining any degree from this or any other University or Institution.

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Acknowledgement

We are thankful to Allah Almighty for successful completion of our project. Our special thanks to our supervisor Engr. Naveed Anwar for giving his supervision. We are also grateful to Engr. Mian Farhan Ullah who gave his precious time and guiding us in project completion and all faculty members who helped us with their advice's and comments. We are thankful to the administration of Electrical Department for allowing us to use the lab equipment as per requirement.

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Abstract

With the increment of grid connected solar PV systems that need net metering, the importance of power or energy monitoring has become increasingly critical. Power can flow in each directions, from the consumer side a PV panel to the grid(reverse) or from the grid to the consumer side PV panel(forward). Accurate billing is impossible if there is no measurement of the power flow from both sources (grid source , PV source) and unused surplus power is not store at the moment. Because of this, a bidirectional energy meter is required that can measure the power in both direction (forward as well as reverse). The goal of this study is to design a micro controller-based bidirectional energy meter. This project contribution consists of a micro-controller, current sensor unit, voltage sensors unit, bulbs acting as loads, and a display unit. Voltage, current RMS values are calculated and displayed on the LCD. The calibration is then performed in the newly created program. The power is then computed and shown after that.

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List of Acronyms

AC	Alternating current
ACS-712	Allegro Current Sensor
ADC	Analogue to Digital Converter
ALU	Arithmetic Logic Unit
AVR	Advance Virtual RISC
CPU	Central Processing Unit
DC	Direct Current
EEPROM	Electrically Erasable Programmable Read Only Memory
ETAP	Electrical Transient Analyzer Program
EV	Electric Vehicle
GPS	Global Positioning System
GSM	Global System for Mobile communication
IC	Integrated Circuit
IoT	Internet of Things
KW	Kilo Watt
LCD	Liquid Crystal Display
LCL	Inductor Capacitor Inductor filter
MCB	Miniature Circuit Breaker
MEPCO	Multan Electric Power Company
MHz	Megahertz
MIPS	Microprocessor without Interlock Pipeline Stages
MLF	Machine Learning Framework
MLI	Multi Listing Service
MPPT	Maximum Power Point Tracking

NEPRA	**National Electric Power Regulatory Authority**
PCB	**Printed Circuit Board**
PSU	**Power Supply Unit**
PV	**Photovoltaic**
PZEM	**Programmable Zero-Phase Energy Meter**
RES	**Renewable Energy Source**
RISC	**Reduce Instruction Set Computer**
SCADA	**Supervisory Control And Data Acquisition**
SDGs	**Sustainable Development Goals**
SEM	**Search Engine Marketing**
SMS	**Short Message Service**
SPI	**Serial Peripheral Interface**
SRAM	**Static Random Access Memory**
TQFP	**Thin Quad Flat Pack**
USB	**Universal Serial Bus**
WAPDA	**Water And Power Development Authority**

Chapter # 1

Introduction

Nowadays for grid-tied PV systems, accuracy of power monitoring is a crucial need from the energy sector. When consumer has an off-grid system, power may be measured with ease. However, with a grid connected solar PV system, power will be supplied from the grid towards system during period of minimal radiation. Power that comes from grid is refer to as "forward power" or "incoming power" while power is produced by the solar panels and returned to the grid is referred to as "reverse power" or "outgoing power". A bi-directional power meter must be used to measure the positive and negative power. Here a bi-direction power meter is designed using ATMEGA 328P micro-controller. At this time, controlling the power that is lost in the system needs proper voltage and current measurement. The net bill cannot be determined if the power coming from the grid and entering the grid cannot be monitored and saved. A bi-directional energy meter has been designed for this purpose. This meter also enables the determination of power flow direction.

1.1 Net metering and its phenomena

Net energy metering is a service that allows customers to use both their own on-site power producing system and grid energy during peak ON hours. It returns any excess power it generates to the electric grid during off-peak times. The net energy meter is used for net metering (also known as a bidirectional energy meter). One meter that can detect current flowing in both directions is all that is needed for net metering. Contrary to the feed-in tariff, this needs the use of two meters in order to operate.

Every country and company has a unique policy. Typically, the export energy units are deducted from the import energy units when calculating a monthly bill or a bill after a certain period of time. And to create the net tariff, the resulting units are multiplied by unit rates. Net metering is different from feed-in tariffs because it requires only one meter for measurement, which is a bi-directional energy meter. The entire process of net metering system is displayed in Fig 1.1.

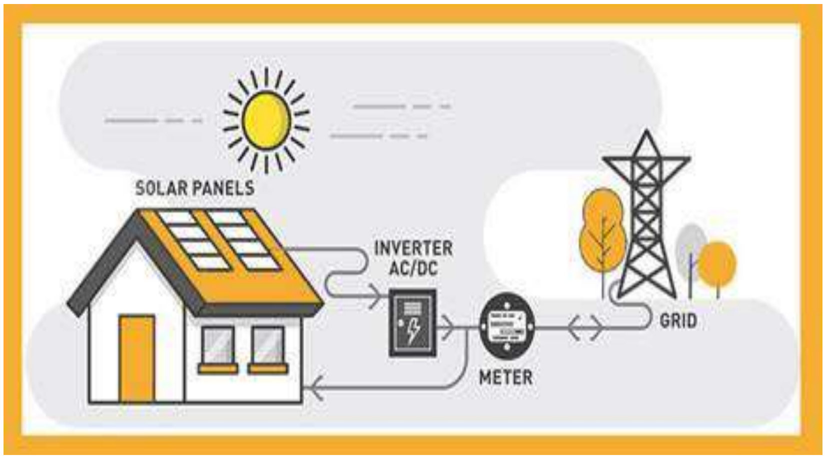


Fig 1.1 Schematic Representations of Net Metering [1]

1.2 History of net metering

In the 1980s, it was introduced in the United States, where users are authorized to use power generated by their own producing systems, such as solar and wind, as well as connect to the grid. The first net metering law was introduced in 1983. Every consumer was permitted to generate power under this law. The additional energy would either be paid to the user or credited per kilowatt-hour for the next month. Customers were permitted to sell electricity at retail prices starting in 2000. In 2016, 43 states adopted the service of net metering. The slowdown in the implementation of net metering in Europe was caused by a lack of knowledge about services and tariffs. Net metering was only provided by the "Great Britain Electricity Business.". Today, numerous countries throughout the world, including the United Kingdom, Canada, the Philippines (accepted in 2008), and recently Pakistan, have adopted net metering [2].

1.3 Net metering in Pakistan

The National Electric Power Regulatory Authority (NEPRA) authorized the net metering laws and standards in 2015. It states that anybody can create power from renewable sources like solar and wind and sell it to companies that distribute energy. By implementing this regulation, consumers are rewarded for producing their own electricity, and their electricity bills are reduced as a result.

As per NEPRA regulations, consumers are only allowed to use bidirectional meters. When a consumer uses electricity from the grid (they are generating less energy and their consumption is high), as well as when they are supplying power to the grid (they are producing more energy and their consumption is low), this meter will measure energy in both situations.

Ending of each month, the consumer receive charged for net energy used. All net metering systems are connected to the grid, which they will use to distribute surplus supply and credit in accordance with established standards.

1.4 Controversies regarding net metering system

These debates involve those countries whose economies rely on the sale of power at a profit.

- The demand for a main or central power plant can be decreased by installing a private power plant on site. Government power plants generated electricity and provided consumers with energy. They made a good profit. Net metering reduces government profit by bringing independence from the central power plant.
- Power companies will share in the advantages of electricity production (as customers of a utility). As was mentioned in the previous point, less money is made from producing electricity. Actually, utilities and consumers share the profit. Reduced power production profits have an impact on a country's economy. This is the main argument against net metering.

1.5 History and development of bi-directional energy meter

The idea bi-directional meter was developing in united state. When micro-wind turbines and solar panels have been installed and are interconnected to the primary grid station. These renewable energy sources were established by local groups of users who desired to be able to utilize their energy at various times and be aware of the amount of energy they exported to the main grid. The first net metering law in America was passed in Minnesota in 1983. The difference between energy imports and exports is measured in net metering. They also let them create up to 40 KW, and they receive payment in the form of per-kilowatt credits for the future billing cycle [3].

This innovation was adopted by many other countries. In 1981 Arizona, in 1982 Massachusetts adopt this technology. Utilities in the United States were asked to offer net metering on request in 2005. Because of the issue with value-added tax, net metering adoption in Europe is moving extremely slowly.

1.6 Change in trend of measuring system and modern opportunities

Since the beginning of the twenty-first century, new techniques have been used to improve the functionality and efficiency of measuring instruments. Modern electronic technology has changed the way that meters are measured. First, mechanically driven meters were replaced with digital meters, and now smart meters have taken their place. These days, due to the expansion of the power system and the modernization of measuring techniques, consumers are also contributing to the generation of power by utilizing their own power generation methods, such as independent power resources, to be enabled to address the electricity problem. In addition, at the off peak interval they export or sell power to the grid while at on peak interval they import or purchase power from the grid. Thus, by observing this modern approach, a meter that can measure both forward and reverse power flow on a single conducting line is needed; hence, a bidirectional meter was created to accommodate this novel technology.

1.7 Existing technologies and innovation

The net metering idea, which was adopted in early 1980s in America, gave rise to bi-directional meter technology. Net metering is only a method for identifying differences. Additionally a bi-directional energy meter is created using that's techniques invention and it has capacity to measure both net amount of energy as well as import and export of energy units over time.

1.8 Bi-directional energy meter

A device used to monitor the flow of electricity in both directions is known as a bi-directional energy meter. It is frequently employed in situations when power is both drawn from and supplied back into the grid. A bi-directional energy meter can precisely follow the flow of power in both directions, unlike conventional energy meters that can only measure the flow of electricity in one direction (from the grid to the user).

A bi-directional energy meter is essential in the context of renewable energy systems, such as solar cells or wind turbines. The excess power produced by these systems can be fed back into the grid when it is produced in excess of what is needed locally. The consumer can obtain credits or compensation for the extra energy they supply to the grid thanks to the bi-directional energy meter's precise measurement and recording of the data.

In contrast, the meter precisely measures the electricity drawn from the grid when the quantity of on-site energy consumption exceeds the amount being generated. This enables proper billing for the energy spent. A bi-directional energy metre supports fair and accurate invoicing for electricity usage by giving a thorough measurement of energy flow in both directions. This encourages effective management of energy resources.

The initialization of "Bi-directional energy meter" for the net metering consumer/customer records the flow of energy in both the forward and backward direction. The amount of energy is used from main grid and the amount of energy supplied by our system to main grid will be measured.

A bi-directional meter attributes include:

- A device that record forward and reverse power flow
- Allow customers to take an active role .
- It introduce multiple new products , markets and services
- It predict the system instability in a self -healing approach

This meter has the capacity to measure energy flowing in both directions, which it does automatically. With the help of this meter, consumers may actively participate in electricity generation and load balancing.

1.9 Features of bi-directional energy meter

1.9.1 Reliability

The bidirectional meter measures the current and voltage values before displaying the power and total energy units on the LCD screen in accordance with the programming. This will make the transmission of electricity more reliable. Although the old meters also have the ability to measure the flow of power and display the result accurately, all of them are single-direction and installed on the live wire. The bi-directional measurement does not only measure the power transfer but also gives the direction that either the power is imported or exported, or the results are accurate and reliable.

1.9.2 Prediction regarding the nature of load

These meters provide real time information regarding loads. One can easily predict the nature of load from this information and take appropriate response.

1.9.3 Design of network and its flexibility

The meter behaves well for all network design, whatever the design being used. It determines the amount of current flowing and the direction of power flow and shows the results along that line, indicating whether power is flowing forward or backward.

1.9.4 Reduction of bills

A bidirectional meter enables consumers to participate actively in energy production. The bill is reduced by exporting self-generated energy to the grid.

Monthly bill = (energy imported – energy exported) * retail rate *..................Eq (1.1)*

The next step is to change load needs and consumption by obtaining information about consumption from the meter. As a result, both energy and money can be saved.

