February 2016

TECHNOLOGY FOR PHOTOVOLTAIC DATA MONITORING BY A CENTRAL SERVER SYSTEM

Thesis submitted for partial fulfillment of the requirements for Masters of Science (MS) in Renewable Energy Technology, Institute of Energy, University of Dhaka.

Submitted By:

Md. Abu Bakar Siddique

Exam Roll No: 410

Registration No: Ha-298

Session: 2013-2014

MS in Renewable Energy Technology (RET)

Institute of Energy, University of Dhaka

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Dedicated to…

Alhaz Md. Afsar Ali Mondol
Mst. Morium Khatun
Md. Abu Sayeed

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Md. Abu Bakar Siddique
Exam Roll No: 410
Registration No: HA-298
Session: 2013-14
Institute of Energy, University of Dhaka

CERTIFICATE OF APPROVAL

I do hereby recommended that the thesis prepared under my supervision by ***Md. Abu Bakar Siddique*** bearing ***Exam Roll No: 410***, entitled "*TECHNOLOGY FOR PHOTOVOLTAIC DATA MONITORING BY A CENTRAL SERVER SYSTEM*" be accepted in partial fulfillment of the requirements for the degree of Masters of Science (MS) in Renewable Energy Technology (RET) from Institute of Energy, University of Dhaka. To the best of my knowledge and as per his declaration, the whole work has been prepared by him and has not been submitted to anywhere else.

Professor Dr. Saiful Huque

Director,

Institute of Energy (IE),

University of Dhaka, Bangladesh

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Date: February, 2016

Md. Abu Bakar Siddique

ABSTRACT

The condition of the Solar Photovoltaic (PV) systems should be monitored continuously for obtaining better performance and timely maintenance. PV systems installed at different locations with monitoring capabilities provide information in advance about performances. Based on this information, maintenance can be carried out to improve the performance and life cycle of the system, thereby also reduce overall operating cost. Quality of several monitoring systems for local and remote application, based on the techniques of communication, such as, computer to computer, embedded system to computer (GSM) and embedded system to embedded system (GSM, GPRS). In different locations solar radiation, solar day, latitude, geographical zone are also different with sun earth astronomical relation. For getting peak data and actual data is differing with weather condition and seasonal basis. It is difficult to measure correct data by conventional monitoring system. Those monitoring techniques are sometimes unable to collect required data for long time and at specific time duration. A new technique is proposed as a solution to overcome the limitations of other techniques. The proposed technique uses distributed Point to Point (P2P) communication (Ethernet), for the collection of data, with a standard supervision graph and data server. A dedicated computer server will collect actual data with distributed P2P connection and will store in server's database view as a graph and data sheet. In order to study and evaluate the performance of proposed technique, measures actual data values. By the technique we can easily get hourly, daily, monthly and yearly performance data of a PV system.

TABLE OF CONTENTS

TABLE OF CONTENTS

Page No

TABLE OF CONTENTS

Page No

TABLE OF CONTENTS

Page No

LIST OF FIGURES

Name **Page No**

LIST OF FIGURES

Name **Page No**

LIST OF TABLES

Name **Page No**

CHAPTER: 01

INTRODUCTION

CHAPTER: 01

INTRODUCTION

1.1 Introduction:

Clean solar electricity can be generated by solar photovoltaic as well as by solar thermal technologies as a vital source of Renewable Energy. The contribution of solar electricity in the world’s total electricity generation is currently small percentage of total world energy production but it is increasing at very high rate. During the last several years, the average annual growth rates of renewable energy capacity have been 70%. In order to promote installation of solar power plants in Bangladesh, the Government of Bangladesh formed Renewable Energy Policy of Bangladesh, has been in force since 2009, which envisions having 5% power from renewable energy sources by 2015 and 10% by 2020. [7] The government has established Sustainable and Renewable Energy Development Authority (SREDA) to promote renewable energy and energy efficiency. To strengthen international cooperation, Bangladesh became one of the initial members of the International Renewable Energy Agency (IRENA), the only inter-governmental agency working exclusively on renewable energy. Those endeavors manifest Bangladesh's commitment towards development of renewable energy. [8]

Bangladesh receives an average daily solar radiation in the range of 4-5 kWh/m². Encouraged by the availability of solar radiation, Power Division has initiated a programme to generate 500 MW of solar-based electricity. Under this programme, projects for electrification of rural health centers, educational institutions, E-centers at union levels, religious establishments and remote railway stations are required to be implemented by authorities concerned. Private sector is expected to implement commercial projects like Solar Irrigation, Solar Mini Grid, Solar Park and Solar Rooftop applications.

The government is gradually meeting part of the lighting and cooling load of public offices by installing solar panels. The national capacity of solar power development currently exceeds 150 MW. Most of the capacity addition is from Solar Home Systems (SHS) implemented by Infrastructure Development Company Limited (IDCOL), a government-owned financial institution. Until recently, more than 3 million SHSs have been installed with aggregated capacity of about 135 MW. The international community recognizes Bangladesh's SHSs as the fastest growing solar power dissemination programme in the world.

Today, hydropower makes up the largest share of electricity generated from renewable sources as the global capacity reaches 1,000 GW. The only hydroelectric power plant was established at Kaptai with present installed capacity of 230 MW. Bangladesh Power Development Board (BPDB) identified two other sites at Sangu (140 MW) and Matamuhuri (75 MW) for large hydropower plants. Further exploitation of hydropower appears to be limited due to flat terrain of

Bangladesh. Several studies have identified a few sites having potential ranging from 10 kW to 5 MW, but no appreciable capacity has yet been established.

Bio-energy is energy derived from any form of biomass, including bio-heat, bio-power, and bio-fuel. Bangladesh Agricultural University and Bangladesh Council of Scientific and Industrial Research (BCSIR) launched biogas technology in the country in early 1970s. Against an estimated potential of 4 million biogas plants about 70,000 plants have been established so far throughout the country. Tapping potential of biomass, two rice husk-based power plants of 250 kW at Gazipur and 400 kW at Thakurgaon, and seven poultry waste-based power plants at different sites with aggregated capacities exceeding 1 MW, have been established at the initiative of private sector with support from IDCOL.

