Development of Micro-Controller Based Smart Grid System Framework



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Date of Submission: January -2020

DECLARATION

It is declared here by that this project or any part of it has not been submitted to anywhere else for the award of any degree.

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Certification

This is to certify that this project entitled "**Development of Micro-Controller Based Smart Grid System Framework**" is done by the following students under my direct supervision. This project work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

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ACKNOWLEDGEMENT

The report titled as on "**Development of Micro-Controller Based Smart Grid System Framework**" has been prepared to fulfill the requirement of our practicum program. In the process of doing and preparing our practicum report, we would like to pay our gratitude to some persons for their enormous help and vast co-operation.

At first, we would like to show our gratitude to the University authority to permit us to do our practicum. Specially, we would like to thank to our honorable teacher **Syed Raihan Hossain,** Lecturer, Department of Electrical & Electronics Engineering, Sonargaon University (SU), Dhaka, for his valuable and patient advice, sympathetic assistance, co-operation, contribution of new idea. Deep theoretical and hardware knowledge & keen interest of our supervisor in this field influenced us to carry out this project. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior draft and correcting them at all stage have made it possible to complete this project.

Finally, we would like to thanks again to the respected **Vice- Chancellor of SU, Professor Dr. Md. Abul Bashar** also thanks to **Head of Department of SU, Electrical & Electronics Engineering, Professor Dr. M. Bashir Uddin** because they are designated such an environment for learning through which we got the opportunity to acquire knowledge under B. Sc. in EEE program, and that will be very helpful for our prospective career.

We are, indeed, grateful to all those from whom we got sincere cooperation and help for the preparation of this report

ABSTRACT

Smart grid technology has been recognized as a promising solution for the next-generation energy efficient electric power systems to mitigate energy crisis. Smart grid provides highly consistent and reliable services, efficient energy management practices, smart metering integration, automation and precision decision support systems and self-healing facilities. The smart power grid introduces a sensing, monitoring, and control system that provides end users with the cost of energy at any moment through real-time pricing. The classical power system operation has no control over the loads except in an emergency situation when a portion of the loads can be dropped as needed to balance the power grid generation with its loads. Furthermore, the smart power grid supplies the platform for the use of renewable energy sources that acts as a safeguard against a complete blackout of the interconnected power grid. In this work, all the concepts involved in smart grid mechanisms implemented with ATmega328P micro-controller and other supplementary components. Piezoelectric Sensor and a solar module with storage capacity is connected to the proposed system for minimizing grid energy consumption and plays a primary energy sources for maximum utilization of green energy. This intelligent device may inherently reduce the consumption of electrical energy during peak hours and also allow consumers to sell back electricity into grid using bi-directional technique. Barriers, challenges, benefits and future trends regarding the technologies and the role of users have also been discussed in this report.

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CHAPTER I
Introduction

1.1 Introduction

The term “smart grid” defines a self - healing network equipped with dynamic optimization techniques that use real - time measurements to minimize network losses, maintain voltage levels, increase reliability, and improve asset management. The operational data collected by the smart grid and its sub - systems will allow system operators to rapidly identify the best strategy to secure against attacks, vulnerability, and so on, caused by various contingencies. In a classical power grid, a fixed price is charged to energy users. However, the cost of energy is highest during the daily peak load operation.

Today’s electric grid was designed to operate as a vertical structure consisting of generation, transmission, and distribution and supported with controls and devices to maintain reliability, stability, and efficiency. However, system operators are now facing new challenges including the penetration of RER in the legacy system, rapid technological change, and different types of market players and end users. The next iteration, the smart grid, will be equipped with communication support schemes and real - time measurement techniques to enhance resiliency and forecasting as well as to protect against internal and external threats. The design framework of the smart grid is based upon underling and restructuring the power sector and optimizing its assets [5]. The new grid will be capable of:

- Handling uncertainties in schedules and power transfers across regions
- Accommodating renewable
- Optimizing the transfer capability of the transmission and distribution networks and meeting the demand for increased quality and reliable supply
- Managing and resolving unpredictable events and uncertainties in operations and planning more aggressively.

For an efficient smart power grid system design and operation, substantial infrastructure investment in the form of a communication system, cyber network, sensors, and smart meters must be installed to curtail the system peak loads when the cost of electric energy is highest. The smart power grid introduces a sensing, monitoring, and control system that provides end users with the cost of energy at any moment through real-time pricing. In addition, the smart power grid enables every energy user to become an energy producer by giving the user the choice of PV or wind energy, fuel cells, and combined heat and power (CHP) energy sources

and to participate in the energy market by buying or selling energy through the smart meter connection.

Bangladesh is a subtropical country, 70% of year sunlight is dropped in Bangladesh. For this reason, we can use solar panels to produce electricity largely. Solar radiation varies from season to season in Bangladesh. Bangladesh receives an average daily solar radiation of 4-6.5 kWh/m2.Renewable Energy Research Centre (RERC) presently named as Institute of Energy (IE), Dhaka University is the only source which has got long term measured data of Dhaka Solar Energy can be a great source for solving the power crisis in Bangladesh. Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east which is an ideal location for solar energy utilization.

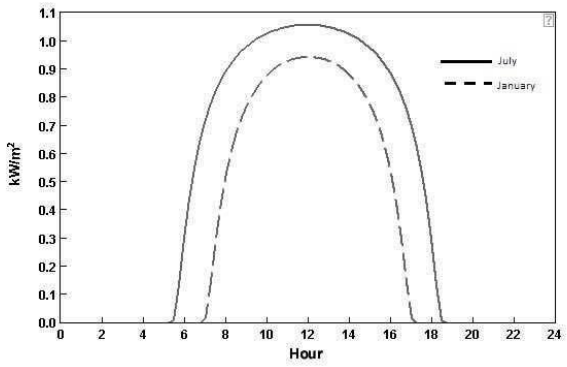


Fig: 1.1 The highest and lowest intensity of direct radiation in W/m²

In fact, the Bangladesh government has recently taken many steps to encourage people to use photo voltaic energy. Almost every newly built apartment building is now using solar panels along with the grid connection to get support during the load shedding period.

Our project aim is to make this huge solar PV energy usable in our daily life. The system will monitor the total load consumption in peak and off peak hour and will provide solar PV energy if required. It can also charge a storage battery to give power in any instance.

The implementation of an advanced metering infrastructure provides real-time pricing to the energy end users. In parallel, the penetration of renewable energy sources is providing a platform for autonomous control or local control of connected micro-grids to the local power grid. A distributed autonomous control will provide reliability through fault detection, isolation, and restoration. The autonomous control and real-time pricing also delivers efficiency in feeder voltage to minimize feeder losses and to reduce feeder peak demand of plug-in electric vehicles. The maturing storage technology will provide community energy storage, which becomes yet another important element for micro-grid control and allows the energy user to become an energy producer. These interrelated technologies require a

coordinated modeling, simulation, and analysis system to achieve the benefits of a smart power grid. A comparison of the current grid and the smart grid is presented in the following table.

1.2 Background

A photo voltaic system, also PV system or solar power system is a power system designed to supply usable solar power by means of photovoltaic. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution, as prices for storage devices are expected to decline.

1.3 Objectives

The aim of this research is mainly to design and develop a Smart mini grid concept and make people understand how it is beneficial. The main objectives of this research can be summarized as:

- To learn about the potential benefits of smart grid system and the integration mechanism with legacy power system how an intelligent energy management system can be implemented in micro-controller platform.
- To develop a automatic smart grid framework using micro-controller.

1.4 Project Organization

The report is organized as follows. Chapter-01 covers introduction, background Study, Smart Grid Concept and objectives. Chapter-02 represents description of the Solar Energy, Phasor Measurement Units (PMU), Smart Meters, Smart Appliances, Advanced Metering Infrastructure (AMI) & Micro-grid. Chapter-03 describes theory and working principle of the system micro-controller ATmega328P, Solar PV Module, current transformer, LCD Display, transformer, voltage regulator IC, diode, resistors and other parts. We have discussed design & fabrication. Cost estimation, Result. Future modification and conclusion are drawn in chapter-04 & 05.

CHAPTER II

Fundamentals of Smart Grid

2.1 Introduction

Energy technology plays a central role in societal economic and social development. Fossil fuel-based technologies have advanced our quality of life, but at the same time, these advancements have come at a very high price. Fossil fuel sources of energy are the primary cause of environmental pollution and degradation; they have irreversibly destroyed aspects of our environment. Global warming is a result of our fossil fuel consumption. Our relentless search for and need to control the valuable fossil fuel resources such as oil and natural gas have promoted political strife. We are now dependent on energy sources that are unsustainable as our energy needs grow and we deplete our limited resources. As oil supplies dwindle, it will become increasingly urgent to find energy alternatives that are sustainable as well as safe for the environment and humanity.