1.9.5 Market enabling

The main grid and the consumer's channel for importing and exporting electricity in accordance with load are provided by the bidirectional meter. Consumers now want to actively participate in load management and work to prevent power failures by generating their own electricity using renewable energy sources..

Therefore, the bidirectional metre has considerable marketing value for establishing policies and determining retail per unit pricing. It makes it possible for the user to start a helpful business. The costumer which need to channelize their power source with main grid have use bidirectional meter.

1.9.6 Enhance efficiency

Many contributions are made to reduce the energy shortage and boost the effectiveness of the power monitoring system. The tiny renewable customer energy sources should be connected to the main grid without reducing system efficiency; the measurement device should be efficient enough that only minimal losses occur. Our metre has a very high efficiency and a very low internal power loss.

1.10 Problem statement

In case of consumer having own energy source (Such as PV) along with Grid/ WAPDA then how reverse energy is measure flowing into the Grid.

The world is currently moving toward renewable energy sources. Both the consumer and the electric company will supply the power that is used by the consumer. The consumer uses both energy from the grid and energy generated by itself during on-peak hours. In a similar way, consumer demand is low and energy production is high during off-peak hours. As a result, energy, or reverse power, will be delivered to the grid. So, how is excess energy or reverse power calculated? For this, a net meter or a bi-directional energy meter is required.

1.11 Statement of project

The project is about to design an energy meter that measures energy in both forward and reverse direction, i.e., when consumers supply their surplus energy to the grid or an electric utility during off-peak hours.

1.12 Aims & objective

The primary objective of this project is to design single phase bi-directional energy meter for measuring reverse power flow exported into the grid.

The aim of this project is to measure the two way electrical parameters. Following are:

- Imported, exported and net energy
- Imported, exported and net power
- Current of both sources
- Voltages of both sources

1.13 Methodology

The main steps for designing bi-directional energy meter are:

- First of all WAPDA source and consumer source are linked together and synchronize automatically.
- Potential transformer is used as a voltage sensor for measuring input voltages of both sources (WAPDA, consumer).
- Potential transformers reduce the voltages of both sources to the desired value, and the output of the potential transformers or voltage sensors is then supplied to the bridge rectifier which converts AC voltages into DC voltages.
- After filtering, the output of bridge rectifier is supplied to micro-controller, which subsequently measures and displays the voltage data of both sources on the LCD.
- The ACS 712 Hall effect sensor is used as a current sensor for measuring load current in positive as well as negative direction..
- The output of the current sensor is fed to micro-controller then controller measure and display current data on LCD.
- At on peak hour , consumer load is high than its generation so in this case, consumer source need some power from utility grid to fulfill load requirement so current is flow from utility grid to consumer, the ACS712 current sensor detects this positive flow of current and give output to micro-controller.

- Then micro-controller use the data of current , voltage and display forward power on LCD.
- Similarly at off-peak hour consumer load is low than its generation so in this case surplus power is fed back to utility grid hence current is flow from consumer source to utility grid, the ACS712 current sensor detect the negative flow of current and give output to micro-controller.
- Then micro-controller use the data of current , voltage and display reverse power on LCD
- Finally micro-controller display all data on LCD with respect to delays added in source code.

1.14 Block diagram

Block diagram of designed bi-direction energy meter is shown in Fig 1.2

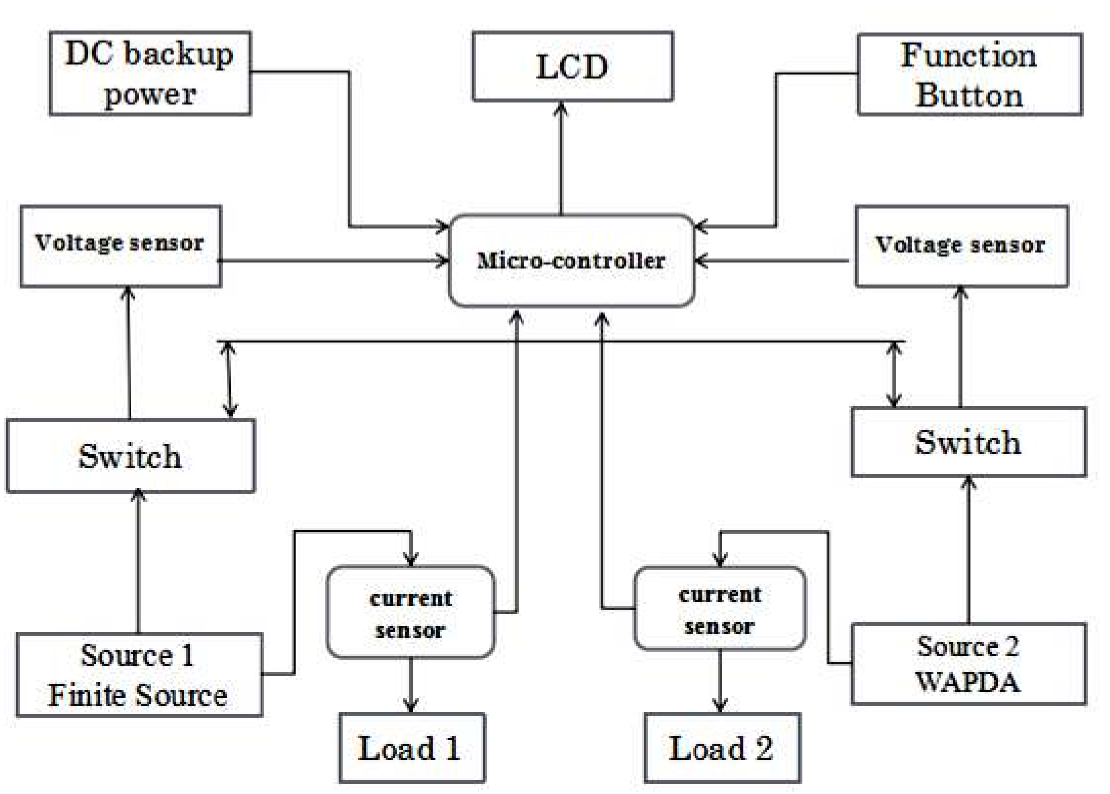


Fig1-2 Block Diagram of Developed Energy Meter

1.14.1 Explanation

The control unit has been developed using a micro-controller based board. Since the system will be driven by software. Although a separate micro-controller is used to develop this system (ATMEGA 328P). The system may be designed by using variety of current sensor; here a bi-directional Hall Effect current sensor (ACS712) has been used. This sensor can handle currents ranging between -30 Amps to 30 Amp.

Even though the micro-controller (ATMEGA 328P) can sense voltage, 220 volts are too high, so 220 volts cannot directly fed to the micro-controller. Hence, a voltage sensor circuit uses a step down transformer (potential transformer) as a voltage sensor.
Display unit consist of 16x4 LCD which display the outputs of micro-controller.

Chapter # 2
Literature Review

2. Literature Review

2.1. Relevant Work

A micro-controller, a current sensor, bulbs operating under load, and a display constitute this paper's work. Voltage and current rms values are calculated and displayed on the display. The calibration is then performed within the created software. The power is then computed and shown after that. The direction of the power is then determined based on the direction of the power (positive or negative), which is also dependent on the phase difference between the voltage and current.

The efficiency of the proposed meter greatly depends on the sources of the power flow. The net bill cannot be determined if the power incoming from the grid and leaving the generating device cannot be monitored and saved. A low-cost meter has been created for this purpose, utilizing items that are readily available in the area [4].

" Malikarjun. G Hudemani "proposed project is aimed at developing a particular type of bi-directional energy meter that tracks net use, exports, and monetary exchange. It uses a roof-top system. Solar panels are made with an MPPT controller to provide continuous power production. Rooftop solar PV systems are becoming more practical and inexpensive nowadays, so correct metering is required for both the usage of any excess power generated and its export to the grid. An embedded meter that can manage the energy information and transactions of a home user may result from the suggested micro controller-based bidirectional energy metering technology. The proposed work may be done using current digital meters with the appropriate extra circuitry and measurements. Additional communications, such as GSM-based solutions, can provide improved speed and security in the future [5].

Due to the harmful impacts the harmonics may have on connected loads, especially sensitive equipment, an LCL filter is frequently desired as an addition to grid-connected PV systems. Due to poor dynamic responses and related costs, it is sometimes more difficult to achieve workable filters for very large systems since the value of inductance required is proportional to the capacity of the system. In a grid-connected setup, the LCL filter contributes to lowering the switching frequency harmonics between the grid and the inverter. When the simulated household load needed exceeded the power provided by the inverter and vice versa, the planned counter-based bi-directional metering efficiently supplied electricity from the grid, creating an overall smart system with net metering and billing capacity [6].

To fulfill the purpose of using power in a economical way, renewable energy source (RES) might be followed by net metering. Energy produced using RES one may fulfill the electrical needs of a household during the interval when they have the ability to produce energy. Electricity from the grid may be utilized during the remaining time when RES cannot be used. Customers who feed the extra energy produce by RES returning to the grid receive payment from utility. In addition to lowering power costs, this procedure also saves electricity that may be used by another user in need.

The term "synchronization" refers to the process of reducing the variation in voltage, phase differences, and frequency differences between the grid supply and the RES generator.

Here are a few grid synchronization techniques:

- Zero crossing detection
- Kaman filter
- Discrete Fourier Transform
- Nonlinear least square
- Adaptive Notch Filter
- Artificial Intelligence
- Delayed Signal Cancellation

- Phase Locked Loop
- Frequency Locked Loop [7]

When the supply voltage is 230V at up to 50A, direct readings by a micro-controller are challenging. This necessitates that line voltage and current be indirectly measured at a level suitable for a micro-controller and that these readings be re-scaled to yield the original value. Since a transducer has been employed to create a voltage proportionate to the load current, measuring current in this situation is essentially comparable to measuring voltage. After that, the real voltage and current data may be calculated [8].

A smart energy meter with better two-way connectivity without data loss and security from electricity theft tactics Regulations governing net metering may help power demand curves become more consistent and assist utilities in better managing their peak electricity use. By encouraging generation near the point of consumption, net metering reduces the burden on transfer networks and prevents long-distance losses in electricity transmission and distribution.

The system's graphical user interface is user-friendly and makes it simple for users to comprehend net energy use. The primary drawbacks of smart meter now available on the market have been mostly solved thanks to the usage of online services and SMS services. As a result, data may be simply accessible online. The ability of ZigBee to connect to other ZigBee devices and build a circuit may be leveraged to reduce price of the meter fewer GSM modules will be needed [9].

This study presents a smart energy meter for EVs that functions as a smart grid application. The meter measures and shows the battery voltage, current, and power when the EV is connected to the grid. In addition, it shows if the battery is charging or discharging, and whether car is receiving power from the grid (G2V) or the grid is receiving it from the car (V2G).

Through a ZigBee wireless connection, the data is shown on an LCD shield in addition to a distant computer. To test the effectiveness of the suggested method, a workable prototype utilizing an Arduino and ZigBee wireless communication is put into place. Smart meters, bidirectional connectivity, and remote monitoring may all be used to compute the energy used to charge and discharge EV batteries. Bidirectional smart meter that measure both energy delivered to the grid and energy used to charge vehicles should be installed. The electric grids current and voltage waveform phase angle difference allows for the determination of the direction in which energy is used [10].

In order to lessen the goal of managing on nonrenewable energy sources, this article stresses the usage of clean, renewable energy sources like the sun. The study also includes a suggested concept for using a net meter to integrate PV arrays with the supply grid. Following residential use, the extra energy generated by the solar panels is fed into the electric network via the solar panels erected on the roofs of retail structure. As a result, there is a significant decrease in the net energy uses of power system.

After the PV module, a boost converter is used to increase the voltage level to the necessary level. A cascaded H-bridge inverter is then used to decrease sinusoidal instability in the inverter's output. As a result, the quality of energy also enhances, meeting a key customer requirement. The level of MLI can be raised to further enhance the power quality [11].