Except for two pilot wind-power plants at Muhuri Dam (0.9 MW) in Feni and Kutubdia Island (1.0 MW) in Cox's Bazaar, comprehensive assessment of wind power potential is still ongoing. BCSIR, LGED, Bangladesh Centre for Advanced Studies, German Development Cooperation (GIZ) and Renewable Energy Resource Centre of Dhaka University assessed wind resource, at some length, in a few sites. Currently, Power Division is implementing a project with support from USAID to develop wind map for Bangladesh. Potentials of ocean and geothermal energy are yet to be explored in Bangladesh while global capacities reached 530 MW and 12 GW respectively. [8]

1.2 Solar Energy:

Solar Energy is inexhaustible and pollution free energy. Solar energy resource is the amount of sun light available to the solar panels to generate electricity. It is available everywhere but the greatest amount is available between two broad band's encircling the earth between 15" and 35" latitude north and south. Fortunately, Bangladesh is situated between 20"43' north and 26"38' north latitude and as such Bangladesh is in a very favorable position in respect of the utilization of solar energy. Annual amount of radiation varies from 1840 to 1575 kWh/m². Which is 50- 100% higher than in Europe. Taking an average solar radiation of 1900 kWh per square meter, total annual solar radiation in Bangladesh is equivalent to (1010*10)E18 J. Present total yearly consumption of energy is about (700*10)E18 J. this shows even if 0.07% of the incident radiation can be utilized, total requirement of energy in the country can be met. At present energy utilization in Bangladesh is about 0.15 watt/sq. meter land area, whereas the availability is above 208 watt/ m². This shows the enormity of the potentiality of this source in this country. [12]

1.3 Rational of the work:

The Solar Photovoltaic (PV) power systems are installed in different rural as well as urban areas. Solar radiation and solar time is different in various areas. In different locations solar radiation, solar day, latitude, geographical zones are also different with sun earth astronomical relation. The systems (PV) are also situated in dusty, dry, and challenging locations. Due to impact of surrounding a system provides variable voltages because they are not properly maintained and cleaned daily basis. Thus a system will never provide actual data to the data collector. Change of weather and sunlight the system will provide changing data information.

For smooth, safe and optimum operation, PV systems should be regularly monitored and evaluated. In this study we can set real time monitoring and identify actual information, data, and problems of the system and can archive data statistics in every year. A centralized monitoring of PV system will be more efficient and cost effective. The proposed monitoring system also reduces the cost of system operation and maintenance.

The thesis is accordance with below objectives for PV systems or plants.

i. Time to time voltage monitoring of solar photovoltaic (PV) systems.
ii. Hourly, daily, monthly and yearly based Output Voltage monitoring.
iii. Specific panels/systems performance measurement in different time duration.
iv. Shows variation of values in different weather (seasons) basis.
v. Actual data collection for long time basis which helps to setup a large power plant.
vi. Random data comparison.

CHAPTER: 02

REVIEW OF LITERATURE

CHAPTER: 02

REVIEW OF LITERATURE

2.1 Introduction:

In recent year's significant changes in the monitoring technique in the power sectors, this led to new forms of performance data. Central Monitoring is one important outcome of this development.

In the last few years, there has been a growing demand for electricity on the part of industries, commercial establishments and residential dwellings. This has been the situation in all over the world. In the period 200 0–2010, the per capita energy consumption in the world increased by was 24%, respectively. Therefore, such a scenario requires a more intelligent electricity system, which can allow energy consumption to be reduced in every piece of electronic equipment and encourage consumers to employ efficient strategies for the reduction of energy consumption.[40]

Information technology for the electric power system, integrated to the systems of communication and electrical network infrastructure, known as the smart grid, allows us to monitor and manage the electrical power system, anywhere and anytime. In this sense, the use of smart grids has become increasingly important in the urban scenario, as they offer the integration of various energy sources, such as solar power, hydroelectric, atomic, and wind power. [39]

At the same time in power generation, a real boost in information technology took place, allowing the transfer of large masses of data over long distances. As a result the idea of using remote monitoring to mitigate for long term service contracts was born.

2.2 Solar Power:

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into an electric current using the photovoltaic effect. [3]

Photovoltaic were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. As the cost of solar electricity has fallen, the number of grid-connected solar PV systems has grown into the millions and utility-scale solar power stations with hundreds of megawatts are being built. Solar PV is rapidly becoming an inexpensive, low-carbon technology to harness renewable energy from the Sun.