The restructuring of the electric power industry was a critical step for individual stakeholders, facilitating their wide participation in the production, delivery, utilization of energy and efficient use of electric energy. The restructuring is facilitating integration of internet technology in protection, control and real-time pricing. Furthermore, the worldwide awaking of global warming has created a market for integration of renewable and green energy sources. Now, technology is rapidly moving in a direction where every energy user can become energy producer.

The smart grid has made it possible to set up micro-grids that could be operated as stand-alone islands in critical operating conditions. Such small installations can enhance the reliability of regional electric power systems when the larger grid is faced with major contingencies. There are several practical examples of micro-grid installations which have demonstrated that the use of smart switches in distributed power grids could reduce the number and the duration of outages. In addition, the smart grid allows micro-grids to optimize the use of volatile and intermittent renewable energy resources and enhance the sustainability of regional power systems. The applications of solar photo-voltaic, which mostly follows the daily load profile for power generation, on-site or local wind energy, along with storage devices for micro-grid installations could provide an inexpensive and sustainable means of supplying micro-grid loads. The principles of a widespread utilization of energy storage can

also be found in the emerging market of plug-in electric vehicles, which would utilize wind energy at off-peak hours. Such micro-grid applications could also eliminate the need for extensive additions of high voltage lines for the transmission of renewable energy across densely populated regions of the world. However, the convolutions in the electric power industry that I believe will truly revolutionize the way we deliver electricity to individual consumers are smart grid applications related to real-time pricing, hourly demand response, and the expansion of customer choices for promoting energy efficiency. The use of new smart grid innovations would make it possible for consumers to prioritize their energy use according to their daily schedules, needs, and preferences, taking into account a variable cost of electricity to save money. Smart grid advancements would also enable automated control systems to optimize energy use at home or for businesses, identifying the most appropriate times for device operation to reduce the cost of electricity. Customer participation will offer a number of incentives for the optimization of electric power operations, including lower operation costs by eliminating the commitment of costly generating units at peak hours, mitigating mandatory system upgrades that are required for responding to a few hundred hours of annual peak loads, and reducing the chance of transmission congestion, which could otherwise operate the power system at a state close to its critical point of collapse. Demand response could also offer a less fluctuating and flatter daily profile, which would make it possible to forecast the daily load profile and schedule fuel and hydro consumption more comprehensively and efficiently for power generation." This description of a smart power grid ushers the design and development of electric energy system for centuries to come.

2.2 Solar Energy

Solar energy is a readily available renewable energy; it reaches earth in the form of electromagnetic waves (radiation). Many factors affect the amount of radiation received at a given location on earth. These factors include location, season, humidity, temperature, air mass, and the hour of day. Insolation refers to exposure to the rays of the sun, i.e., the word "insolation" has been used to denote the solar radiation energy received at a given location at a given time. The phrase incident solar radiation is also used; it expresses the average irradiance in watts per square meter (W/m^2) or kilowatt per square meter (kW/m^2). The surface of the earth is coordinated with imaginary lines of latitude and longitude.

2.3 Pharos Measurement Units (PMU)

Phasor Measurement Units give operators a time - stamped snapshot of the power system. The PMUs consist of bus voltage phasors and branch current phasors, in addition to information such as locations and other network parameters. Phasor measurements are taken with high precision from different points of the power system at the same instant, allowing an operator to visualize the exact angular difference between different locations. PMUs are equipped with GPS receivers which allow synchronization of readings taken at distant points. Microprocessor - based instrumentation such as protection relays and Disturbance Fault Recorders (DFRs) incorporate the PMU module with other existing functionalist as an extended feature. The IEEE standard on Synchro phasors specifies the protocol for communicating the PMU data to the Phasor Data Concentration.

2.4 Smart Meters

Smart meters have two functions: providing data on energy usage to customers (end - users) to help control cost and consumption; sending data to the utility for load factor control, peak - load requirements, and the development of pricing strategies based on consumption information and so on Automated data reading is an additional component of both smart meters and two - way communication between customers and utilities. The development of smart meters is planned for electricity, water, and gas consumption.

Smart meters equip utility customers with knowledge about how much they pay per kilowatt hour and how and when they use energy. This will result in better pricing information and more accurate bills in addition to ensuring faster outage detection and restoration by the utility. Additional features will allow for demand - response rates, tax credits, tariff options, and participation in voluntary rewards programs for reduced consumption. Still other features will include remote connect/disconnect of users, appliance control and monitoring, smart thermostat, enhanced grid monitoring, switching, and prepaid metering.

2.5 Smart Appliances

Smart appliances cycle up and down in response to signals sent by the utility. The appliances enable customers to participate in voluntary demand response programs which award credits for limiting power use in peak demand periods or when the grid is under stress. An override function allows customers to control their appliances using the Internet. Air conditioners, space heaters, water heaters, refrigerators, washers, and dryers represent about 20% of total

electric demand during most of the day and throughout the year. Grid - friendly appliances use a simple computer chip that can sense disturbances in the grid's power frequency and can turn an appliance off for a few minutes to allow the grid to stabilize during a crisis.

2.6 Advanced Metering Infrastructure (AMI)

AMI is the convergence of the grid, the communication infrastructure, and the supporting information infrastructure [6]. The network- eccentric AMI coupled with the lack of a composite set of cross industry AMI security requirements and implementation guidance, is the primary motivation for its development. The problem domains to be addressed within AMI implementations are relatively new to the utility industry; however, precedence exists for implementing large - scale, network - concentric solutions with high information assurance requirements. The defense, cable, and telecom industries offer many examples of requirements, standards, and best practices that are directly applicable to AMI implementations.

2.7 Micro-grid of Renewable and Green (MRG) Power Grids

A micro-grid of renewable and green (MRG) energy system. The MRG systems consists of PV, wind power of renewable energy sources and green energy sources such as fuel cells and high speed micro turbine generating stations. The micro-grid of MRG are designed to supply power to local grid or import power on prior contract agreements. The combined heat and power (CHP) and micro turbine generating stations and some induction generator based wind generating are directly connected to AC bus of MRG systems. However, PV, variable speed wind, and fuel cell generating stations produced DC power. The PV power can be directly connected to DC-AC inverters to AC bus of MRG systems. Alternative design is based on using a DC-DC boost converter to step up the DC voltage and use higher rating DC-AC inverters. When MRG systems are synchronized to AC bus of the local power grids, the AC bus voltage and frequency are controlled by the local power grid's energy management. However, upon separation of MRG systems from the local power grid, the energy management of MRG must control the MRG AC bus voltage and frequency for stable operation. The load control is essential in proper balance of MRG's loads and generation when the MRG is separated from the local power grid. The MRG power grid system is shown in below figure 2.1.

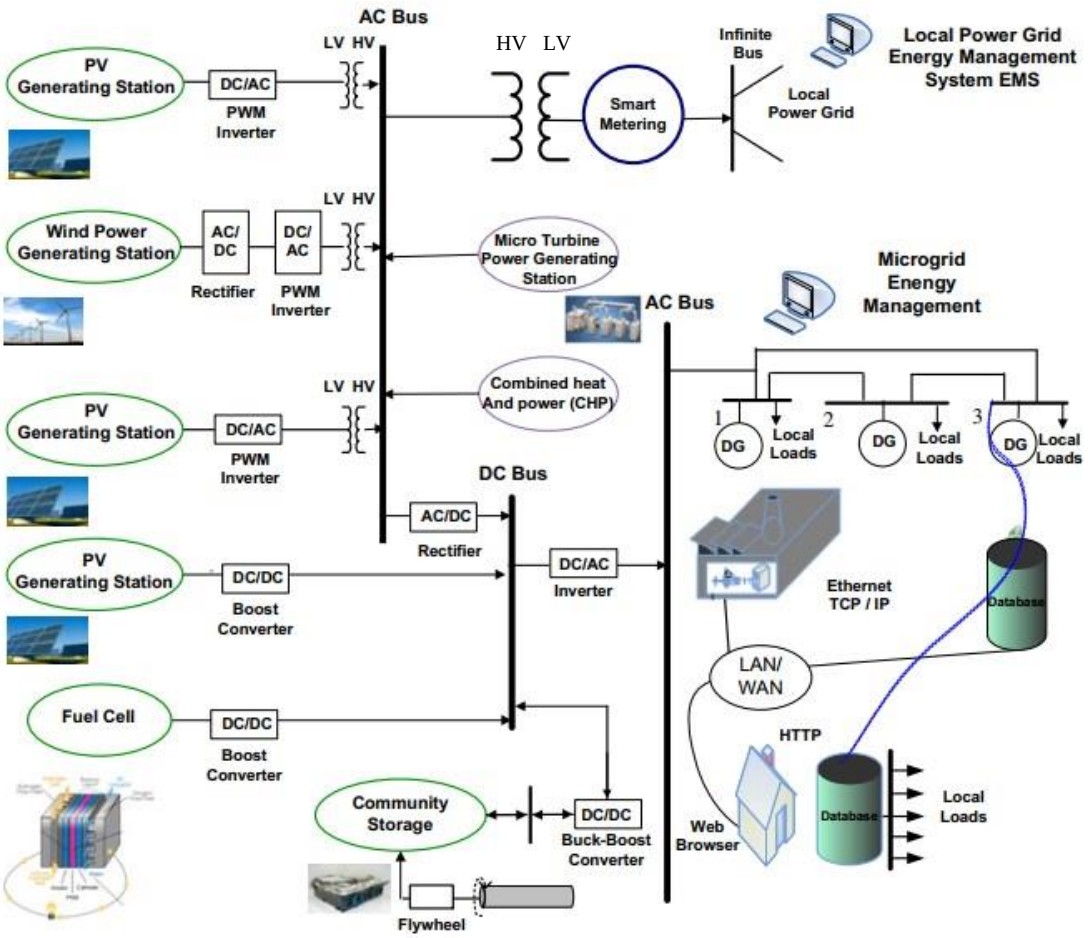


Fig: 2.1 A Micro-grid Renewable and Green (MRG) Power Grid [1]