In this study, the power and energy generated by PV systems are collected online in real time using a web-based net energy monitoring system. The gathered information is made available on a website that is always accessible and may be further evaluated, optimized, and made more effective. The power and energy generated by PV systems are gathered in real time and online using the web-based net energy monitoring system.

The PZEM004T sensors used by the net energy metre system have read voltage, current, power, and energy created at the inverter output terminal and load terminal. These numbers can be used to calculate the net energy export to or import from utilities. The measurement data may be instantly recorded on the client computer thanks to the system's data logger capability. When compared to the Hoki 3286-20 clamp meter, the

PZEM004T results show a fair degree of accuracy with an average power difference of 0.29%[12].

The tremendous growth in energy requirement is simply maintained with them as they are compatible with renewable energy sources including solar, wind, tidal, and geothermal energy are readily available in abundance. When electricity is added to the system outside of peak time, Net metering, an modern metering or charging method, can run the meter backwards, allowing the consumer to sell units.

In this study, several Bus22 instances on the feeder for CITY-3 using solar net-metering mechanisms are undertaken, and essential analyses, including as study of oscillation and load circulating analysis, are also done on the ETAP software. The Bus22 is chosen based on MEPCO's net-metering status. As seen in Out of Control, many loads are linked to an N-M network transformer [13].

In comparison to conventional energy systems, smart meter technologies and other extensive applications supported by SEMs provide impressive benefits.

Furthermore, it is getting easier to predict how REBN will advance. A biodegradable foundation will let power meter to become smarter and considerably more flexible. in which additional functionality is integrated by adding new modules, and the framework is constructed as an open framework. Additionally, another alternative is to install a SEM unit in other appliances to carry out the smart metering function. The fundamental route of development for DH and NG networks as well as power grids is "smarter" or "more intelligent" REBNs [14].

In this study, a smart bidirectional meter powered by the Internet of Things (IoT) that can operate in prepaid and postpaid modes that is linked to or is landing on a smart grid with integrated renewable energy is described.. This article explains why errors found using positional data without using the Global Positioning System (GPS). This smart gadget cuts off power and sends the appropriate data to the server when a user uses more energy than is available. The main micro-controller for this investigation was an ATmega328pu, and the ESP8266-12E was used for data transmission and reception from the server [15].

An inverter is required to disconnect the grid when the frequency changes sink PVs connected to the grid require a constant frequency to function. In order to return the grid to its normal frequency, real electricity needs to be transferred there as soon as feasible.. When active power and load demand are equal at given times, the frequency is constant. Up until energy supply and demand are equal, all active and reactive power deficiencies must be made up for [16].

Chapter # 3

Components Description

3. Components Description

This project "Designing of bi-directional energy meter for measuring reverse power flow" consist of the four hardware unit:

1. Power supply unit
2. Control unit
3. Display unit
4. Load unit

3.1. Power supply unit:

The circuit will get electricity from this unit. A PSU, power supply, power pack, or power converter is a device or system that provides electrical energy to a power monitoring system. For our project, we require 5V and 12VDc, thus we use a rectifier and regulator.

Power supply unit consist of following components

- Step down transformer
- Bridge rectifier
- Capacitor
- Resistors
- Voltage regulator LM7805 IC

3.1.1 Step down transformer

A transformer that adjusts the voltage at the primary and secondary windings from high to low is known as a step-down transformer. In terms of coil windings, a step-down transformer's main winding has more turns than the secondary winding. A conventional step-down transformer is shown in Fig 3.1..

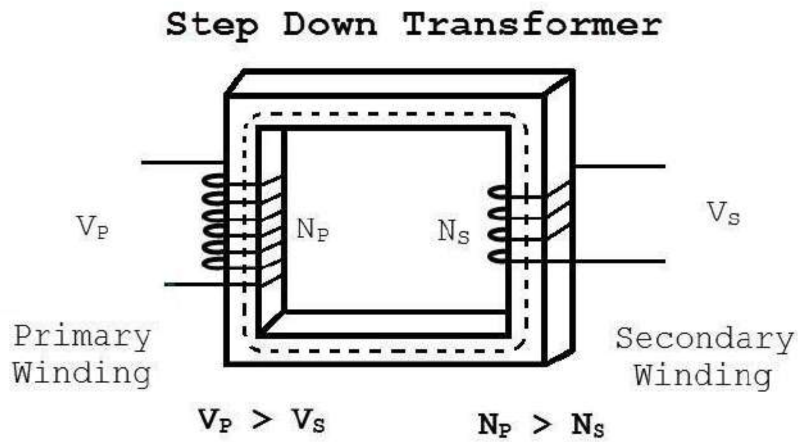


Fig 2.1 Step-Down Transformer [17]

3.1.2. Bridge rectifier

In order to efficiently convert alternating current (AC) to direct current (DC), bridge rectifiers, a type of full-wave rectifier, use four or more diodes in a bridge circuit configuration. A bridge rectifier's basic architecture is shown in Fig 3.2.

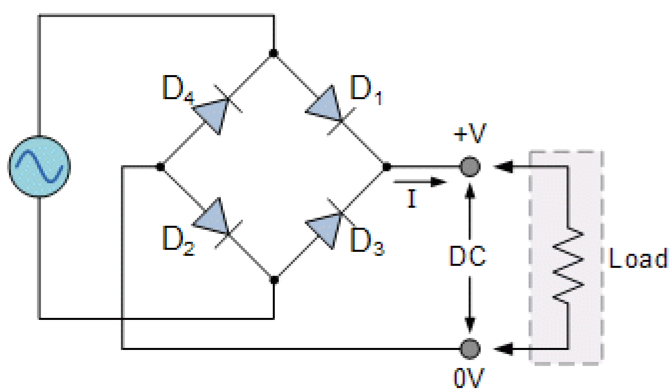


Fig 3.2 Bridge Rectifier Circuit [18]

3.1.3. Capacitor

A device called a capacitor has the capacity to store energy in the form of an electric charge. Although a capacitor's energy storage capacity is around 10,000 times lower than a battery's for a given size, it is nevertheless helpful for many different circuit designs.

In order to keep the DC value constant, the output filter capacitor of a DC power supply must reduce power ripple. Due to their DC value, these capacitors are really retaining a significant amount of energy that is never utilized.

The best electrolytic capacitors for PSUs are those rated at 105 degrees Celsius since they have a longer lifespan than those rated at 85 degrees Celsius. Of course, the capacitor's maker is important; Japanese-made capacitors are always the best option. Different symbols of capacitors are shown in Fig 3.3.

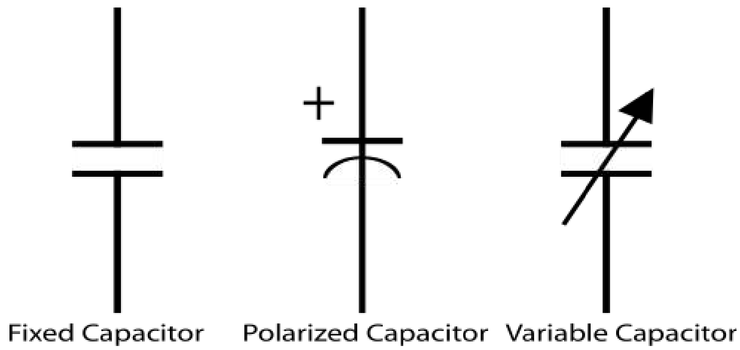


Fig 3.3 Symbols of Capacitors [19]

3.1.4 Resistor

The most commonly used electronic component is a resistor. Its main responsibilities are limiting electrical current flow when necessary and ensuring that the proper voltage is applied to a component. In ohms, resistance is measured. However, as one ohm represents a relatively low resistance, resistance is typically measured in kilo or mega ohms (1000 or 1,000,000). A typical symbol and resistor is shown in Fig 3.4.

Symbol

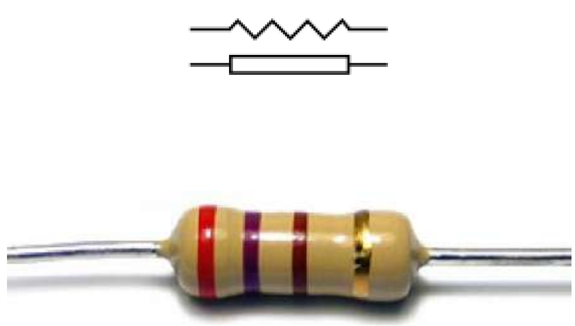


Fig 3.4: Resistor [20]

3.1.5. Voltage regulator LM7805 IC

It belongs to the LM78XX series and has received favorable feedback. 5 VDC is its output, while 6 VDC to 12 VDC is its input. The regulator functions similarly to a voltage divider or potentiometer, continuously showing the difference between the input and the output voltage that has been controlled. When the LM7805's input voltages are higher than 12 VDC, excessive heat is produced that might harm the regulator, or when they are lower than 5 VDC, insufficient voltages appear at the input. Voltage regulator is shown in Fig 3.5.

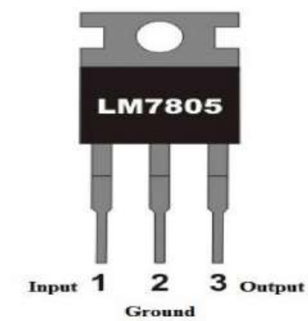


Fig 3.5 7805 Voltage Regulator [21]

3.2. Control unit

Controlling unit consist of

- ATMEGA 328P Micro-controller
- Hall effect current sensor (ACS712)
- Potential transformer as a voltage sensor
- Circuit Breaker
- Filters
- Variable resistor

3.2.1. Atmega 328P micro-controller

A single-chip micro-controller belonging to the mega AVR family, the ATmega328 was developed by Atmel (later Microchip Technology acquired Atmel in 2016). It has an 8-bit RISC processing core with a modified Harvard architecture. Atmega328 micro-controller is shown in Fig 3.6.

1 Specifications:

The 8-bit AVR-based micro-controller from Atmel includes a serial programmable USART, a byte-oriented 2-wire serial interface, an SPI serial port, a 6-channel 10-bit A/D converter (8 channels in TQFP and QFN/MLF packages), internal oscillator timer, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, 3 flexible timer/counters with compare modes The device's operating voltage range is 1.8 to 5.5 volts. The system's performance is close to 1 MIPS/MHz. Pin configuration of ATMEGA32P micro-controller is shown in Fig 3.7.

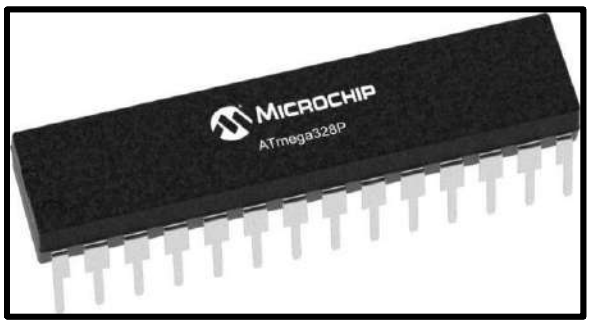


Fig 3.6 Atmega 328P Micro-Controller [22]

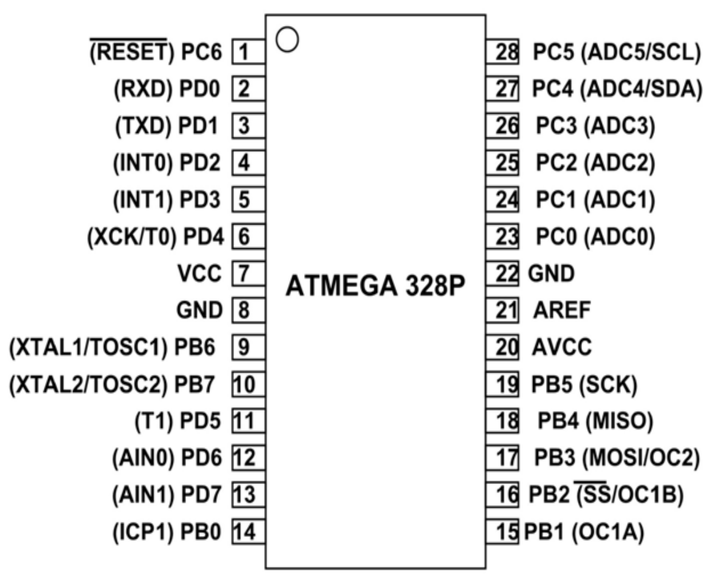


Fig 3.7 ATMEGA 328P Pin Configuration [23]

2 Features:

Basic features of Atmega328P micro-controller is shown in Table 3.1.