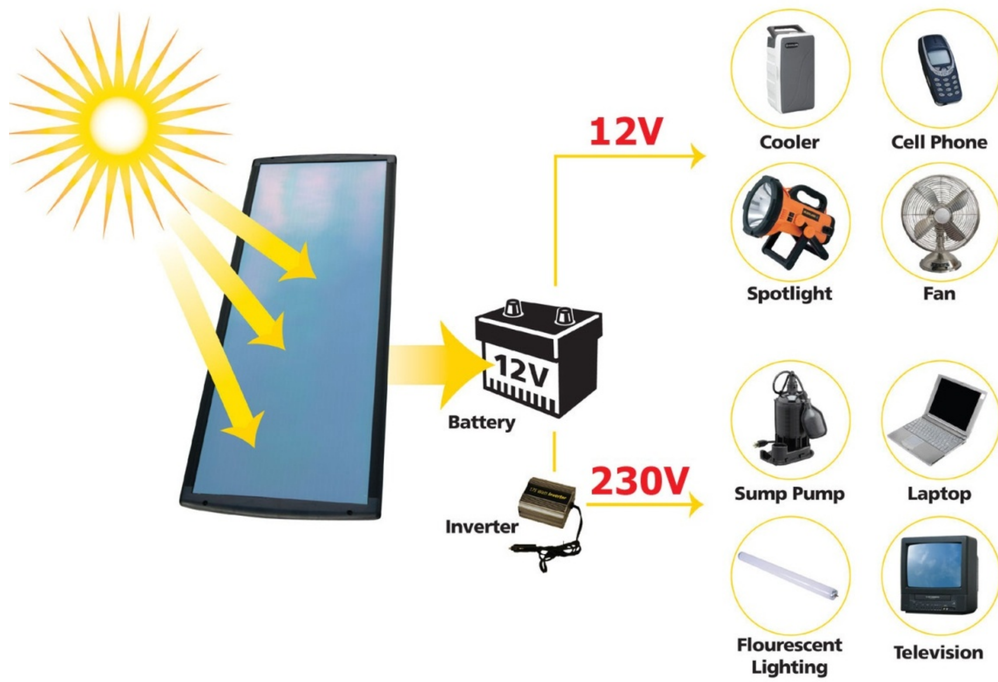


Figure 2.1: Solar Power Systems.

2.2.1 Energy conversion:

Photovoltaic devices allow the direct production of electricity from light absorption. The active material in a photovoltaic system is a semiconductor capable of absorbing photons with energies equal to or greater than its band gap. Upon photon absorption, an electron of the valence band is promoted to the conduction band and is free to move through the bulk of the semiconductor. In order for this free charge to be captured for current generation, decay to the lower energy state, i.e. recombination with the hole in the valence band, has to be prevented through charge separation. [41]

2.2.2 Solar cells Parameters:

The IV curve: The current-voltage (I-V) characteristic is the basic descriptor of photovoltaic device performance. A fundamental understanding of how solar irradiance, cell temperature and electrical load affect I-V curves is essential in designing, installing and evaluating PV system applications. [1]

The I-V curve represents an infinite number of current-voltage (direct-current, DC) operating points, the specific operating point being determined by the electrical load connected to the PV device. [19]

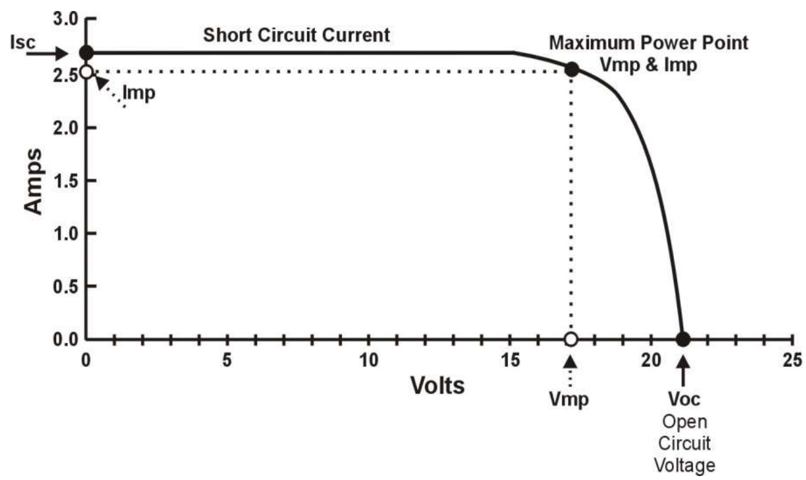


Figure 2.2: I-V curve for PV device

Open circuit Voltage (V_{OC}): The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light-generated current.

An equation for V_{oc} is found by setting the net current equal to zero in the solar cell equation to give:

$$V_{OC} = \frac{nkT}{q} \ln\left(\frac{I_L}{I_0} + 1\right)$$

The equation shows that V_{oc} depends on the saturation current of the solar cell and the light-generated current. While I_{sc} typically has a small variation, the key effect is the saturation current, since this may vary by orders of magnitude. The saturation current, I_0 depends on recombination in the solar cell. Open-circuit voltage is then a measure of the amount of recombination in the device. Silicon solar cells on high quality single crystalline material have open-circuit voltages of up to 730 mV under one sun and AM1.5 conditions, while commercial devices on multi-crystalline silicon typically have open-circuit voltages around 600 mV.

The V_{OC} can also be determined from the carrier concentration:

$$V_{OC} = \frac{kT}{q} \ln\left[\frac{(N_A + \Delta n)\Delta n}{n_i^2}\right]$$

Where, kT/q is the thermal voltage, N_A is the doping concentration, Δn is the excess carrier concentration and n_i is the intrinsic carrier concentration. The determination of V_{OC} from the carrier concentration is also termed Implied V_{OC}.

Short circuit current (I_{sc}): It is the current through the solar cell when the voltage across the solar cell is zero. The short-circuit current is due to the generation and collection of light-generated carriers. For an ideal solar cell at most moderate resistive loss mechanisms, the short-circuit current and the light-generated current are identical. Therefore, the short-circuit current is the largest current which may be drawn from the solar cell.

Maximum power current (I_{mp}): It is the maximum current available when the panel is operating at peak efficiency in a circuit.

Maximum power point (P_{max}): It is the condition under which the solar cell generates its maximum power. The current and voltage in this condition are defined as I_{max} and V_{max}, respectively.

The fill factor (FF): It represents the degree to which the voltage at the maximum power point (V_m) matches the open-circuit voltage (V_{OC}) and that the current at the maximum power point (I_m) matches the short-circuit current (I_{SC}). The fill factor (FF) is calculated using the following formula:

$$FF = \frac{V_m \times I_m}{V_{oc} \times I_{sc}} = \frac{P_m}{V_{oc} \times I_{sc}}$$

The efficiency: The efficiency of a solar cell is determined as the fraction of incident power which is converted to electricity and is defined as:

$$P_{max} = V_{OC} I_{SC} FF$$

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}}$$

Where,

V_{oc} is the open-circuit voltage
I_{sc} is the short-circuit current
FF is the fill factor
η is the efficiency.