To ensure security and reliability, power plant facilities and resources must first be planned then managed effectively. A large power grid is comprised of many elements including generating units, transmission lines, transformers, and circuit breakers. As new green energy sources are adopted into the power grid and a smart power grid is put in place, additional equipment such as DC/DC converters and DC/ AC converters must be integrated and scheduled for power grid operation. In addition, market structure and real-time pricing of energy need to be evaluated.

In a classical power grid, a fixed price is charged to energy users. However, the cost of energy is highest during the daily peak load operation. The classical power system operation has no control over the loads except in an emergency situation when a portion of the loads can be dropped as needed to balance the power grid generation with its loads. Therefore, most elements of grid are used for a short time during the peak power demand and they remain idle during the daily operation.

For an efficient smart power grid system design and operation, substantial infrastructure investment in the form of a communication system, cyber network, sensors, and smart meters must be installed to curtail the system peak loads when the cost of electric energy is highest. The smart power grid introduces a sensing, monitoring, and control system that provides end users with the cost of energy at any moment through real time pricing. In addition, the advanced control systems of smart metering provide the energy users with the ability to respond to real-time pricing.

Furthermore, the smart power grid supplies the platform for the use of renewable and green energy sources and adequate emergency power for major metropolitan load centers. It safeguards against a complete blackout of the interconnected power grids due to man-made events or environmental calamity. It also allows for the break-up of the interconnected power grid into smaller, regional clusters. In addition, the smart power grid enables every energy user to become an energy producer by giving the user the choice of PV or wind energy, fuel cells, and combined heat and power (CHP) energy sources and to participate in the energy market by buying or selling energy through the smart meter connection.

The implementation of an advanced metering infrastructure provides real-time pricing to the energy end users. In parallel, the penetration of renewable energy sources is providing a platform for autonomous control or local control of connected micro-grid to the local power grid. A distributed autonomous control will provide reliability through fault detection, isolation, and restoration. The autonomous control and real-time pricing also delivers efficiency in feeder voltage to minimize feeder losses and to reduce feeder peak demand of plug-in electric vehicles. The maturing storage technology will provide community energy storage, which becomes yet another important element for micro-grid control and allows the energy user to become an energy producer. These interrelated technologies require a coordinated modeling, simulation, and analysis system to achieve the benefits of a smart power grid.

When a smart micro-grid DG is connected to a power grid, then the smart micro-grid generating station should operate, using a master and slave control technology [7]. The master is the EMS of the power grid system. The EMS controls the infinite bus voltage located at the connection node of one micro-grid to its local power grid. The smart grid is connected to the power grid system by a transformer. The slave controller controls the AC bus voltage of the micro-grid inverter (bus voltage magnitude and phase angle) and the inverter current. Therefore, the slave controller of the micro-grid inverter also controls active and reactive power. The micro-grid inverter is designed to operate as a unity power factor and to leave the

voltage control, that is, the reactive power (VAR) control, to the EMS of the power grid system. Or, the inverter of micro-grid operates with a leading power factor, a lagging power factor. If the smart grid is suddenly separated from its local power grid and system stability is maintained, then the slave controller takes over LFC and voltage control.

The word “smart” refers to the requirement that a micro-grid controls its loads, and that it accepts the “price signal” and/or the “emergency operation signal” from its local power grid to adjust its active and reactive power generation. Other designs are also possible such as a net smart metering communication between the EMS of the local power grid and the EMS of the micro-grid system. The smart micro-grids should have hardware in place to shed loads, in response to the price signal, or they should have hardware to rotate nonessential loads and to supply power to critical loads. However, because disturbances in a power grid system cannot be predicted, the DG micro-grid system should be designed to rapidly disconnect from its power grid system to maintain the stability of the micro-grid systems. To ensure stable operation, the storage system of the micro-grid, with its inverter, has to be able to participate in the ancillary market. The architecture of Fig. 2.1 is of interest to distributed generation technology because it facilitates plug and play capabilities. In this architecture, green energy sources, such as fuel cells, micro-turbines, or renewable sources, such as PV-generating stations and wind farms, can be connected to a DC bus, using uniform interchangeable converters. This architecture allows for the selling of and buying of energy to and from local utilities. Note that the micro-grid can offer real-time pricing or a tariff-based contract by facilitating load control through a caber-controlled smart meter or net metering, if a customer has local generation at the customer site to control loads.

2.8 Research Issues

The integration of photo voltaic (PV) and battery storage-generating stations will have a trans-formative impact on the development of smart power grids by rapidly increasing the penetration of PV-generating stations. Power engineers need a high fidelity model for PV and storage-generating stations to study power-grid planning, evaluation of future scenarios, and answers to “if/then conditions” for grid designs. A number of studies conducted by Sandia National Labs have shown that when the penetration of PV or wind generation exceeds 30% of the distribution grid, the grid may become unstable under certain conditions.

Key questions to be answered by simulations are as follows: Does the grid meet performance standards? How does the addition of a new, PV-based storage system affect grid reliability and stability? To seek answers to these questions, high fidelity models of PV and storage

stations are needed for grid power flow static voltage stability and control, dynamic rotor angle stability and voltage recovery and short circuit breaker duty, protection design and coordination, control interaction, and harmonics, etc. Figure 1.13 depicts the architecture of the micro-grid of PV and battery storage-generating stations in the power grids. Other architectures may be considered depending on the intended applications. The model of the micro-grid as seen from the local power grids is needed for the planning, design, and operation of smart power grids. A modeling and estimation methodology must be developed from both theoretical and experimental viewpoints to develop an equivalent generating station that represents the micro-grids.

There are a number of research problems that must be studied to facilitate the penetration of PV and battery storage-generation systems into smart power grids. These problems include the following: a) development of MPPT control of PV source. b) PV models based on manufacturers' data that are non-confidential and can be used by smart grid stakeholders for micro-grid studies; c) battery storage models based on charging and discharging test data that are non-confidential; d) PV and battery storage-generating station models that are validated and non-confidential that can be used by utilities for bulk power flow and short circuit studies ; and e) PV and battery generator equivalent dynamic models for bulk power system stability studies.

CHAPTER III
Theory of Required Elements

3.1 Introduction

Bangladesh is a subtropical country, 70% of year sunlight is dropped in Bangladesh. For this reason, we can use solar panel & piezoelectric Sensor to produce electricity largely. The main Controlling Unit Micro-Controlling Unit. We use ATMEGA328 micro-controller to control it. The other unit is Rectification unit where use Bridge Rectifier, Capacitor, etc. We also use 12v & 5v relay. For inverting DC to AC we use to inverter with Transformer (Step-Up), MOSFET, etc. To storage charge used to 12v Battery and to measure electric energy used single phase Energy meter.

Therefore we have got a huge opportunity to harness solar PV power and piezoelectric sensor to mitigate the shortage of our energy crisis. One of the best solution could be the On Smart Grid System. Therefore our project aim is to develop an intelligent energy management system by which we can utilize the piezoelectric sensor and solar PV generation with the utility grid as well as to charge the storage battery if required.

3.2 Theory

Our project aim is to develop a smart mini grid concept. The basic concept is to provide solar PV power to the user when crossing maximum load capacity of utility. The total project can be classified into main two sections. One is hardware part and second one is software part. The hardware part consists of Micro-Controller IC, CT, solar panel, LCD display, transformer, resistor, diode, wire, etc; and the software part consists of program codding software Micro C, design software eagle CAD etc. the following section will discuss the hardware components in details.

3.3 Micro-controller

The ATMEGA328 is a single-chip micro-controller created by At meal in the mega AVR family.