Table 3.1 Features of ATMEGA 328P Micro Controller

PARAMETER	VALUE
CPU type	8-bit AVR
Maximum CPU speed	20 MHz
Performance	20 MIPS at 20 MHz
Flash memory	32KB
SRAM	2KB
EEPROM	1KB
Package pin count	28 or 32
Capacitive touch sensing channel	16
Maximum I/o pins	23
External interrupts	2
USB interface	No

3 Advantages of using ATMEGA 328P micro-controller

- As comparison to 32 and 64 bit processor, which are more difficult to use, 8 and 16 bit processor are simpler.
- Containing 32 kilobytes of onboard self-programmable flash memory and 23 programmable I/O lines, it may be used instantly without the addition of any other computer components..
- Due to the direct connection of all 31 registers to the arithmetic logic unit (ALU)., it is code-efficient and 10 times faster than conventional CISC micro-controllers.

- The enhanced RISC instruction set for AVR is optimized.

3.2.2. Hall effect current sensor (ACS 712)

Hall Effect Sensors are a form of transducer that may convert magnetic input into electrical signals for further processing by an electronic circuit. Commonly, current sensors employ the Hall Effect to convert current inputs into voltage outputs.

Electrons from an electric current flow through a magnetic field plate in the Hall Effect. The field then "pushes" the electrons to one side of the plate, creating a voltage difference between the two sides. The voltage difference from the plate's side controls the sensor's output..

The ACS712 is a current sensor that can work on both AC and DC. This sensor generates an analogue voltage output proportionate to the measured current when driven by a 5V source. A number of carefully calibrated hall sensors are joined by copper cables to form this system. Pin configuration of ACS712 current sensor is shown in Fig 3.8.

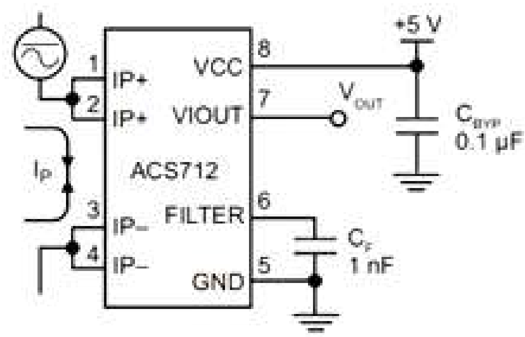


Fig 3.8 ACS 712 Pin Configurations [24]

This sensor has a 5V Vcc power supply, a Vcc x 0.5 = 2.5 output voltage, and a 0A input current. There are three different varieties based on the readable current range: 5A, 20A, and 30A. These have output sensitivity values of 185mV/A, 100mV/A, and 66mV/A, respectively. Since the output of this current sensor is analogue, we can read it using either a voltmeter to measure the output voltage directly or an Arduino or other micro-controller having an analogue read pin or an analogue to digital converter (ADC) pin.

ACS712 current sensor module is shown in Fig 3.9.

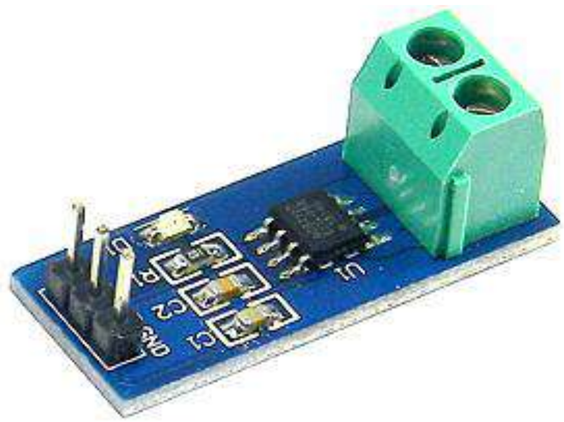


Fig 3.9 ACS 712 Current Sensor Module [25]

3.2.3. Potential transformer

The definition of a potential transformer is an instrument transformer converts voltages from one value to another value. This transformer limits the voltages so that it is safe value that can be easily measure by a voltmeter, watt meter, watt-hour meters, or other common low voltage instrument.

Potential transformers are basically step-down transformers that are employed to reduce voltages to a specified or safe level. For the purpose of measuring the phase voltages in our project, we utilized a potential transformer. A typical Potential transformer is shown in Fig 3.10.

Features:

- Primary voltages: 220 V AC
- Secondary voltages: 12 V AC

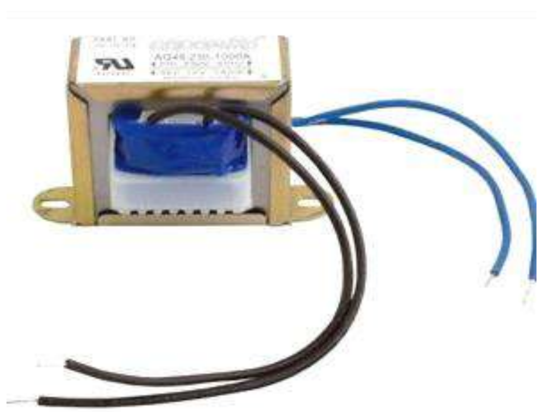


Fig 3.10 Potential Transformer 220 V to 12 V [26]

3.2.4. Circuit Breaker

An electrical safety device known as a circuit breaker is a switch that automatically blocks the flow of current in an overloaded electrical circuit, ground faults, or short circuits. Protective relays detect a problem, causing circuit breakers to "trip" and cut off current flow. Circuit breakers are often not damaged, therefore they may be reset as opposed to being replaced, in contrast to the fuses that were formerly utilized. Circuit breakers are utilized in both home and commercial settings.

In this project we use Miniature Circuit Breaker (MCB). The delayed thermal tripping mechanism for overload protection and the magnetic tripping mechanism for short circuit protection are both features of MCBs. Miniature circuit breaker shown in Fig 3.11.

Fig 3.11 Miniature Circuit Breaker [27]

3.2.5. Filter

Filters are used to create a smooth dc output after dc rectification with alternating current power. As filters, capacitors are used. In this project, smooth dc voltage was generated using capacitors of 100 uF and 25 V, which were then delivered to the micro-controller and other circuits.

3.2.6. Variable resistor

Variable resistors are defined as resistors whose electric resistance value may be altered. A variable resistor is essentially an Electro-Mechanical transducer since it works by moving a contact (wiper) across a resistive element. It operates as a variable resistance and is known as a rheostat when just two terminals are present. Similarly when three terminals are used then it is known as potentiometer. In this project it is used to control the contrast of LCD. Variable resistor shown in Fig 3.12.

Fig 3.12 Variable Resistor [28]

3.3. Display unit

Display unit consist of an 16 x 4 LCD which is used to display the outputs of micro-controller. The liquid crystal display, or LCD, relies on the liquid crystals' light modulation capabilities. It is offered in flat panel displays, video displays, and electronic visible displays.

3.3.1. 16 x 4 LCD

The dot matrix liquid crystal display module is a 16 x 4 character LCD module that is specifically designed to show letters, numbers, symbols, etc. A 16 x 4 LCD display is capable of showing 4 lines of text with 16 characters per line. A 16 x 4 Lcd module shown in Fig 3.13.

Features and Specifications:

- Display format 16 x 4 character
- Outline dimension 87.0 (w) x 60 (h) x 12.5 (t) mm
- Viewing direction 6.00
- Backlight color green
- Power supply 3.5 / 5 V
- Supply current max 1800 micro ampere

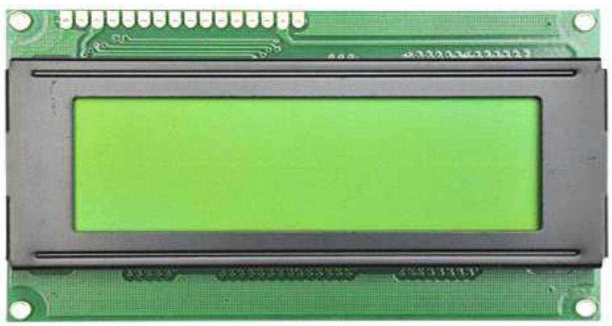


Fig 3.13 16 x 4 LCD [29]

3.4 Load Unit

Load unit consist of series of incandescent light bulbs. Typical incandescent light bulbs are shown in Fig 3.14

Fig 3.14 Incandescent Light Bulbs [30]

CHAPTER # 4

Project layout and Software Simulation

4. Project layout and software simulation

Software simulation is done on Proteus software and in which virtual connection is used to clarify components connects.

4.1. LCD interfacing with micro controller

Interfacing of LCD with micro-controller is shown in Fig 4.1 and Fig 4.2

- 16 x 4 LCD is used to display data.
- Pin Vss, R/ W are ground together..
- Pin RS is connected to micro controller at pins 12.
- Pin E of LCD is connected to micro controller at pins 13.
- The data pin D4, D5, D6, D7 of LCD is connected to micro controller pins 14, 15, 16, 17.

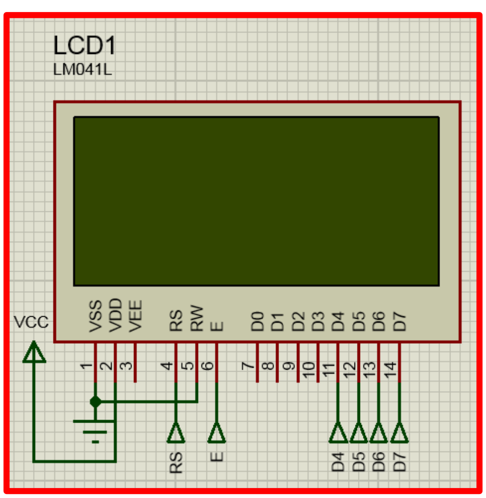


Fig 4.1 LCD Interfacing

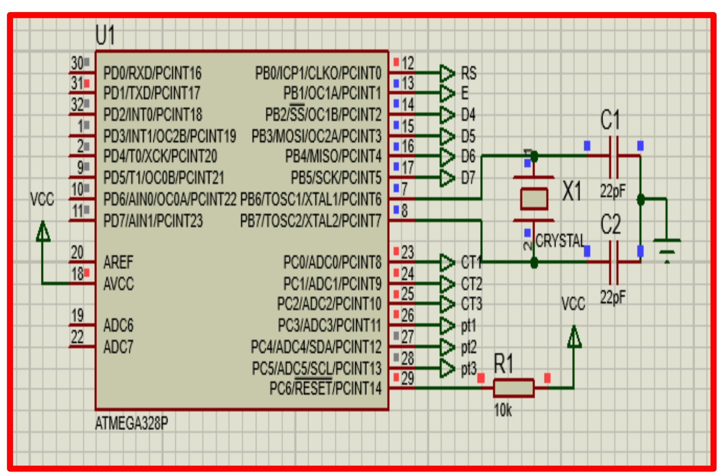


Fig 4.2 Micro Controller Connections

4.2. Interfacing of Ac voltage sensors with micro-controller

4.2.1. Voltage sensor 1:

Interfacing of Voltage Sensor 1 with Micro Controller is shown in Fig 4.3.