PV cells are most commonly made of silicon, and come in two varieties, crystalline and thin-film type. Photovoltaic (PV) cells are made of semiconducting materials that can convert incident radiation in the solar spectrum to electric currents. There has been an explosive growth in the solar industry, which in turn has intensified the need for measurement solutions for testing of various components of solar powered systems. [20]

2.3 Hydroelectric Power:

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy.

By taking advantage of gravity and the water cycle, we have tapped into one of nature's engines to create a useful form of energy. In fact, humans have been capturing the energy of moving water for thousands of years. Today, harnessing the power of moving water to generate electricity, known as hydroelectric power, is the largest source of emissions-free, renewable electricity in the world. [42]

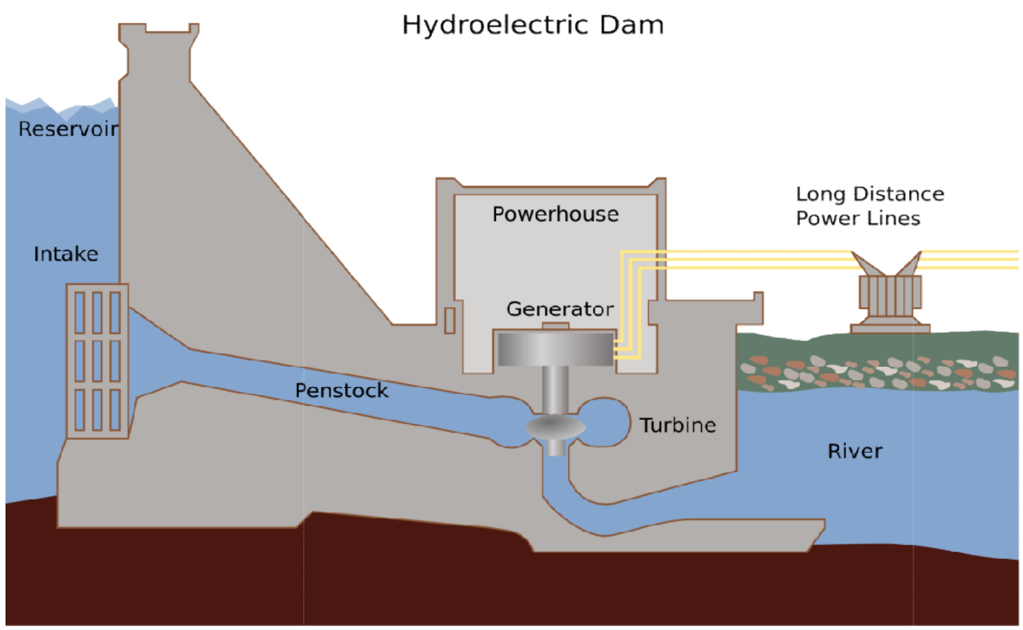


Figure 2.3: Hydroelectric power generation dam.

2.3.1 *The components of a hydropower plant: [43]*

Dam: Most hydropower plants rely on a dam that holds back water, creating a large water reservoir that can be used as storage.

Intake, penstock and surge chamber: Gates on the dam open and gravity conducts the water through the penstock (a cavity or pipeline) to the turbine. There is sometimes a head race before the penstock. A surge chamber or tank is used to reduce surges in water pressure that could potentially damage or lead to increased stresses on the turbine.

Turbine: The water strikes the turbine blades and turns the turbine, which is attached to a generator by a shaft. There is a range of configurations possible with the generator above or next to the turbine. The most common type of turbine for hydropower plants in use today is the Francis Turbine, which allows a side-by-side configuration with the generator

Generators: As the turbine blades turn, the rotor inside the generator also turns and electric current is produced as magnets rotate inside the fixed-coil generator to produce alternating current (AC).

Transformer: *The transformer inside the* powerhouse takes the AC voltage and converts it into higher-voltage current for more efficient (lower losses) long-distance transport.

Transmission lines: Send the electricity generated to a grid- connection point, or to a large industrial consumer directly, where the electricity is converted back to a lower voltage current and fed into the distribution network.

Outflow: Finally, the used water is carried out through pipelines, called tailraces, and re-enters the river downstream. The outflow system may also include "spillways" which allow the water to bypass the generation system and be "spilled" in times of flood or very high inflows and reservoir levels.

2.3.2 *Energy production formula:*

Release of potential energy:

$$P_{th} = \rho\, q\, g\, h$$

Where,

P_{th} = *power theoretically available (W)*

ρ = *density (kg/m^3) (~ 1000 kg/m^3 for water)*

q = *water flow (m^3/s)*

g = *acceleration of gravity (9.81 m/s^2)*

h = *falling height, head (m)*

Efficiency:

$$h = P_{out} / P_H$$

Water is one of our most valuable resources, and hydropower makes use of this renewable treasure. For future energy needs in a manner that protects the environment by improving hydropower projects and operating them more effectively. Hydroelectric power is important to all. Growing populations and modern technologies require vast amounts of electricity for creating, building, and expanding. Although the amount of energy produced by this means has steadily increased, the amount produced by other types of power plants has increased at a faster rate Hydropower is an essential contributor in the national power grid because of its ability to respond quickly to rapidly varying loads or system disturbances, which base load plants with steam systems powered by combustion or nuclear processes cannot accommodate. [44]

2.4 Atomic Power Generation:

An Atomic Power Generation is a thermal power station in which the heat source is a nuclear reactor. As is typical in all conventional thermal power stations the heat is used to generate steam which drives a steam turbine connected to an electric generator which produces electricity. As of 23 April 2014, the IAEA report there are 435 nuclear power reactors in operation operating in 31 countries. Nuclear power plants are usually considered to be base load stations, since fuel is a small part of the cost of production. [45]

2.4.1 Energy conversion process:

The conversion to electrical energy takes place indirectly, as in conventional thermal power plants. The fission in a nuclear reactor heats the reactor coolant. The coolant may be water or gas or even liquid metal depending on the type of reactor. The reactor coolant then goes to a steam generator and heats water to produce steam. The pressurized steam is then usually fed to a multi-stage steam turbine. After the steam turbine has expanded and partially condensed the steam, the remaining vapor is condensed in a condenser. The condenser is a heat exchanger which is connected to a secondary side such as a river or a cooling tower. The water is then pumped back into the steam generator and the cycle begins again. The water-steam cycle corresponds to the Rankine cycle. [45]

There are two fundamental nuclear processes considered for energy production: fusion and fission.