3.4 ATMEGA328

The ATmega328P provides the following features: 32 Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbyte EEPROM, 2 Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three

flexible Timer/Counter with compare channel 10 bit ADC (8 channels in TQFP and QFN/MLF packages), a Programmable Watchdog Timer with internal Oscillator, an SPI serial port and six software select-able power saving mode. The idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port and interrupt system to continue functioning. The power-down mode saves the register contents but freezes the oscillator disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run while the rest of the device is sleeping.

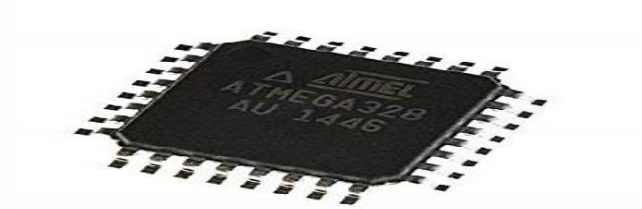


Fig: 3.1 ATMEGA328 Micro-Controller [5]

3.5 Internal Structure of a Micro-Controller (At-Mega 328p)

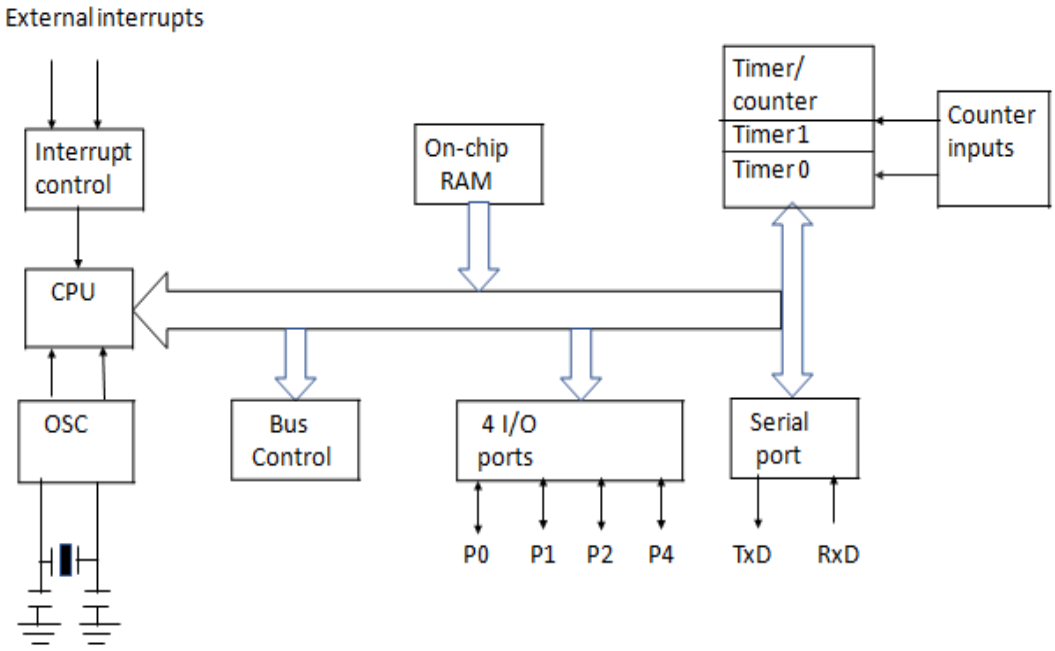


Fig: 3.2 Internal Structure of a Micro-controller [5]

3.6 Pin Descriptions

V_{cc}: Digital supply voltage.

GND: Ground.

i. Port B (PB[7:0]) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running. Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit. Atmel ATmega328/P [DATASHEET] Atmel-42735B-ATmega328/P_ Data sheet_Complete-11/2016 17

ii. Port C (PC[5:0])

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC [5:0] output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

iii. PC6/RESET

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C. If the RSTDISBL Fuse is programmed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a Reset.

iv. Port D (PD[7:0])

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

v. AVcc

AVcc is the supply voltage pin for the A/D Converter, PC [3:0], and PE [3:2]. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter. Note that PC [6:4] use digital supply voltage, VCC.

vi. AREF

AREF is the analog reference pin for the A/D Converter.

vii. ADC[7:6] (TQFP and VFQFN Package Only)

viii. In the TQFP and VFQFN package, ADC [7:6] serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channel

3.7 AVR CPU core of ATMEGA 328 Micro-controller

This section discusses the AVR core architecture in general. The main function of the CPU core is to ensure correct program execution. The CPU must therefore be able to access memories, perform calculations, control peripherals and handle interrupts. In order to maximize performance and parallelism, the AVR uses Harvard architecture- with separate memories and buses for program and data. Instructions in the program memory are executed with a single level pipelining. While one instruction is being executed, the next instruction is per-fetched from the program memory.

3.8 AVR ATMEGA328 Memories

This section describes the different memory types in the device. The AVR architecture has two main memory spaces, the Data Memory and the Program Memory space. In addition, the device features an EEPROM Memory for data storage. All memory spaces are linear and regular.

The ATmega328P contains 32 Kbytes On-chip In-System Re-programmable Flash memories for program storage. Since all AVR instructions are 16 or 32 bits wide, the Flash is organized as 16K X 16. For software security, the Flash Program memory space is divided into two sections – Boot Loader Section and Application Program Section in the device.

3.9 I/O memory of ATMEGA328 Micro-controller

The I/O space definition of the device is shown in the register summary. All device I/Os and peripherals are placed in the I/O space. All I/O locations may be accessed by the LD/LDS/LDD and ST/STS/STD instructions, transferring data between the 32-general purpose working registers and the I/O space. I/O registers within the address range 0X00-0X1F are directly bit-accessible using the SBI and CBI instructions. In these registers, the value of single bits can be checked by using the SBIS and SBIC instructions. When using the I/O specific commands IN and OUT, the I/O address 0X00-0X3F must be used. When addressing I/O registers and data space using LD and ST instructions, 0X20 must be added to these addresses. The device is a complex micro-

controller with more peripheral units than can be supported within the 64-location reserved in Opcode for the IN and OUT instructions.

3.10 Piezoelectric Sensor

A piezoelectric sensor is a device that uses the piezoelectric effect, to measure changes in Pressure, Acceleration, Temperature, Strain, or Force by converting them to an Electrical Charge.

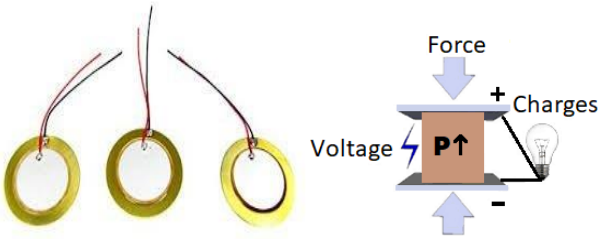


Fig: 3.3 Symbol of Piezoelectric Sensor [5]

Circuit Diagram of Piezoelectric Sensor

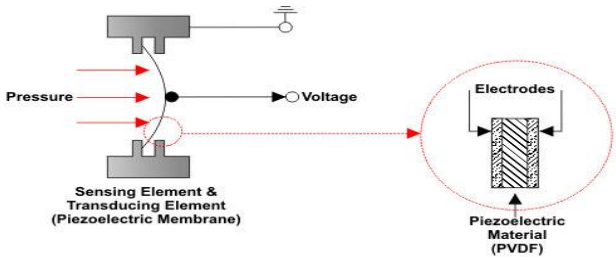


Fig: 3.4 Circuit Diagram of Piezoelectric Sensor[5]

Frequency Response

Frequency Response Curve between Pressure And Frequency

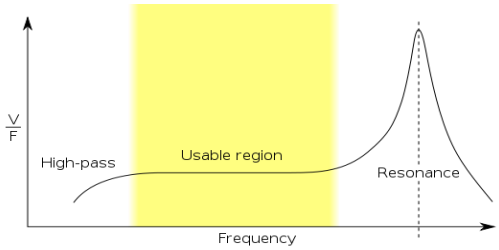


Fig: 3.5 Frequency Response Curve

Principle of Operation

The way a piezoelectric material is cut produces three main operational modes:

- Transverse
- Longitudinal
- Shear.

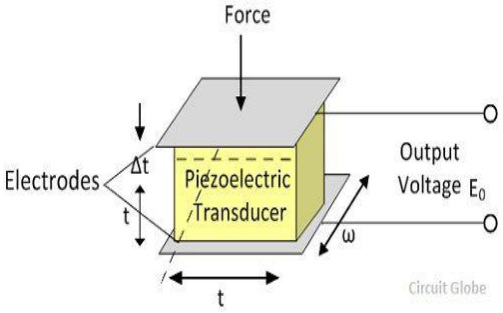


Fig: 3.6 Operational Figure

Transverse effect

A force applied along a neutral axis (***y)*** displaces charges along the (***x***) direction, perpendicular to the line of force. The amount of charge (***Cx)*** depends on the geometrical dimensions of the respective piezoelectric element. When dimensions(***a b d***) apply,.

$$C_x = d_{xy} F_y b / a$$

Where,(***a)***is the dimension in line with the neutral axis,(***b***)is in line with the charge generating axis and(***d)***is the corresponding piezoelectric coefficient.