- A step down (potential transformer) is used as a voltage sensor. It step down 250 V to 12 V.
- First of all phase 1 (P1) and neutral (N1) of source 1 / source 2 is connected to primary side of potential transformer 1.
- Secondary voltages of potential transformer 1 are given to bridge rectifier for the conversion of ac to dc.
- Now capacitor is used to smooth the output dc voltages of bridge rectifier.
- After that bridge rectifier output is connected to voltage divider circuit.
- This voltage divider circuit converts 12 v dc into pure 5 v dc.
- Then this 5v dc is fed to micro controller at pin 26.

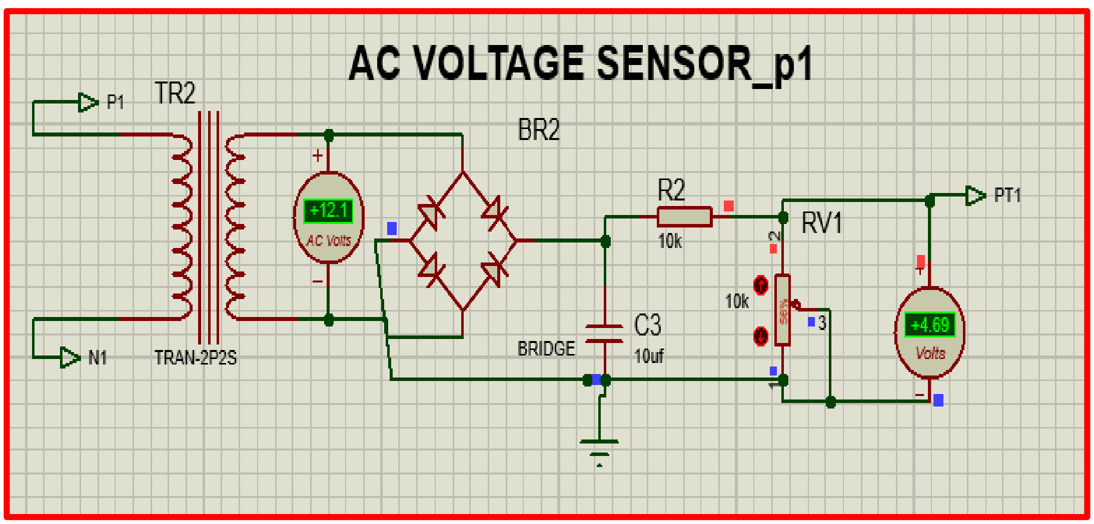


Fig 4.3 Interfacing of Voltage Sensor 1 with Micro Controller

4.2.2. Voltage sensor 2:

Interfacing of Voltage Sensor 3 with Micro Controller is shown in Fig 4.4.

- A step down (potential transformer) is used as a voltage sensor. It steps down 250 V to 12 V.
- Phase 2 (P2) and neutral (N2) of source 1 / source 2 is connected to primary side of potential transformer 2.
- Secondary voltages of potential transformer 2 are given to bridge rectifier for the conversion of ac to dc.
- Now capacitor is used to smooth the output dc voltages of bridge rectifier.
- After that bridge rectifier output is connected to voltage divider circuit.
- This voltage divider circuit converts 12 v dc into pure 5 v dc.
- Then this 5v dc is fed to micro controller at pin 27.

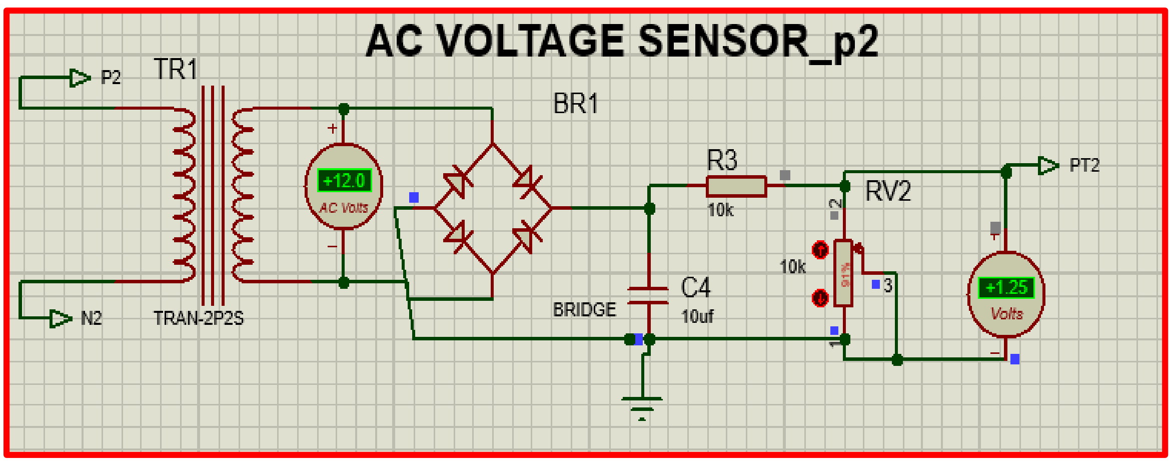


Fig 4.4 Interfacing of Voltage Sensor 2 with Micro Controller

4.2.3. Voltage sensor 3:

Interfacing of Voltage Sensor 3 with Micro Controller is shown in Fig 4.5.

- A step down (potential transformer) is used as a voltage sensor. It step down 250 V to 12 V.
- Phase 3 (P3) and neutral (N3) of source 1 / source 2 is connected to primary side of potential transformer 3.
- Secondary voltages of potential transformer 3 are given to bridge rectifier for the conversion of ac to dc.
- Now capacitor is used to smooth the output dc voltages of bridge rectifier.
- After that bridge rectifier output is connected to voltage divider circuit.

- This voltage divider circuit converts 12 v dc into pure 5 v dc.
- Then this 5v dc is fed to micro controller at pin 28.

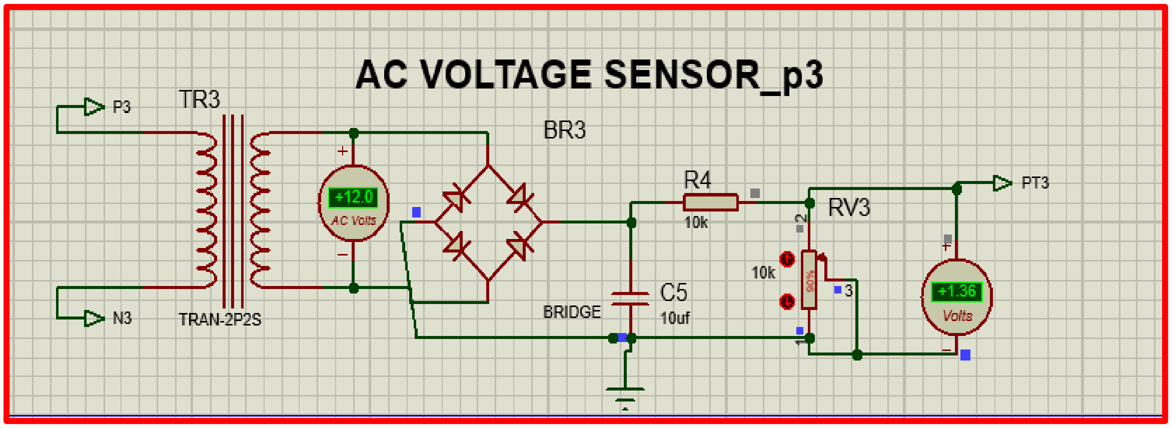


Fig 4.5 Interfacing of voltage Sensor 3 with Micro Controller

4.3. Interfacing of current sensor with Micro Controller

4.3.1. Current sensor 1:

Interfacing of current sensor 1 with micro controller is shown in Fig 4.6.

- ACS712 hall effect current sensor is used.
- Phase 1 (P1) of source 1/ source 2 is connected to IP+ terminal of current sensor 1.
- Ac ampere meter is used in series with phase 1 and IP+ terminal of current sensor 1.
- Now one terminal of load is connected to the IP- terminal of current sensor 1 and second terminal of load is connected to neutral N2 of source 1 / source 2.
- Now Vcc is provided at terminal 8 of current sensor 1.
- Finally VOUT terminal or 7pin- terminal of current sensor 1 is connected to micro controller pin 23.

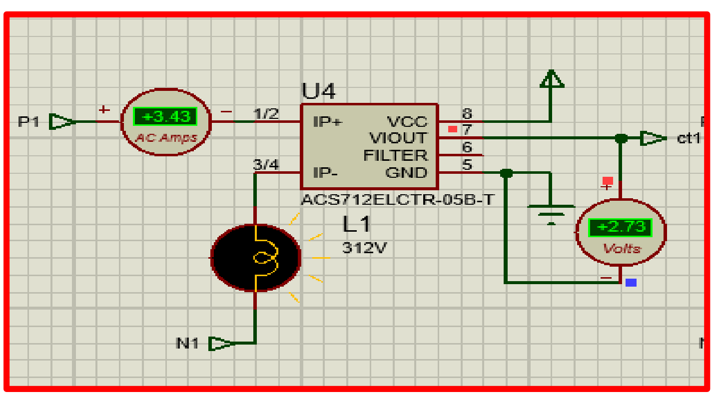


Fig 4.6 Current Sensor 1

4.3.2 Current sensor 2:

Interfacing of current sensor 2 with micro controller is shown in Fig 4.7.

- ACS712 hall effect current sensor is used.
- Phase 2 (P2) of source 1/ source 2 is connected to IP+ terminal of current sensor 2.
- Now one terminal of load is connected to the IP- terminal of current sensor 2 and second terminal of load is connected to neutral N2 of source 1 / source 2.
- Now Vcc is provided at terminal 8 of current sensor 2.
- Finally VIOUT terminal or 7pin- terminal of current sensor 2 is connected to micro controller pin 24.

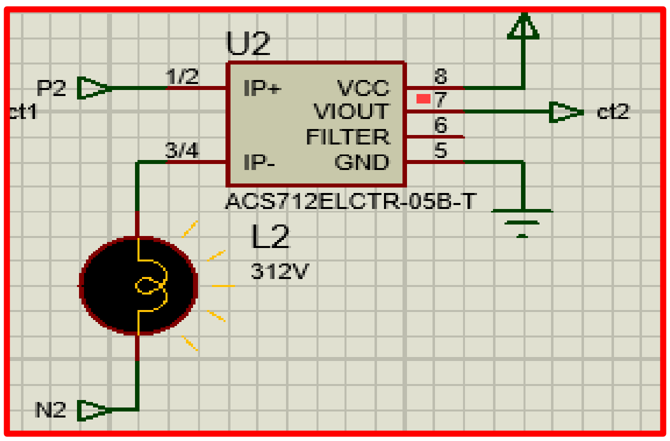


Fig 4.7 Current sensors 2

4.3.3 Current sensor 3:

Interfacing of current sensor 3 with micro controller is shown in Fig 4.8.

- ACS712 hall effect current sensor is used.
- Phase 3 (P3) of source 1/ source 2 is connected to IP+ terminal of current sensor 3.
- Now one terminal of load is connected to the IP- terminal of current sensor 3 and second terminal of load is connected to neutral N3 of source 1 / source 2.
- Now Vcc is provided at terminal 8 of current sensor 3.
- Finally VIOUT terminal or 7pin- terminal of current sensor 3 is connected to micro controller pin 25.

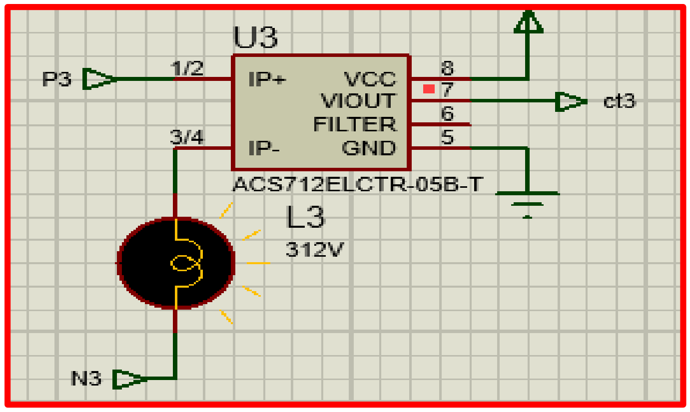


Fig 4.8 Current sensors 3

4.4 Overall circuit simulation

CASE # 1: When source 1 is on

When source 1 is on then overall circuit simulation is shown in Fig 4.9.