Fusion: Fusion is the combining of two small atoms such as Hydrogen or Helium to produce heavier atoms and energy. These reactions can release more energy than fission without producing as many radioactive byproducts. Fusion reactions occur in the sun, generally using Hydrogen as fuel and producing Helium as waste (fun fact: Helium was discovered in the sun and named after the Greek Sun God, Helios). This reaction has not been commercially developed yet and is a serious research interest worldwide, due to its promise of limitless, pollution-free, and non-proliferation features. [46]

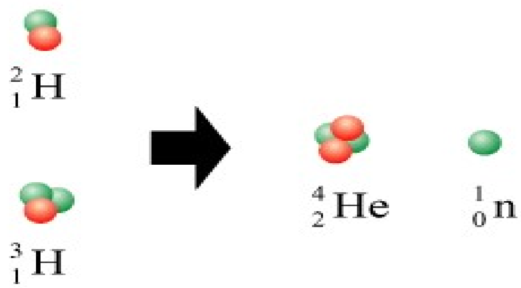


Figure 2.4: The fusion of deuterium and tritium into helium.

Fission: Fission is the energetic splitting of large atoms such as Uranium or Plutonium into two smaller atoms, called fission products. To split an atom, you have to hit it with a neutron. Several neutrons are also released which can go on to split other nearby atoms, producing a nuclear chain reaction of sustained energy release. This nuclear reaction was the first of the two to be discovered. All commercial nuclear power plants in operation use this reaction to generate heat which they turn into electricity. [46]

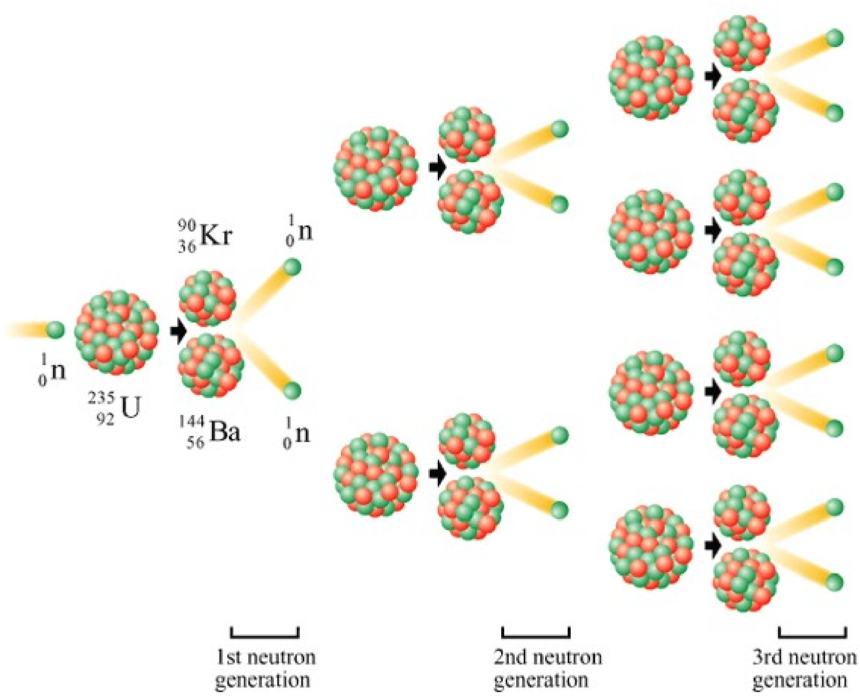


Figure 2.5: The chain reaction of uranium fission

Nuclear power plants are some of the most sophisticated and complex energy systems ever designed and not environmental friendly.

2.5 Wind Power:

Wind power or wind energy describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water), or can be converted into electricity by a generator.

Air flow through wind turbines or sails can produce significant mechanical power. Windmills are used for their mechanical power, wind pumps for water pumping, and sails to propel ships, but the most frequent current use is to turn a generator for electrical power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land. The net effects on the environment are far less problematic than those of nonrenewable power sources. [5]