Longitudinal effect

The amount of charge displaced is strictly proportional to the applied force and independent of the piezoelectric element size and shape. Putting several elements mechanically in series and electrically in parallel is the only way to increase the charge output. The resulting charge is

$$C_x = d_{xx} F_x n$$

Where,(***dxx)*** is the piezoelectric coefficient for a charge in x-direction released by forces applied along x-direction and (***Fxx***) is the applied Force in x-direction and (***n)*** corresponds to the number of stacked elements.

Shear effect

The charges produced are strictly proportional to the applied forces and independent of the element size and shape. For (***n***) elements mechanically in series and electrically in parallel the charge is

$$C_x = 2 d_{xx} F_x n$$

In contrast to the longitudinal and shear effects, the transverse effect make it possible to fine-tune sensitivity on the applied force and element dimension.

3.11 Energy Meter (Single Phase)

Electric utilities use electric meters installed at customers' premises to measure electric energy delivered to their customers for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. They are usually read once each billing period.



Fig: 3.7 Energy Meter (1_{φ})

Stepper Motor Counter display are advanced type of counter which accurately records each electrical impulse, on a cumulative basis, they are used as display device in Electronic Energy Meters.

3.12 Solar PV Module

Photo voltaic is the direct conversion of light into electricity at the atomic level [4]. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity.

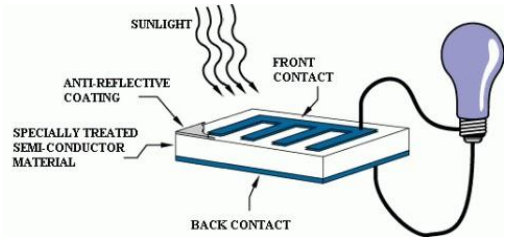


Fig: 3.8 Solar PV working procedure [2]

The diagram above illustrates the operation of a basic photo voltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other [2].

A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photo voltaic module. Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module.



Fig: 3.9 10W Solar Panel [3]

Specification of our used solar PV module

Electrical Characteristics	
Maximum Power at STC - Pm	5 W
Open Circuit Voltage - Voc	21.03 V
Short Circuit Current - Isc	0.59A
Max Operating Voltage - Vmp	17.82 V
Max Operating Current - Imp	0.56 A
Mechanical Characteristics	
Cell	Poly crystalline silicon
No of cells	36
Connections	4 x 9
Connections	4 x 9
Dimensions	355 x 255 x 17 mm
Weight	1.1. kg

Table 3.1: Specification of solar PV module

3.13 MOSFET P55NF

STP55NF06 N-channel 60V, 50A, Power MOSFET in to-220 package.

These Power MOSFETs have been developed using unique Strip FET process, which is specifically designed to minimize input capacitance and gate charge. This renders the devices suitable for use as primary switch in advanced high-efficiency isolated DC-DC converters for

Telecom and computer applications, and applications with low gate charge driving requirements.

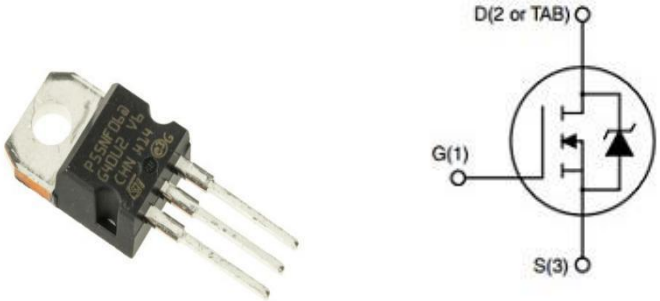


Fig:3.10 P55NF MOSFET internal Diagram

3.14 Current Sensor

A current sensor is a device that detects electric current in a wire, and generates a signal proportional to it. The generated signal could be analog voltage or current or even digital output.



Fig: 3.11 Current Transformer

3.15 12V Lead Acid Sealed Battery (VRLA)

This is a general purpose battery up to 5 years in standby service or more than 260 cycles at 100% discharge in cycle service. As with all CSB batteries, all are rechargeable, highly efficient, leak proof and maintenance free.



Fig: 3.12 12V Storage Battery

3.16 LCD Display (20x4)

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

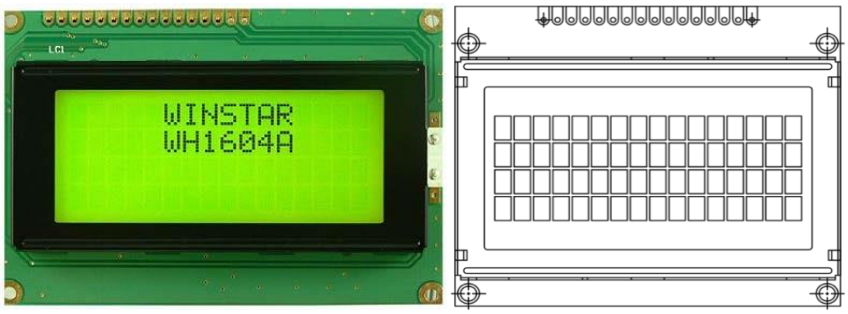


Fig: 3.13 20x4 LCD Display

3.17 220V/ 12V Transformer with Rectifier

The bridge rectifier circuit diagram consists of various stages of devices like transformer, Diode Bridge, filtering and regulators. The first stage of the circuit is a transformer which is a step down type that changes the amplitude of the input voltage. Most of the electronic projects uses 230/12V transformer to step-down the AC mains 230V to 12V AC supply. Next

stage is a diode-bridge rectifier which uses four or more diodes depending on the type of bridge rectifier. It is responsible for producing unidirectional or DC current at the load by conducting a set of diodes for every half cycle of the input signal.

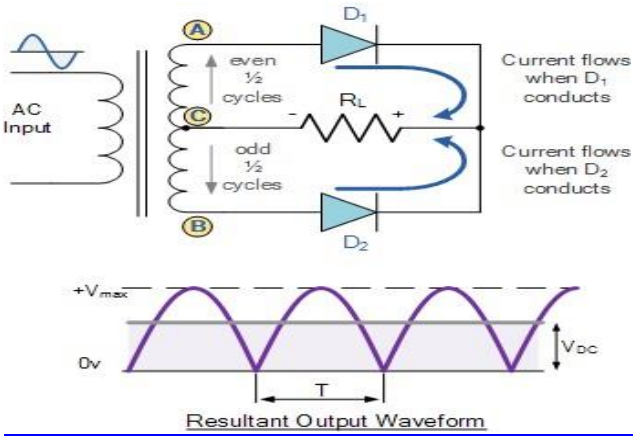


Fig: 3.14 Output Wave forms of 220V/12V rectifier[11]

3.18 LM7805 (Voltage Regulator IC)

7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805 provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

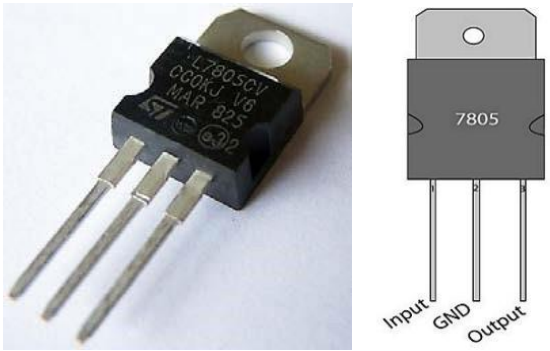


Fig: 3.15 7805 (Voltage Regulator IC)

3.19 Transistor (BC547)

BC547 is an NPN bi-polar junction transistor. A transistor, stands for transfer of resistance, is commonly used to amplify current. A small current at its base controls a larger current at

collector & emitter terminals. BC547 is mainly used for amplification and switching purposes.

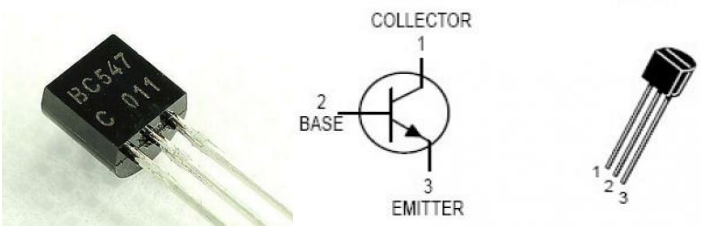


Figure:3.16 BC547

3.20 Relay

A relay is usually an elector-mechanical device that is actuated by an electrical current. The current flowing in one circuit causes the opening or closing of another circuit. Relays are like remote control switches and are used in many applications because of their relative simplicity, long life, and proven high reliability. Relays are used in a wide variety of applications throughout industry, such as in telephone exchanges, digital computers and automation systems. Highly sophisticated relays are utilized to protect electric power systems against trouble and power blackouts as well as to regulate and control the generation and distribution of power.