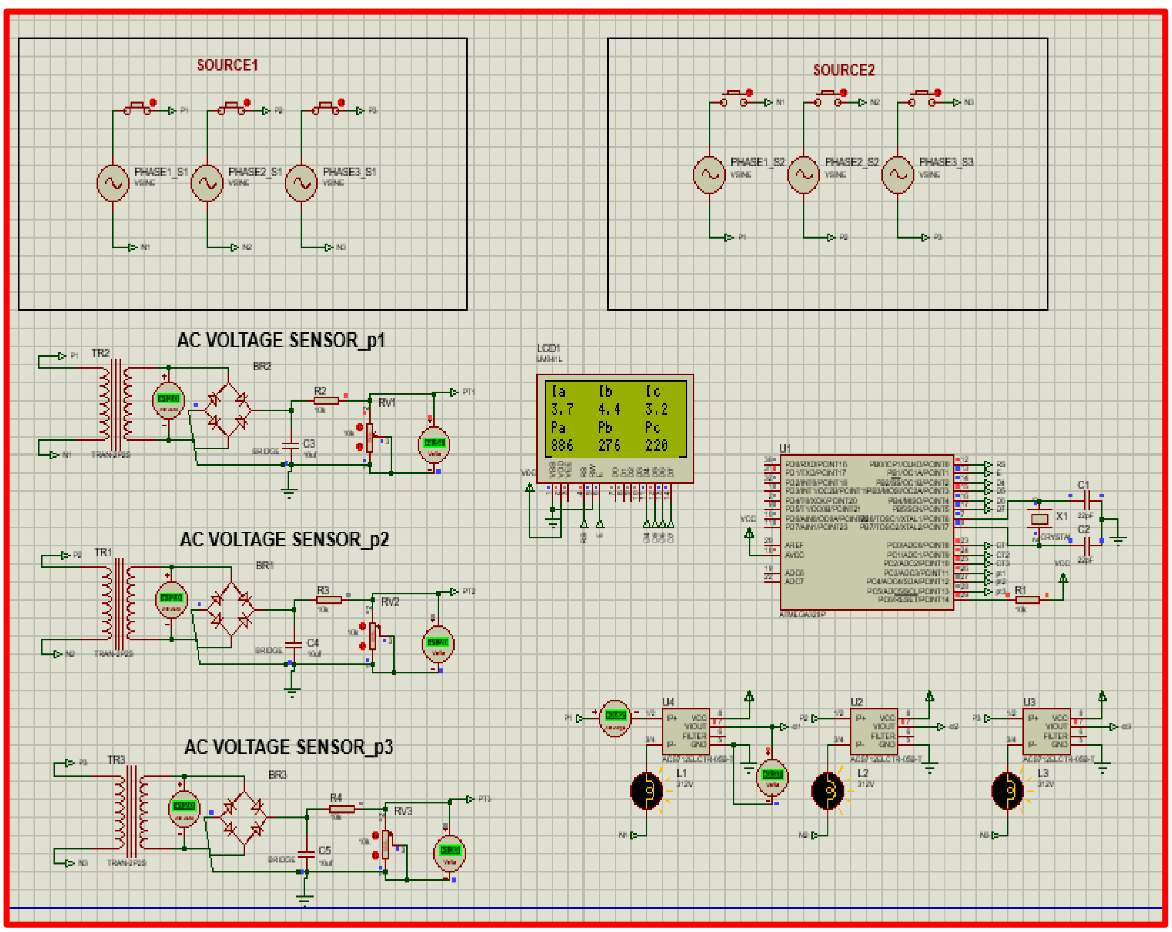


Fig 4.9 Overall Circuits When Source 1 is on

CASE # 2: When source 2 is on

When source 2 is on then overall circuit simulation is shown in Fig 4.10

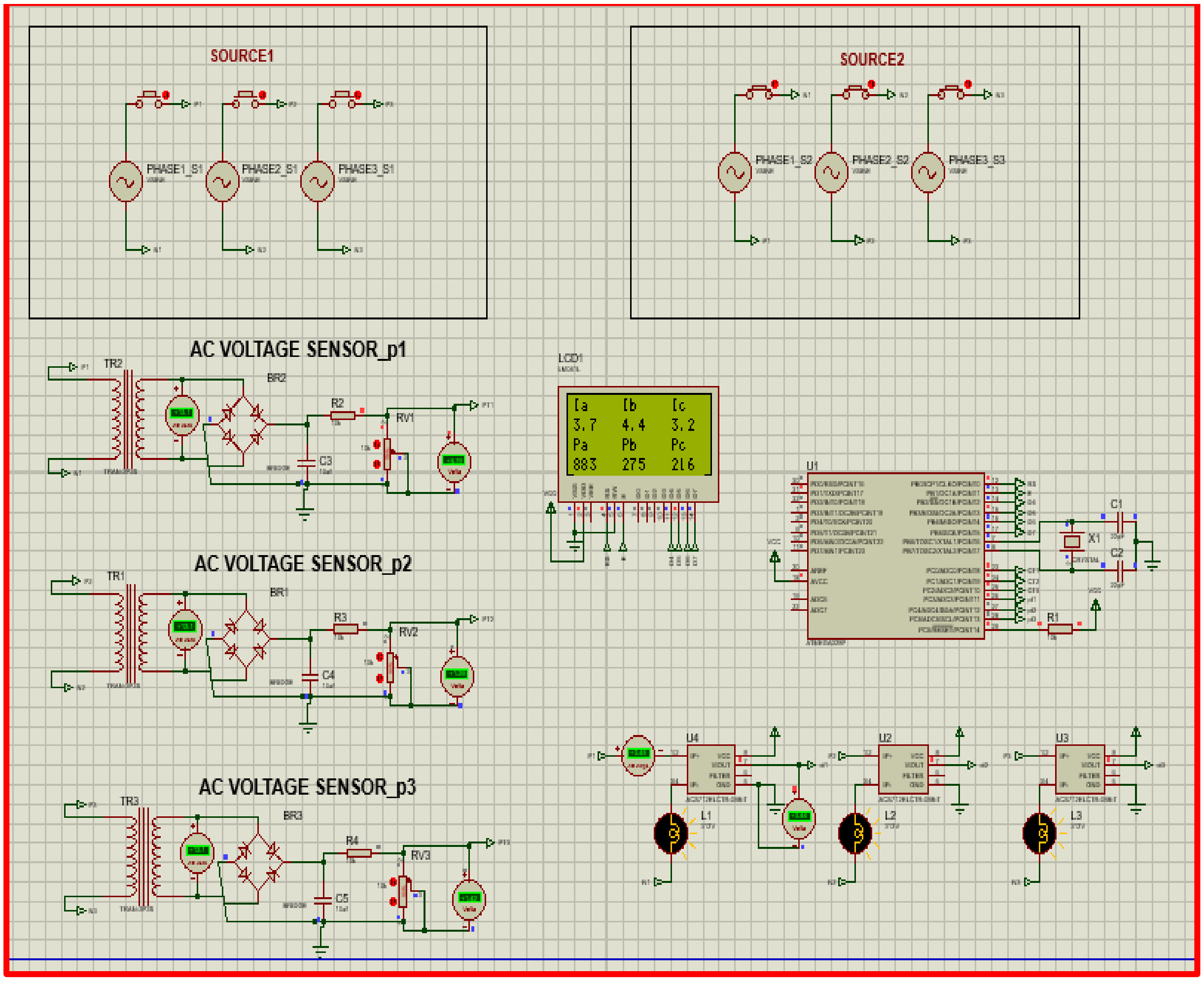
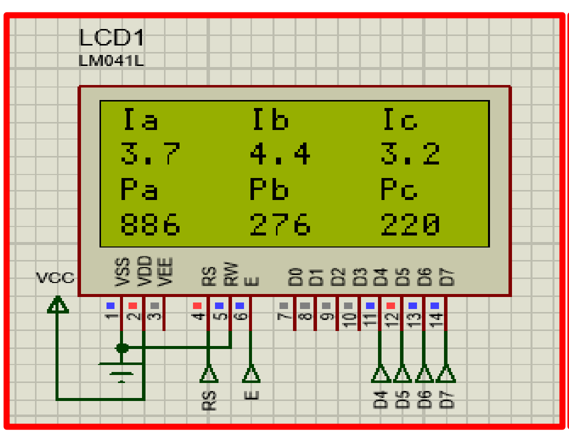


Fig 4.10 Overall Circuits When Source 2 is on



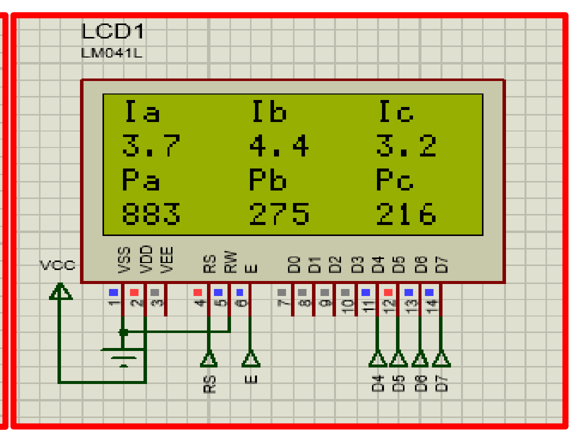


Fig 4.11 Output When Source 1 is on   Fig 4.12 Output When Source 2 is on

CHAPTER # 5

Design and Implementation

5. Design and implementation

Complete project consist of following unit:

1. PCB designing
2. Voltage sensor or Potential transformers and their connections
3. Bridge rectifier circuit
4. ACS 712 Current sensors and their connections
5. Micro-controller interfacing with LCD
6. Current transformer interfacing
7. Synchronization module
8. Loads unit connections

5.1. PCB Designing

The complete PCB layout of main circuit is shown in Fig 5.1.