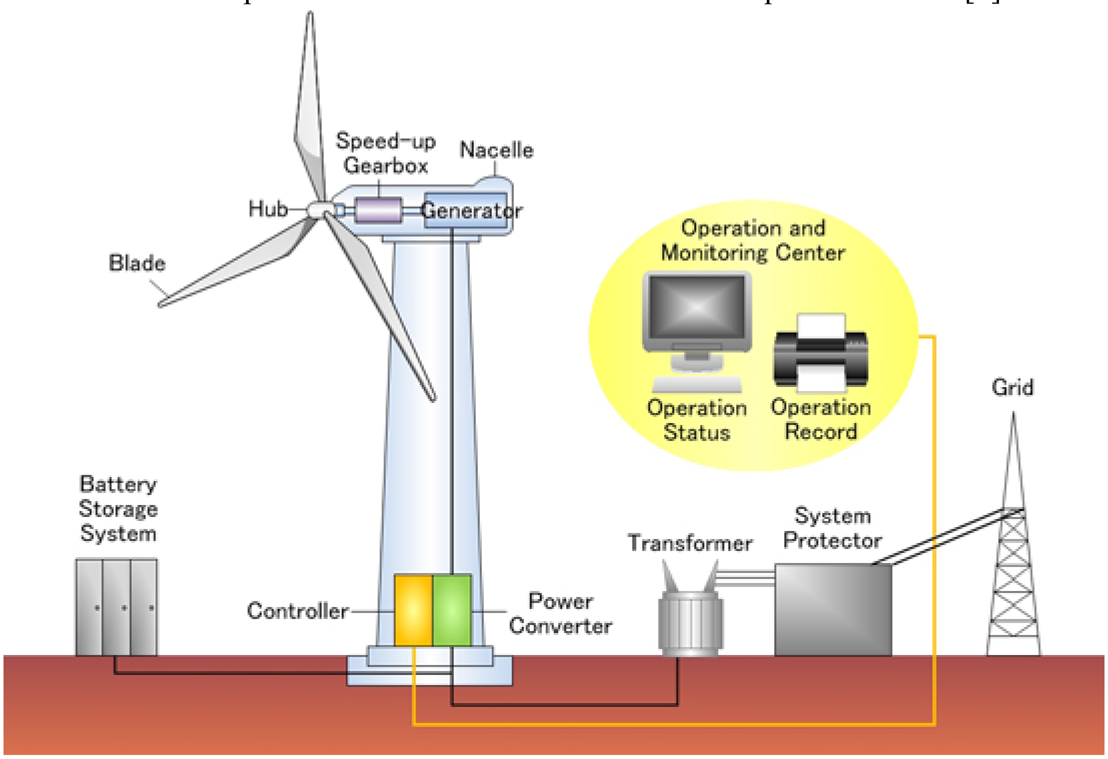


Figure 2.6: Wind Power Process

Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

2.5.1 Types of wind turbines: Modern wind turbines fall into two basic groups; the horizontal-axis variety, like the traditional farm windmills used for pumping water, and the vertical-axis design, like the eggbeater-style Darrieus model, named after its French inventor. Most large modern wind turbines are horizontal-axis turbines. [5]

2.5.2 The Wind Turbine Components:

The blades: Designed like airplane wings, modern wind turbine blades use lift to capture the wind's energy. Because of the blade's special shape, the wind creates a pocket of pressure as it passes behind the blade. This pressure pulls the blade, causing the turbine to rotate. This modern blade design captures the wind's energy much more efficiently than old farm windmills, which use drag, the force of the wind pushing against the blades. The blades spin at a slow rate of about 20 revolutions per minute (RPM), although the speed at the blade tip can be over 150 miles per hour.

The nacelle: The nacelle houses a generator and gearbox. The spinning blades are attached to the generator through a series of gears. The gears increase the rotational speed of the blades to the generator speed of over 1,500 RPM. As the generator spins, electricity is produced. Generators can be either variable or fixed speed. Variable speed generators produce electricity at a varying frequency, which must be corrected to 60 cycles per second before it is fed onto the grid. Fixed speed generators don't need to be corrected, but aren't as able to take advantage of fluctuations in wind speed.

The tower: The most common tower design is a white steel cylinder, about 150 to 200 feet tall and 10 feet in diameter. Some turbines use a lattice tower, like the Eiffel Tower. Towers have a ladder running up the inside and a hoist for tools and equipment.

The base: Bases are made of concrete reinforced with steel bars. There are two basic designs. One is a shallow flat disk, about 40 feet in diameter and three feet thick. The other is a deeper cylinder, about 15 feet in diameter and 16 feet deep.

2.5.3 Supply and Transport:

The major challenge to using wind as a source of power is that it is intermittent and does not always blow when electricity is needed. Wind cannot be stored (although wind-generated electricity can be stored, if batteries are used), and not all winds can be harnessed to meet the timing of electricity demands. Further, good wind sites are often located in remote locations far from areas of electric power demand (such as cities). Finally, wind resource development may compete with other uses for the land, and those alternative uses may be more highly valued than electricity generation. However, wind turbines can be located on land that is also used for grazing or even farming.

2.5.4 Wind Energy Conversion Formula:

Wind energy is the kinetic energy of air in motion, also called wind. Total wind energy flowing through an imaginary surface with area *A* during the time *t* is:

$$E = \frac{1}{2}mv^2 = \frac{1}{2}(Avt\rho)v^2 = \frac{1}{2}At\rho v^3,$$

Where,
ρ is the density of air;
v is the wind speed;
Avt is the volume of air passing through A
$Avt\rho$ is therefore the mass m passing through A
½ ρv^2 is the kinetic energy of the moving air per unit volume.

Power is energy per unit time, so the wind power incident on *A* (e.g. equal to the rotor area of a wind turbine) is:

$$P = \frac{E}{t} = \frac{1}{2}A\rho v^3.$$

Wind power in an open air stream is thus proportional to the third power of the wind speed; the available power increases eightfold when the wind speed doubles. Wind turbines for grid electricity therefore need to be especially efficient at greater wind speeds. Wind power, form of energy conversion in which turbines convert the kinetic energy of wind into mechanical or electrical energy that can be used for power. Wind power is considered a renewable energy source. [5]

2.6 Energy Monitoring Server:

Energy consumption in individual data centers is increasing rapidly, by 8% to 12% per year. The energy is used for powering IT systems (for example, servers, storage and networking equipment) and the facility's components (for example, air-conditioning systems, power distribution units and uninterruptible power supply systems). The increase in energy consumption is driven by users installing more equipment, and by the increasing power requirements of high-density server architectures. While data center infrastructure management (DCIM) tools monitor and model energy use across the data center, server-based energy management software tools are specifically designed to measure the energy use within server units. They are normally an enhancement to existing server management tools, such as HP Systems Insight Manager (HP SIM) or IBM Systems Director. These software tools are critical to gaining accurate and real-time measurements of the amount of energy a particular server is using. This information can then be fed into a reporting tool or into a broader DCIM toolset. The information will also be an important trigger for the real-time changes that will drive real-time infrastructure. A change in energy consumption may drive a process to move an application from one server to another [10].