•Contact Arrangement/Poles

The arrangement of contacts on a relay includes a form factor and a number of poles. Each form factor is explained below.

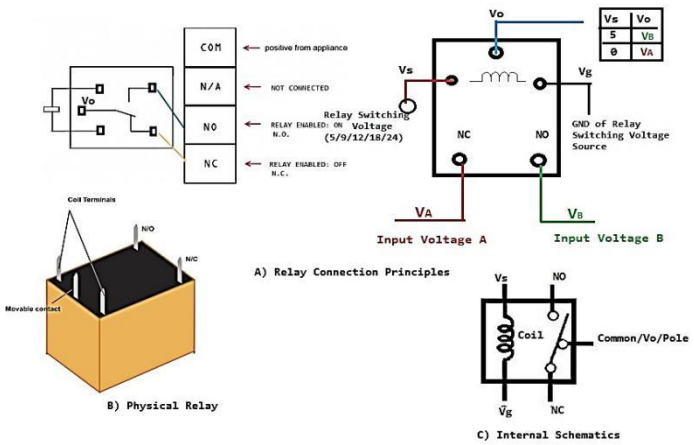
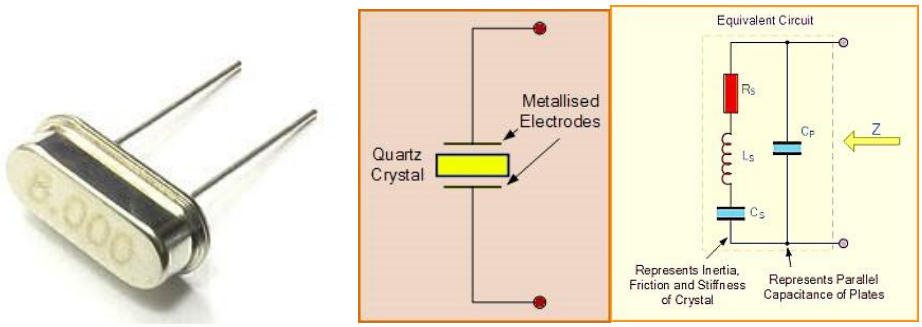


Fig: 3.17 Relay operation [8]

3.21 Crystal Oscillator

An electronic circuit or electronic device that is used to generate periodically oscillating electronic signal is called as an electronic oscillator. The electronic signal produced by an

oscillator is typically a sine wave or square wave. An electronic oscillator converts the direct current signal into an alternating current signal.



Electronic Symbol *Equivalent Circuit Diagram*

Fig: 3.18 Crystal Oscillator

3.22 Diode (IN 4007)

In electronics, a diode is a two-terminal electronic component with asymmetric conductance, it has low (ideally zero) resistance to current flow in one direction, and high (ideally infinite) resistance in the other. A vacuum tube diode has two electrodes, a plate (anode) and a heated.



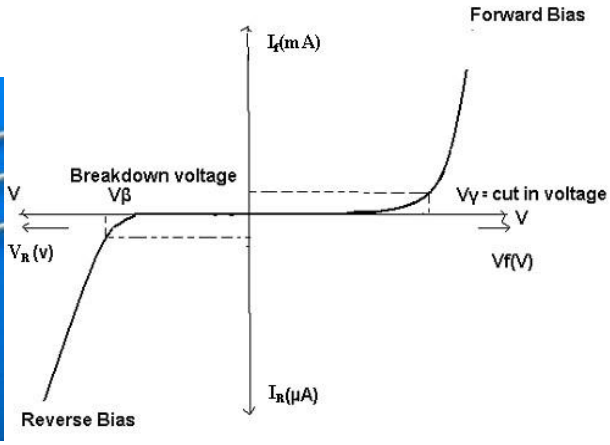


Fig: 3.19 Diode (IN 4007) Fig: 3.20 Diode Characteristics Curve

3.23 Variable Resistor/Potentiometer



Fig: 3.21 Variable Resistor/Potentiometer

A potentiometer /variable resistor is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

The measuring instrument called a potentiometer is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name.

3.24 Vero Board

Strip Board is a widely used type of electronics prototyping board characterized by a 0.1 inch (2.54 mm) regular (rectangular) grid of holes, with wide parallel strips of copper cladding running in one direction all the way across one side of the board.That is the Figure shown up in Fig.3.27.1 . It is commonly known by the name Vero Board. With care, it is possible to break between holes to allow for components that have two pin rows only one position apart such as twin row headers.

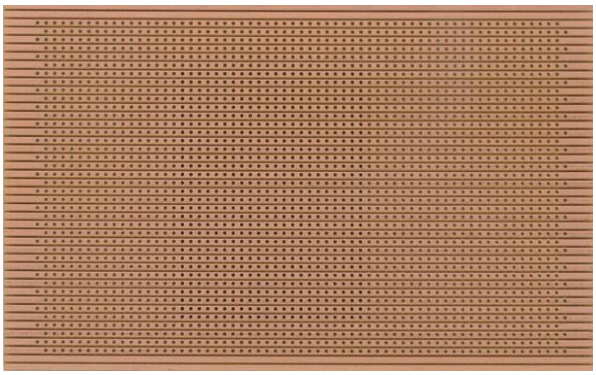


Fig. 3.22 Vero Board

3.25 Buzzer 5V DC

The word "buzzer" comes from the rasping noise that buzzers made when they were electromechanical devices, operated from stepped-down AC line voltage at 50 or 60 cycles. That is the Figure shown up in Fig.3.28.1 .

Other sounds commonly used to indicate that a button has been pressed are a ring or a beep.



Buzzer Symbol Fig: 3.23 Buzzer 5V DC

3.26 LED

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.



Fig: 3.24 Indicator LED

3.27 Discussion

In this chapter we have briefly described the description of micro-controller IC PIC 18F452, Energy meter, Solar PV panel, Current transformer, MOSFET P55nf, 12V, 7.2Ah VRLA Battery, LCD display, transformer (220/12V), voltage regulator IC 7805, diode (IN4007), resistors and other parts. And especially we have discussed widely the main component of this project Micro-controller IC and MOSFET P55NF and others.

Chapter IV

Simulation & Result

4.1 Introduction

In this chapter fully cover with discuss design and fabrication of this project. Here we will discuss about developed block diagram and briefly describe about the circuit description and also learn about working principle. Total project flow chart is also available in this chapter.