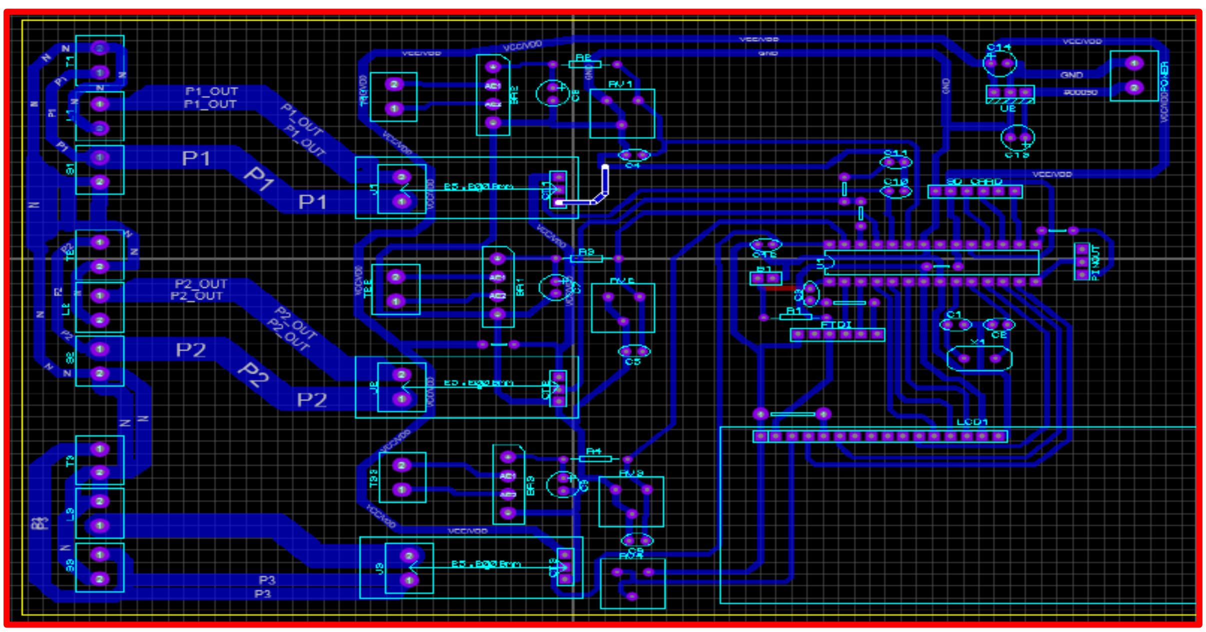


Fig 5.1 PCB Layout of Main Circuit

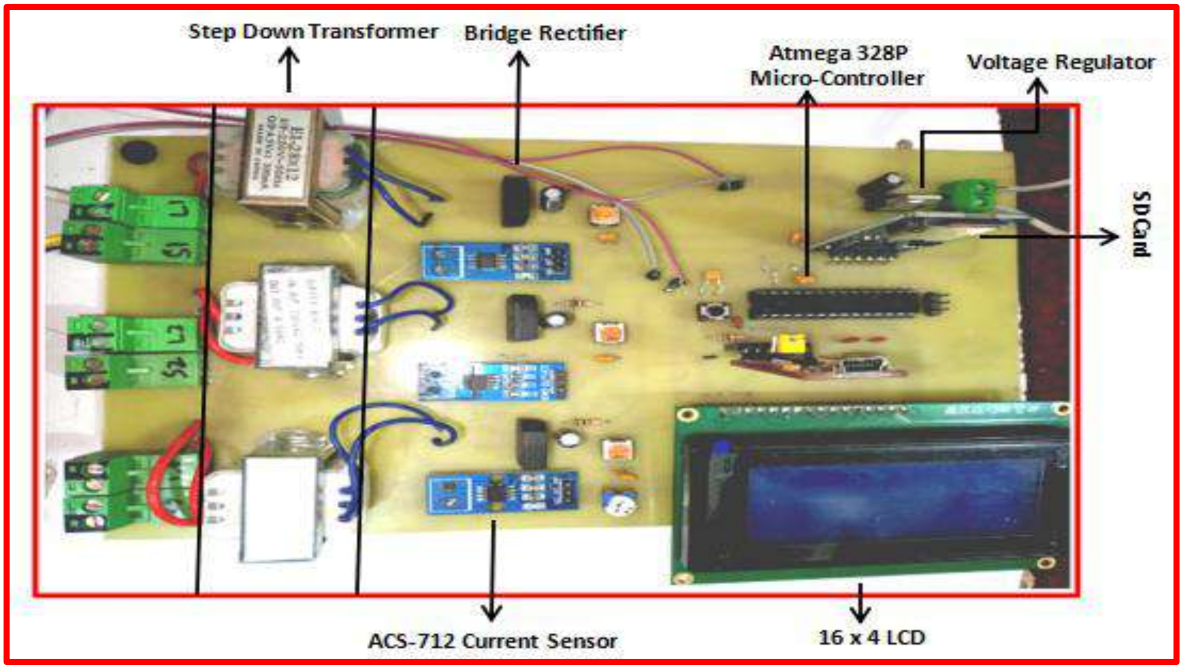


Fig 5.2 Hardware PCB of Main Circuit

5.2 Voltage sensor or Potential transformers and their connections:

Potential transformer is shown in Fig 5.3.

Fig 5.3 Potential Transformer

5.2.1. Explanation

A 220V/4.5V step-down transformer is utilized in this project. This transformer reduces the input 220V to 4.5 V. In order to convert 4.5 ac volts into pure dc, a bridge rectifier is attached to the step-down transformer's output.

5.3. Bridge rectifier circuit:

Bridge rectifier circuit is shown in Fig 5.4.

Fig 5.4 Bridge Rectifier Circuit

5.3.1. Explanation:

Bridge rectifiers are used to convert 4.5 VAC into 4.5 VDC. In a bridge rectifier circuit, a 100- microfarad capacitor is used for smoothing purposes, which eliminates ripples in the output of the bridge rectifier. In this circuit, a variable resistor is also used to maintain the output of the bridge rectifier at 4.5 Vdc.

5.4. ACS 712 Current sensor and its connection:

ACS 712 Current sensor is shown in Fig 5.5.

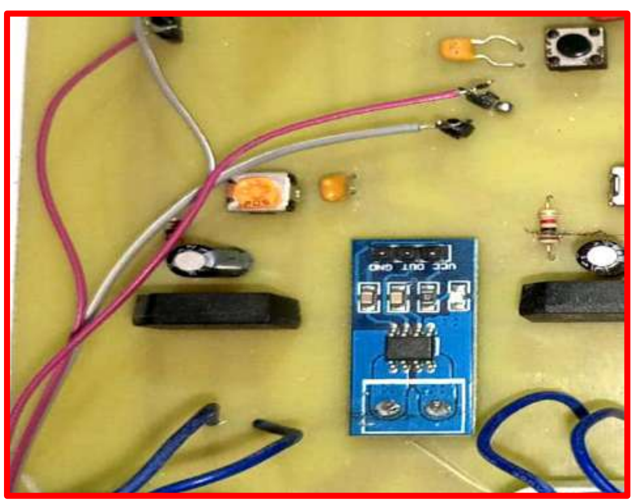


Fig 5.5 ACS 712 Current Sensor

5.4.1. Explanation :

The ACS-712 hall effect current sensor volts is utilized in this project. Both positive and negative currents are measured by this current sensor. This current sensor's DC offset is 5V. The phase is linked to the IP+ terminal in this sensor circuit. One common load unit terminal is linked to the IP terminal, while the second load unit terminal is connected to the neutral. Pin 23 of the micro-controller is linked to the Vout output of the ACS712 current sensor.

5.5. Micro-controller interfacing with LCD:

Interfacing of Atmega 328P Micro-controller is shown in Fig 5.6

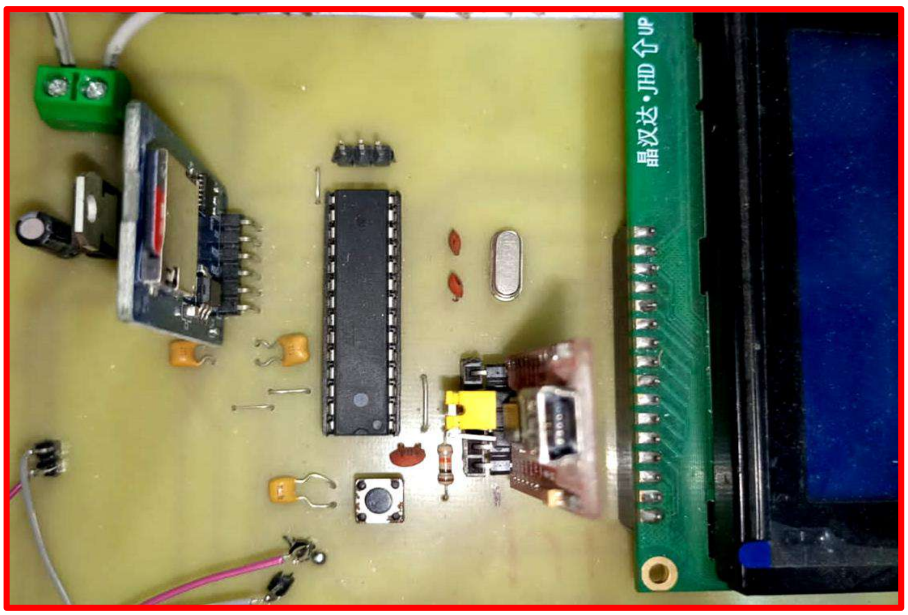


Fig 5.6 Atmega 328P Micro-Controller Interfacing

5.5.1. Explanation:

- 16 x 4 LCD is used to display data.
- Pin Vss, R/W are ground together..
- Pin RS is connected to micro controller at pins 12.
- Pin E of LCD is connected to micro controller at pins 13.
- The data pin D4, D5, D6, D7 of LCD is connected to micro controller pins 14, 15, 16, 17.

5.6. Current transformer interfacing:

Interfacing of current transformer is shown in Fig 5.7.

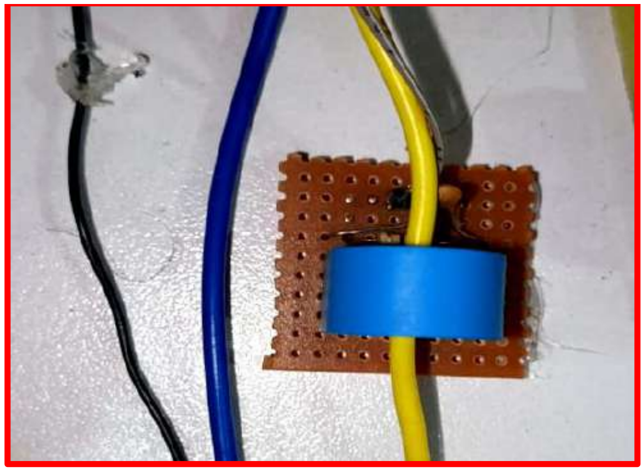


Fig 5.7 Current Transformer Interfacing

5.6.1. Explanation:

In this project, wound current transformers are used to measure the input current of both the WAPDA source and the finite source. A phase is simply passed through a current transformer's hollow space, and the current flowing through the phase is then measured.

5.7. Synchronization module:

Synchronization module is shown in Fig 5.8.

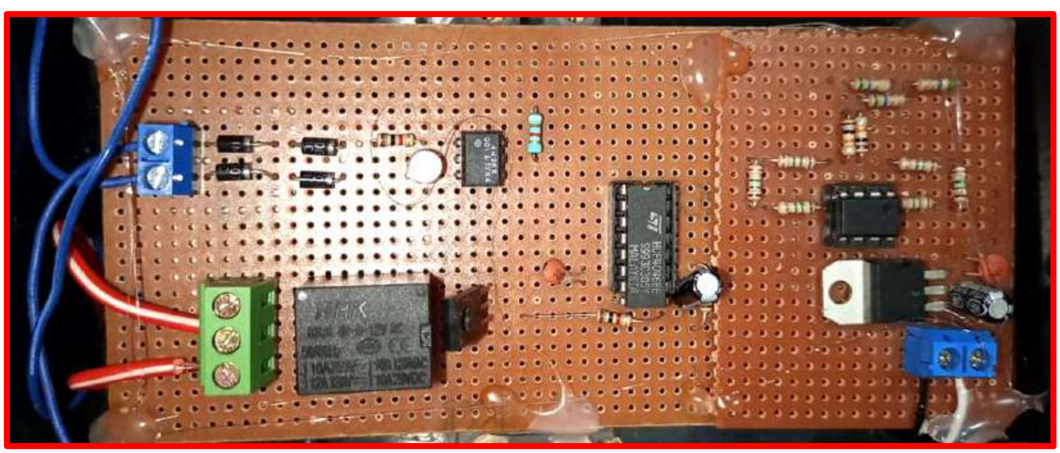


Fig 5.8 Synchronization Module

5.7.1. Explanation

In synchronization module zero-cross detection method and phase locked loop method is used to synchronize WAPDA source and finite source.

5.8. Loads unit connections:

5.8.1 Explanation

In this project we use incandescent light bulbs as a load. Total six incandescent bulb are used and give cumulative load 580 W. We can vary this load by turning on or off switches. These loads are connected with current sensor and sources. Load unit is shown in Fig 5.9.

Fig 5.9 Load unit

5.9. Complete Hardware:

5.9.1. Explanation

Complete hardware consists of main meter circuit, synchronization circuit, current transformers, Circuit breaker, loads unit and switches.