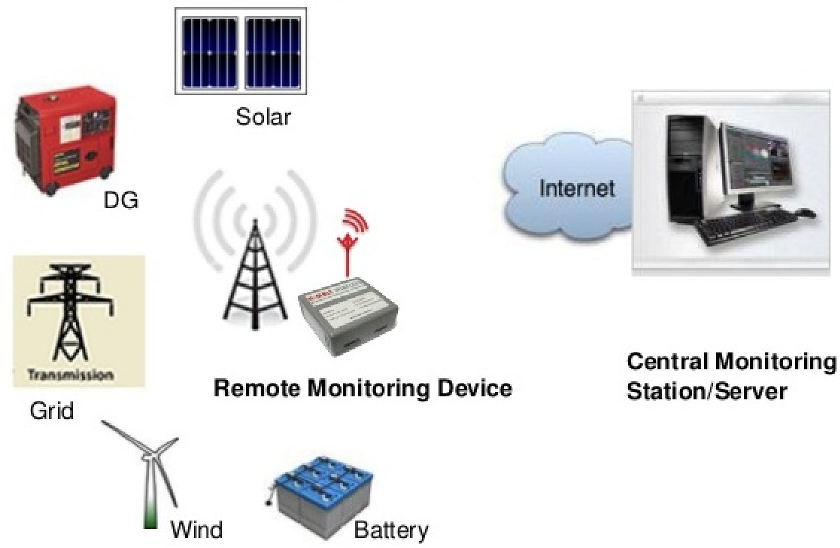


Figure 2.7: Energy Monitoring Server System

Monitoring server types:

i. Central Monitoring Server
ii. Remotely Monitoring Server

2.6.1 Central Monitoring Server:

Central monitoring server is the system with all monitoring equipments is associated with the server system directly. The server is designed for large scale monitoring with performance and alarm declaration.

2.6.2 Remotely Monitoring Server:

Remote monitoring server systems are designed to control large or complex facilities such as factories, power plants, network operations centers, airports, and spacecraft, with some degree of automation remotely.

Systems may receive data from sensors, telemetry streams, user inputs, and pre-programmed procedures. The software may send Tele-commands to actuators, computer systems, or other devices.

Reduce troubleshooting time with an automated remote server monitoring servers gives you a unified view so one can track performance and remediate issues faster. The main benefit of monitoring remote server environment is being proactively notified of performance issues of end-devices notice there is a problem and productivity. [13]

CHAPTER: 03

METHODOLOGY

CHAPTER: 03

METHODOLOGY

3.1 Introduction:

In order to the research methodology is a science that studying how research is done scientifically. It is the way to systematically solve the research problem by logically adopting various steps. Also it defines the way in which the data are collected in a research project. [47]

3.2 Connection Design Method:

For this study there have two design steps which are Physical and Logical stages.

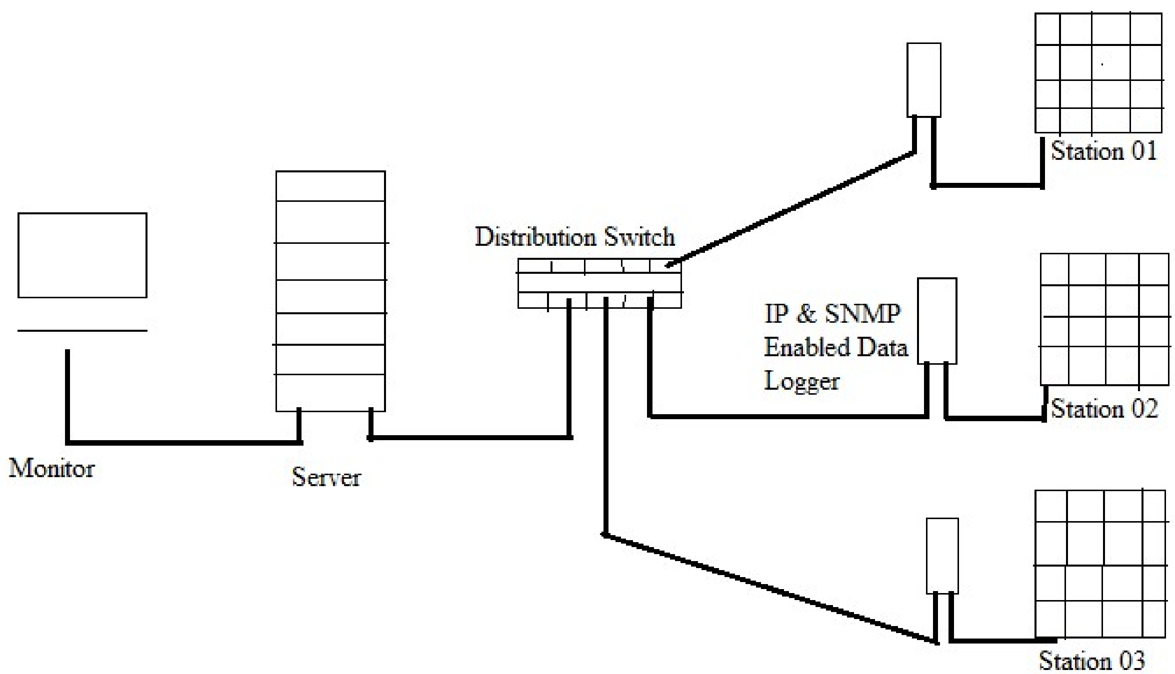


Figure 3.1: Design Methods of the study.

3.2.1 Physical Connection: In the physical part of the system design combines with Solar Photovoltaic (PV) panels which categorized as *Stations (Like station 01, station 02, station 03…..).* Panels are connected with a data logger by wiring. Every single panel is connected with single data logger that's why each panel (station) will provide actual and specific information of data. Data loggers are connected with a distribution Switch by Ethernet RJ45 connector. There UTP (Unshielded Twisted Pair) cable is used for communication.

Distribution switch has different number of Ethernet ports. We can easily connect different number of stations which we need to monitor. Switch is finally connected with a Server which stores collected data from stations and view as a graph and data sheet. For connection switch and server there also used UTP cable with RJ45 connector. Server can easily monitored and view with a Monitor.