4.2 Pin Diagram

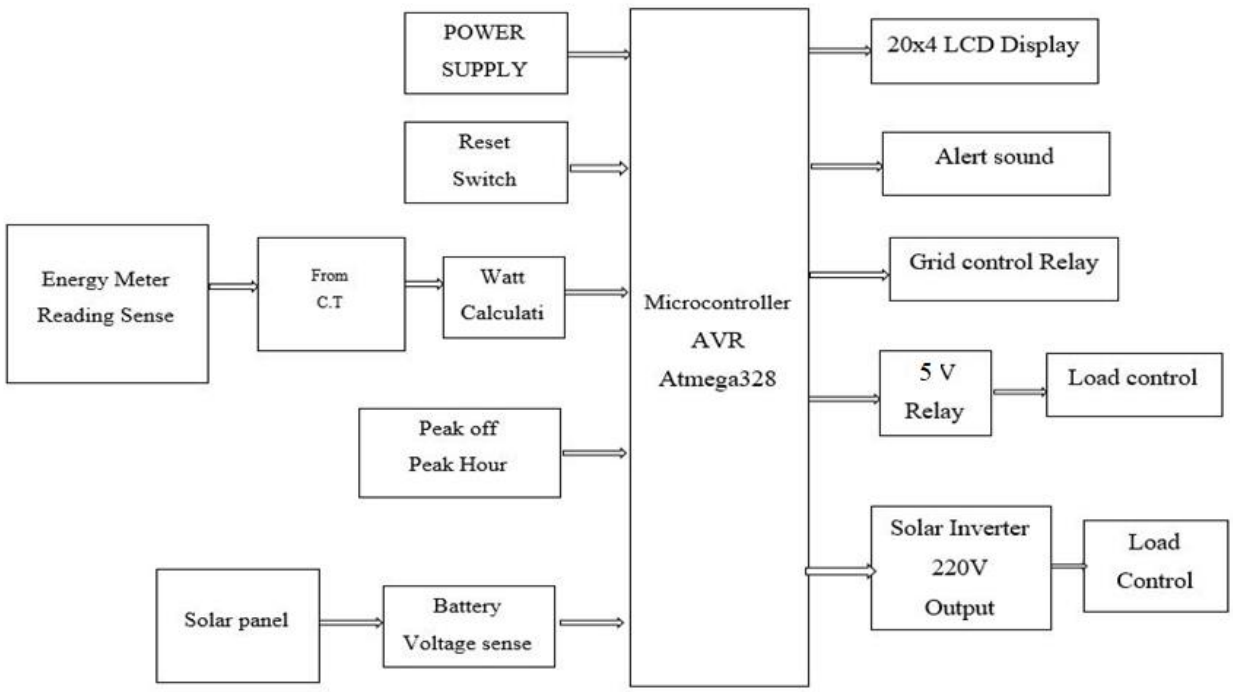


Fig: 4.1 Pin Diagram of the project

4.3 Circuit Diagram & Description

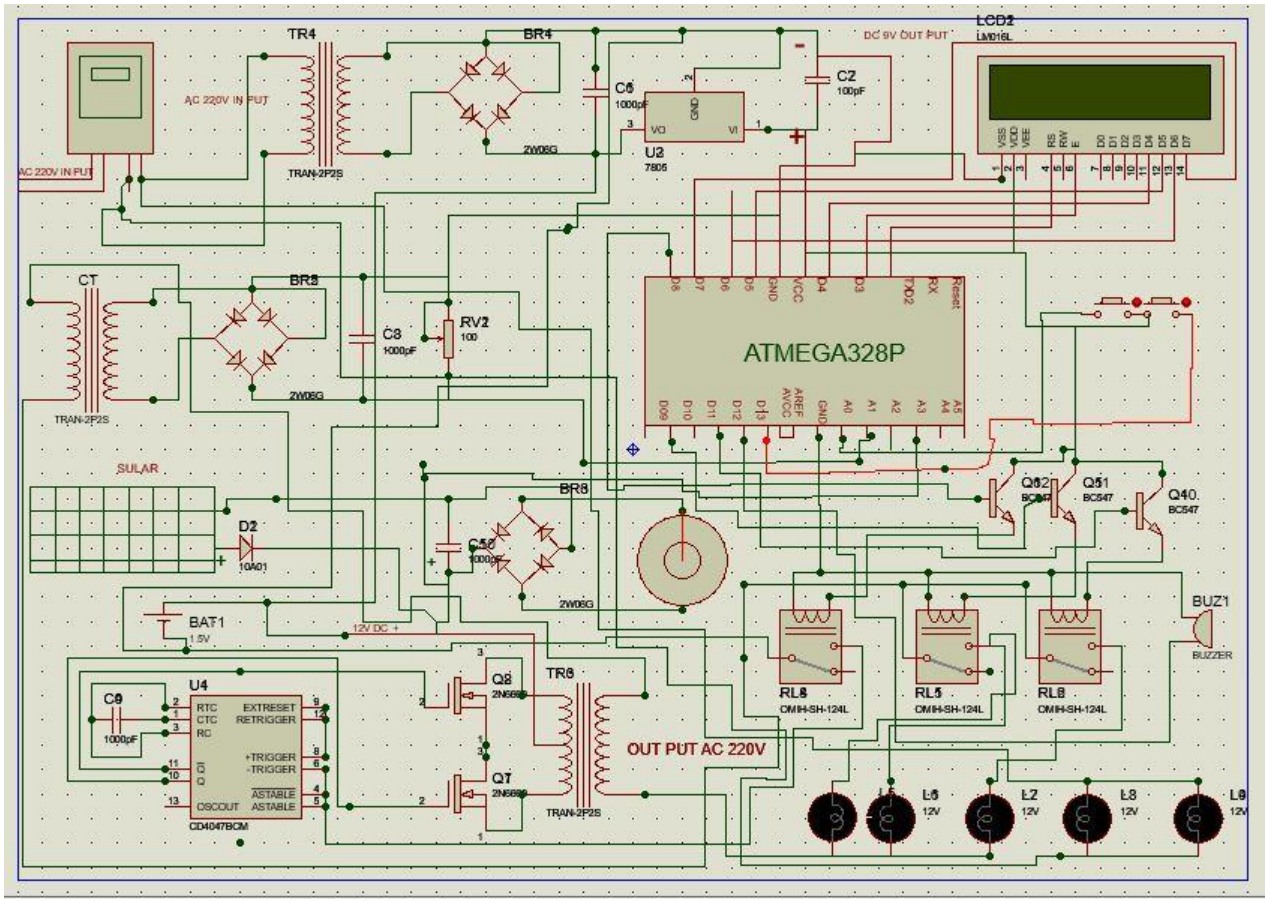


Fig: 4.2 Circuit Diagram of the Project

The above figure 3.3.1 shows the circuit diagram of this project. The main component is ATmega328P, which is a 40DIP micro-controller IC having 35 I/Os. This system works intelligently by detecting few conditions. Peak and off peak hour is our main priority setting. We fix a button to change the condition of peak hour and off peak hour with the pin no 30 of micro-controller. With this system we will be able to know how much power is consumed as well as the instant operating load. We put a single phase energy meter and getting pulse that is connected micro-controller pin no 15. We designed this system to operate 200 watt max load capacity. To generate solar PV dc power into 220 V 50Hz AC, we designed an inverter with P55 MOSFET switching oscillated from micro-controller pin no27 and 28. One 12V battery is placed to storage solar PV generation and its charging and discharging rate is regulated from the micro-Controller pin no 3 as per we designed. The other supplementary components like LCD display is connected with pin no 33 to 38.

4.4 Working Principle

This total system works following some criteria or conditions we applied. It can be divided in to two main functions. One is load side and another one is source of power. Since this is a dual source power controlling system, and utility grid will be the first priority and the maximum operating load we set is 15Watt. There is a battery storage we placed for storing up the dc power and discharge it when needed. In case of peak hour, when user's consumption exceed 15W load, the system will generate a beep to reduce the load for few seconds and will automatically disconnect from the utility. In case of off peak hour when consumer consumes over 15W our system will notify the user that the load is over maximum load and at the same time it will synchronize the solar PV power (after inverting dc to 220V AC) with the utility to power up the whole thing. This smart system also calculate the unit of energy consumed (KWH) along with the monthly bill amount. We have also incorporate protection in battery charging and discharging system i.e. when battery voltage remains under 12V the system will never allow the solar PV generation to supply the load. This is how our system works.