First of all WAPDA source and consumer source are linked together and synchronize automatically in synchronization circuit. Potential transformer is used as a voltage sensor for measuring input voltages of both sources (WAPDA, consumer). Potential transformers reduce the voltages of both sources to the desired value, and the output of the potential transformers or voltage sensors is then supplied to the bridge rectifier which converts AC voltages into DC voltages. After filtering, the output of bridge rectifier is supplied to micro-controller, which subsequently measures and displays the voltage data of both sources on the LCD. The ACS 712 Hall effect sensor is used as a current sensor for measuring load current in positive as well as negative direction. The output of the current sensor is fed to micro-controller then controller measure and display current data on LCD.

At on peak hour , consumer load is high than its generation so in this case, consumer source need some power from utility grid to fulfill load requirement so current is flow from utility grid to consumer, the ACS712 current sensor detects this positive flow of current and give output to micro-controller. Then micro-controller use the data of current , voltage and display forward power on LCD.

Similarly at off-peak hour consumer load is low than its generation so in this case surplus power is fed back to utility grid hence current is flow from consumer source to utility grid, the ACS712 current sensor detect the negative flow of current and give output to micro-controller. Then micro-controller use the data of current , voltage and display reverse power on LCD Finally micro-controller display all data on LCD with respect to delays added in source code. Complete hardware shown in Fig 5.10.

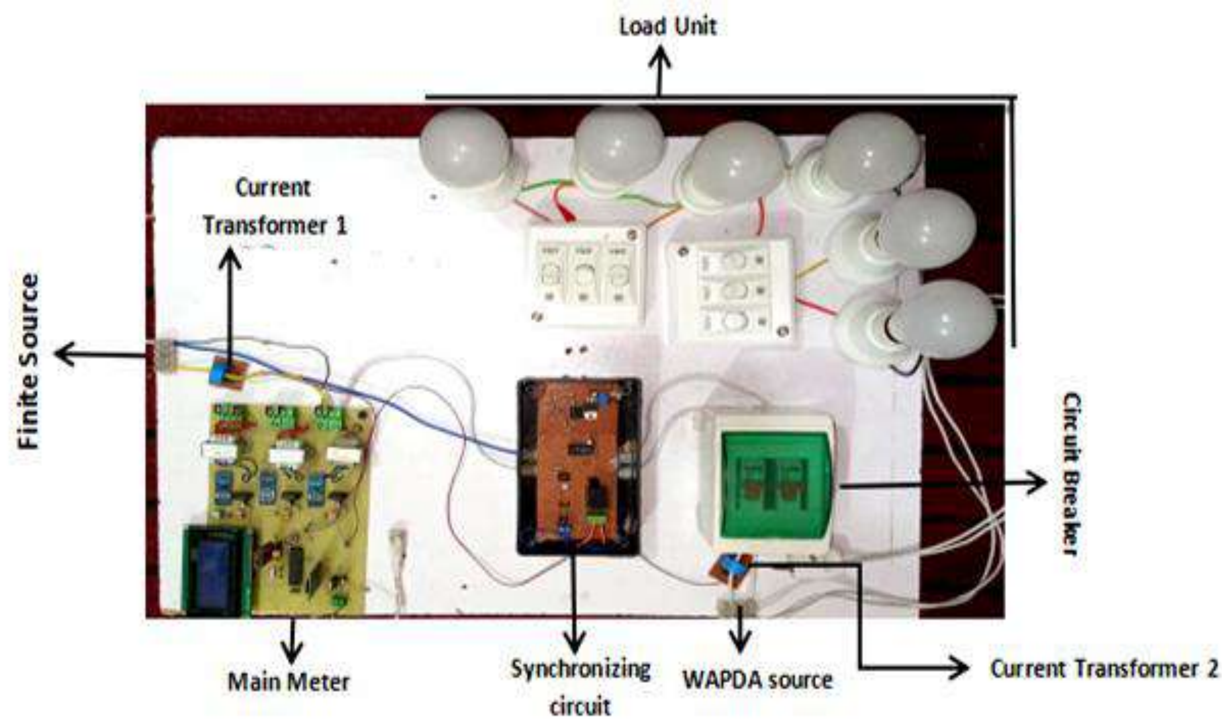


Fig 5.10 Complete Hardware

Chapter # 06

Results and Discussion

6. Results and Discussion

6.1. Results:

By the grace of Allah Almighty, we successfully designed a bi-directional energy meter that measures forward and reverse power. The table 6.1 and output picture of hardware serve as proof of this.

S1: Finite source

S2: WAPDA source

TABLE 6.1 Output at Different loads

Forward power				Reverse Power			
Load	**Import power**	**Export power**	**Power flow**	**Load**	**Import power**	**Export power**	**Power flow**
580 W	171 W	0 W	S2 to S1	360 W	0 W	28 W	S1 to S2
520 W	120 W	0 W	S2 to S1	300 W	0 W	79 W	S1 to S2
480 W	78 W	0 W	S2 to S1	260 W	0 W	117 W	S1 to S2
400 W	2 W	0 W	S2 to S1	200 W	0 W	172 W	S1 to S2

6.2 Discussion:

Forward Power Measurement :

Case # 1: When 580 W Load is Connected

When we connect 580 W load then meter show 171 W import power, which means that the finite source getting 171 W power from WAPDA to fulfill load requirement. Output is shown in Fig 6.1.

Fig 6.1 Output When 580 W Load is Connected

Case # 2: When 520 W Load is Connected

When we connect 520 W load is connected, in this case finite source import 120 W power from WAPDA. In this case load utilize 400 W power from finite source and remaining 120 W power is imported from WAPDA. Output shown in Fig 6.2.

Fig 6.2 Output When 520 W Load is Connected

Case # 3: When 480 W Load is Connected

When 480 W load is connected then finite source need 78 W power import from WAPDA to fulfill load requirement. In this case load utilize 402 W power from finite source and 78 W power from WAPDA. Output is shown in Fig 6.3.

Fig 6.3 Output When 480 W Load is Connected

<u>Reverse Power Measurement</u> :

Case # 4: When 300 W load is Connected

When 300 W load is connected, then meter show 79 W export power which means that finite source fed back surplus 79 W power to WAPDA. Output is shown in Fig 6.4.

Fig 6.4 Output When 300 W Load is Connected

Case # 5: When 260 W Load is Connected

When we connect 260 W load, in this case finite source fulfill load requirement and give 260 W power to load hence surplus 117 W power is exported to WAPDA which is reverse power. Output is shown Fig 6.5.

Fig 6.5 Output When 260 W Load is Connected

Case # 6: When 200 W load is Connected

When 200 W load is connected then finite source capable of handling the load requirement and hence finite source provide 200 W power for load so surplus 172 W power is exported to WAPDA. Output is shown in Fig 6.6.

Fig 6.6 Output When 200 W Load is Connected

Chapter # 07

Environmental and Societal Aspects

This chapter is all about the environmental and societal aspects that may be occurred in our project and will affect society.

7.1. Environmental Aspects:

Environmental aspects are those elements of an organization, or organization's activities, product or services that could have a significant effect on the environment. Our project plays a vital role for handling problems in environment because of its effective energy measurement.. In our project, an energy measurement includes the environmental aspects of energy efficiency, record energy usage, monitor power generation, estimate the cost of energy and improved safety. Some major aspects of this project that affects the environment positively are discussed below in detail.

7.1.1. Clean and Safe:

This project is environmental friendly, neat and clean because there is no produced pollution during working. This project is very safe because all the circuit inside the insulation hard plastic body so there is no shock, hazard produce during working time.

7.1.2. Cost/Enhance efficiency:

Many contributions are made to reduce the energy shortage and boost the effectiveness of the power monitoring system. The tiny renewable customer energy sources should be connected to the main grid without reducing system efficiency; the measurement device should be efficient enough that only minimal losses occur. Our meter has a very high efficiency and a very low internal power loss..

7.1.3 Environmental sustainability:

Our reliance on solar energy for the generation of electric energy is a major factor in the enhancement of sustainable resource usage. Growing attention and study are being done on the long-term viability of bidirectional energy meter vs traditional static energy meter in poor nations.

7.2. Societal Aspects:

Societal aspects are the effects of a business or organization's activities, products, or services on society. These can include economic impacts, social impacts, and environmental impacts. An bi-directional energy meter delivers a number of environmental benefits. It mainly record energy usage, monitor power generation, estimate the cost of energy and improved safety.

7.2.1. Enhance Safety

Circuit breakers and isolation circuits in this project have reduced the frequency of mishaps, injuries, and dangers to operators or workers while causing minimal inconveniences. It can offer features like monitoring, emergency response, and prevention that are rarely seen in manual skills.

7.2.2. Reduction of bills

A bidirectional meter enables consumers to participate actively in energy production. The bill is reduced by exporting self-generated energy to the grid.

Monthly bill = (energy imported – energy exported) * retail rate *………………Eq (7.1)*

7.2.3. Change in Education:

The drastically altered criteria have required a radical transformation in education. The following are the essential instructions for operating an automatic system:

- Educate the population and future generations
- Develop knowledge and skills.
- Methods and educational philosophy

7.2.4. Changing in Labor:

The main discussion of the impending transformation has been on how human labour will alter in an automated world. In fact, 50% of all tasks that individuals are presently paid to accomplish can already be automated thanks to existing technology. For individuals who can utilize them, they also fundamentally alter present business structures and producer-customer relationships and generate new job prospects. It denotes a requirement for knowledgeable and professional labour.

7.2.5. Enhancing Business:

Making improvements and putting new software into use to run the automated system and communication system may also help others gain useful insight into your company. By sharing updates on our progress, we can acknowledge our transformation and utilize this method to win over new clients and earn the trust of our current ones.

7.3. Mapping of FYDP with SDGs:

The Sustainable Development goals (SDGs) are a set of 17 interconnected global objectives that together provide a "blueprint to achieve a better and more sustainable future for all". They are integral and indivisible in order to balance the three pillars of sustainable development—economic, social, and environmental. The mappings of the SDGs to our final project (FYDP) are shown in Table 7.1.

Table 7.1: Mapping of FYDP with SDGs

Project Title "Designing of bi-directional energy meter for measuring reverse power flow"	
GOAL 01: No Poverty	
GOAL 02: Zero Hunger	
GOAL 03: Good Health and Well-Being	
GOAL 04: Quality Education	
GOAL 05: Gender Equality	
GOAL 06: Clean Water and Sanitation	
GOAL 07: Affordable and Clean Energy	✓
GOAL 08: Decent Work and Economic Growth	✓
GOAL 09: Industry, Innovation and Infrastructure	✓
GOAL 10: Reduced Inequality	
GOAL 11: Sustainable Cities and Communities	
GOAL 12: Responsible Consumption and Production	✓
GOAL 13: Climate Action	
GOAL 14: Life Below Water	
GOAL 15: Life on Land	
GOAL 16: Peace and Justice Strong Institutions	
GOAL 17: Partnership to Achieve the Goal	✓

Chapter#08

Conclusion and Future Suggestions

8. Conclusion and Future Suggestions

8.1. Conclusion

This project "Designing of bi-directional energy meter for measuring reverse power flow" is very efficient ,low cost, reliable and attractive for consumers. This designed bi directional energy meter measure and record the two tariff energy imported and exported by/to the small energy producer. At the end of each billing period consumer have a total record that how much power is consumed by itself and how much power is deliver to WAPDA This project fulfill the Net Metering mechanism in order to reduce electricity bills, encourages the consumer to take part in energy regulation, reduce bills.

This project not only activates consumers to participate in energy management but also a secure control system to set and switch load according to their need and choice. As a scope for future, additional communications like GSM based implementations can ensure higher performance and security.

8.2. Future Suggestions

- Power Quality Management System, Load shedding control system and Load management system. In order to do load shedding, load sharing between different sources and load management automatically.
- Measuring reverse power flow through wireless system such as SCADA
- Bi-directional Communication between consumer, utility and Energy Meter
- Notify Power Factor change instantly, which is good for studying nature of Load.
- Security system such as Theft detection system to be installed
- "Time of use" based energy management system.
- Power factor Improvement

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