4.5 Prototype of the Project:

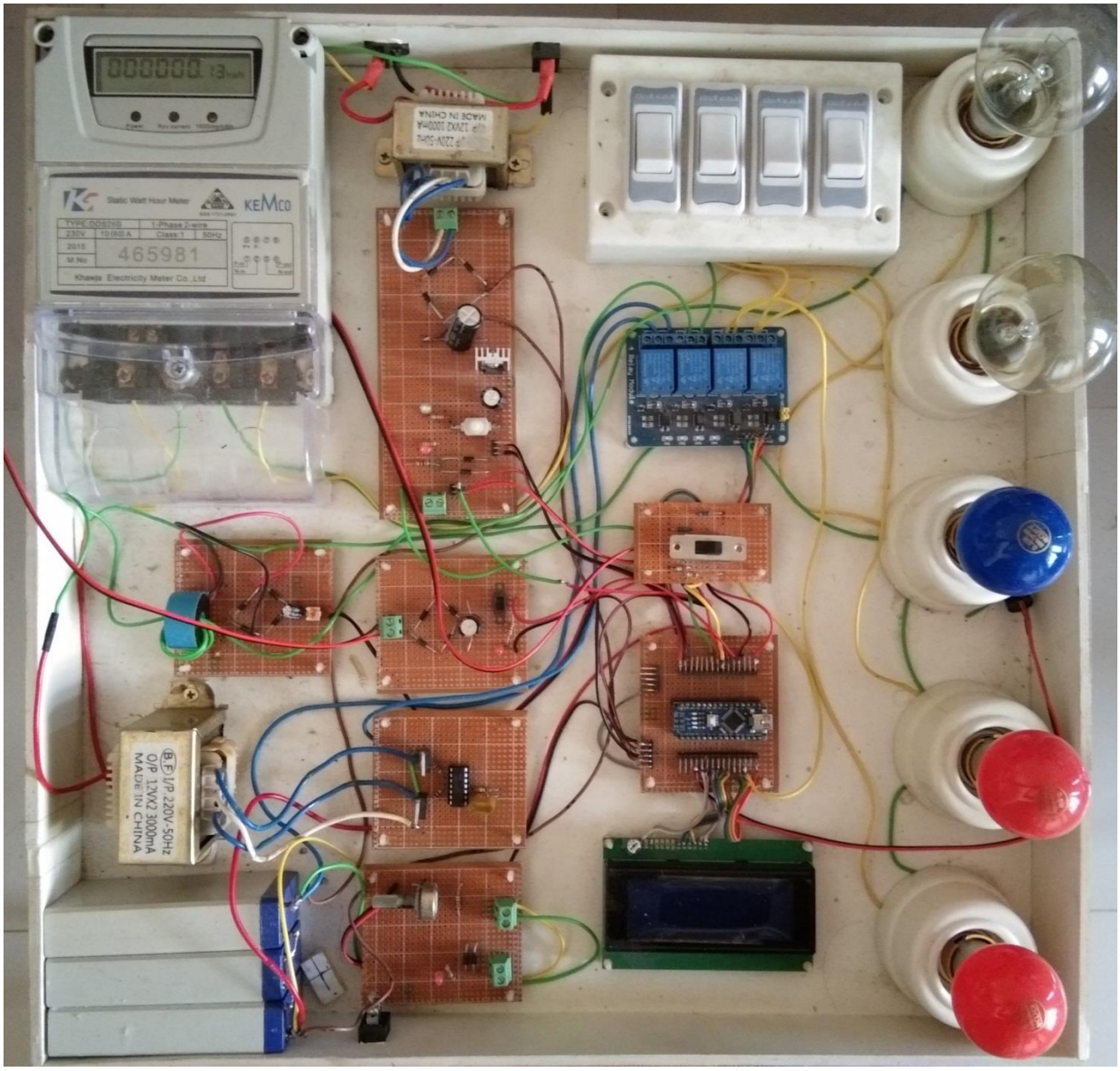


Fig: 4.3 Prototype of the project

4.6 Flow Chart

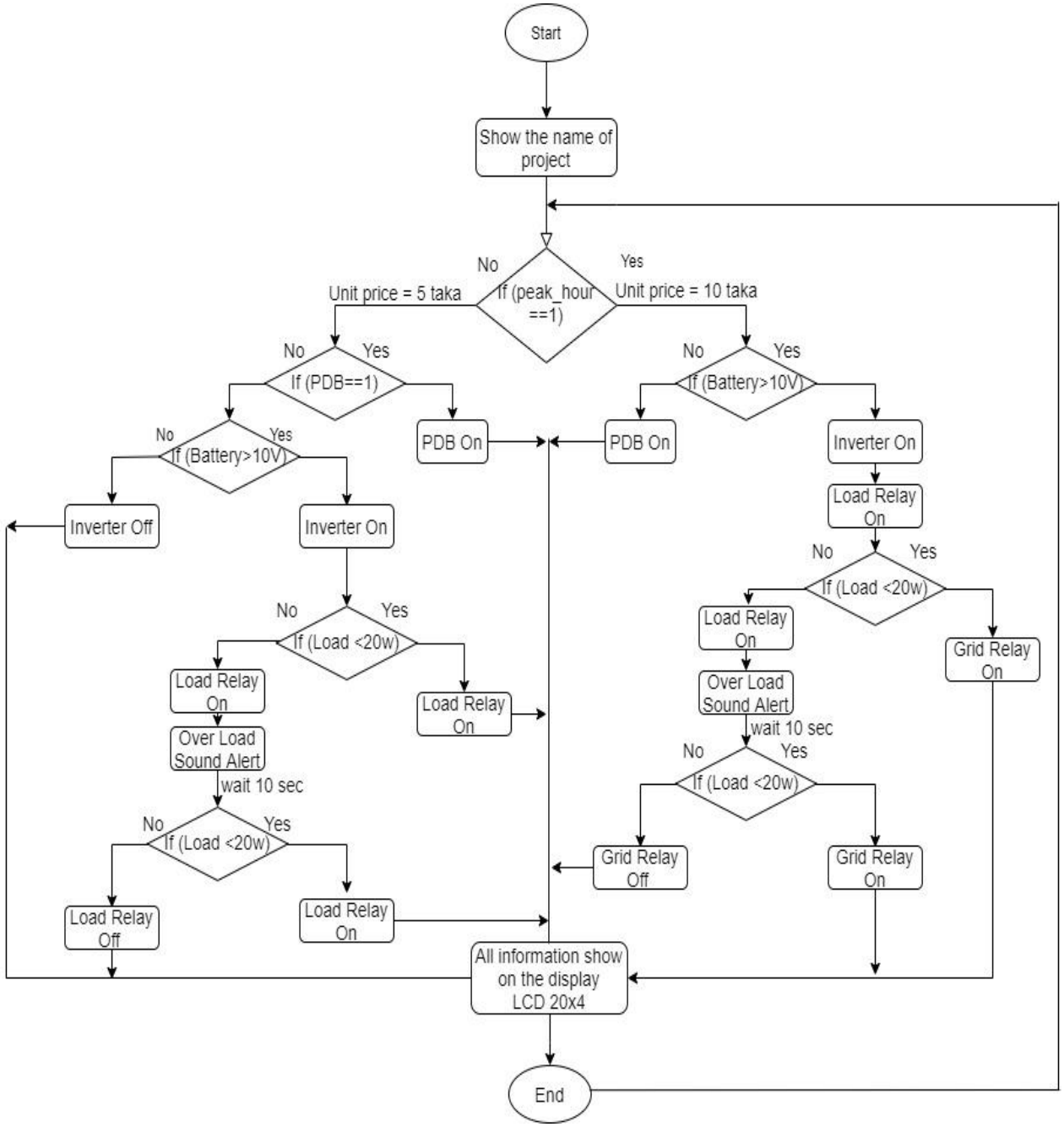


Fig: 4.4 Flow Chart of the Project

4.7 Result

Our aim was to develop an intelligent and smart energy management system that can be functional in different conditions in different ways. Here is two load conditions, peak hour and off peak hour, thus the unit price is different though. The charging system from solar panel is and discharging while operating load also controlled from micro-Controller, when the battery voltage remains under 10 volt it will not invert to AC, thus does not connect to the grid as well. When battery voltage remains over 10 volt it will then connect with the grid in condition only. Besides this system controls the maximum operating load as per expected. So the challenge was to comply all the conditions works under one controlling unit.

4.8 Advantages

- Both on Grid and battery back-up system makes is suitable for peak hour and power Off condition
- Synchronization is done by zero crossing detection makes it safe and smooth start.
- Since this is an intelligent system we can control and maintain the amount of bill per month for ourselves.
- Can use off grid areas as well.

4.9 Limitation

- Protection system did not considered

.

4.10 Cost Estimation

No	Particulars	Specification	Qty.	Unit Price	Total Price
1	Micro-Controller IC	Arduino Nano	1	300	300
2	Energy Meter	1_{φ} digital	1	2000	2000
3	MOSFET	P55NF	2	25	50
4	CT		1	100	100
5	Optocoupler	4N35	1	40	40
6	Solar PV module	5Wp	1	1000	1000
7	Crystal	8MHz	1.	10	10
8	IC Base	40pin	1	10	10
9	LCD Monitor	16x2 Backlit	1	50	50
10	Transformer	220/12V, 2amps	2	350	700
11	Voltage Regulator	LM 7805	2	10	20
12	Diode	IN4007	6	5	30
13	Capacitor	100uF,25V	1	10	10
14	Vero Board	As per design	1	30	30
15	Resistor	Various	20	1	20
16	Soldering cost				30
17	piezoelectric sensor		9	55	495
				Total	**4895.00**

Table: 4.1 Cost Estimation

4.11 Applications

- Smart load management system
- Solar PV Smart mini grid system
- Grid-Solar PV Hybrid system

4.12 Discussion

This project aim was to develop an intelligent energy management system with the facility of synchronizing utility grid to solar PV generation, we have successfully develop the main concept of synchronization procedure as well as to make this inverter usable to charge the battery. Several corrections and trial and error process have been done to make this one functional. We have just shown the process of synchronizing and switching mechanism in this paper.

CHAPTER V

Future Works & Discussions

5.1 Future Works

This is only a prototype of Smart Grid System. Some major development should have to done for commercial use. They are as follows:

(a) Prepaid energy metering concept should be incorporated.
(b) Inversion efficiency should be above or equal to 95%.
(c) Our utility got glitches; so the device should have the capacity of synchronizing within a range of voltage and frequency change.
(d) MPPT facility should be incorporated for better generation
(e) Remote monitoring and data logging system can also be incorporated.

5.2 Discussion

Recent environmental consciousness resulting from conventional power station has encouraged attention on the development of modern smart grid technology and its integration with climate friendly green renewable energy. The use of smart grid operations allows for greater penetration of variable energy sources through more flexible management of the system. Experiments were carried out to investigate the impacts of RE sources in a smart power network, in particular large-scale PV penetration into the grid. From experimental and simulation analyses, it was observed that voltage fluctuations and harmonic injection increases with the increase of PV penetration. Several programs and plans are undertaken to mitigate the energy shortage, day by the demands are growing; the government has a goal to reach 24000MW generation capacity within the next 2021. To reach this target this Smart Grid system will play one of the major role in renewable energy sources for us. But lack of technical devices and dependency of foreign technology, the cost of per watt generation is still higher than other developed countries, government initiates several programs to subsidize this sectors; we hope our approach of making “Smart Grid System” can play a big role to get rid of this situation.

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