3.2.1 Logical Connection: For the logical part of the study, I configured a graph and data server named Cacti. The server has a static IP Address for communication with own network. The IP Address of the server was 192.168.0.252 and subnet mask 255.255.255.0. Server has allowed a Private Network (192.168.0.0/24) for this study. Server has several services running and they are Web service, Apache, MySQL, RRDTool, SNMP and PHP.

Simple Network Management Protocol (SNMP) is used which is a protocol for collecting and organizing information about managed devices on IP networks and for modifying that information to change device behavior. Web Service shows graphical web page and MySQL is a database service that can store data which we achieved from stations.

Data logger is also an IP based and SNMP supported device which connected with panel load and provide actual voltage data from the panel. For this study I used three stations and set IP address of 192.168.0.150, 192.168.0.151 and 192.168.0.152.

For the stable complex station (PV) scenario and Data Logger with IP & SNMP supported problem it was not easy to collect data. In this study I used two Laptops and a Desktop Computer for collecting voltage data into the server.

3.3 Data Collection Method:

Collection and management of proper data (voltage) in different time duration form stations is the main challenge of this study. After full and final networking setup server is able to store data and shows as a graphical view on web window of the server and also data sheet.

3.3.1 Graphical View: Five minutes average data is stored into the server and it calculates for long time basis. The data graph has *Current, Average* and *Maximum* voltage induced graph which shown in below.

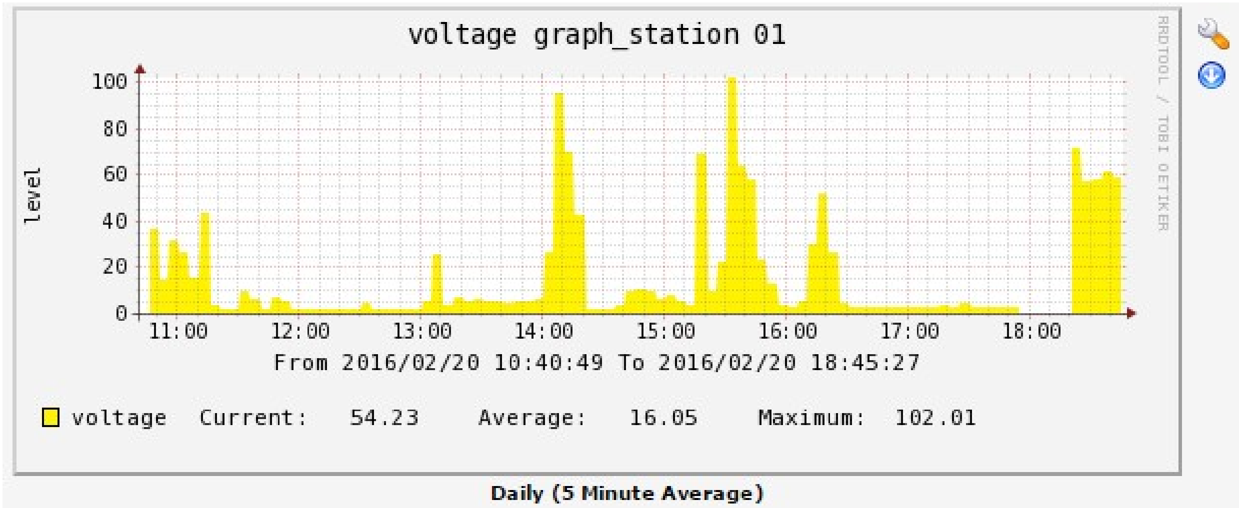


Figure 3.2: Graphical view of data collection.

3.3.2 Data Sheet: For data sheet of daily five minutes average shows as below.

Title:	**'voltage graph_station 01'**
Vertical Label:	'level'
Start Date:	2/19/2016
End Date:	2/20/2016
Step:	300.00
Total Rows:	288.00
Graph ID:	23.00
Host ID:	6.00

Date	**voltage**
2/19/16 23:15	NaN
2/19/16 23:20	NaN
2/19/16 23:25	48.10
2/19/16 23:30	14.12
2/19/16 23:35	28.91
2/19/16 23:40	2.03
2/19/16 23:45	2.23
2/19/16 23:50	3.86

2/19/16 23:55	5.16
2/20/16 0:00	3.84
2/20/16 0:05	4.24
2/20/16 0:10	4.77
2/20/16 0:15	3.37
2/20/16 0:20	4.76
2/20/16 0:25	9.99
2/20/16 0:30	8.41
2/20/16 0:35	20.74
2/20/16 0:40	27.03
2/20/16 0:45	NaN
2/20/16 10:45	NaN
2/20/16 10:50	36.25
2/20/16 10:55	13.87
2/20/16 11:00	30.99
2/20/16 11:05	26.16
2/20/16 11:10	15.51
2/20/16 11:15	43.37
2/20/16 11:20	2.98
2/20/16 11:25	1.12
2/20/16 11:30	1.50
2/20/16 11:35	9.38
2/20/16 11:40	5.95
2/20/16 11:45	1.60
2/20/16 11:50	6.69
2/20/16 11:55	4.74
2/20/16 12:00	1.41
2/20/16 12:05	1.26
2/20/16 12:10	1.27
2/20/16 12:15	1.40
2/20/16 12:20	1.60
2/20/16 12:25	1.24
2/20/16 12:30	1.46

Table 3.1: Data sheet (voltage) for Station 01.

CHAPTER: 04

PHOTOVOLTAIC (PV), TECHNOLOGY AND STORAGE

CHAPTER: 04

PHOTOVOLTAIC (PV), TECHNOLOGY AND STORAGE

4.1 Photovoltaic (PV) or Solar cell:

Photovoltaic (PV) cells are most commonly made of silicon, and come in two varieties, crystalline and thin-film type. Photovoltaic (PV) cells are made of semiconducting materials that can convert incident radiation in the solar spectrum to electric currents. There has been an explosive growth in the solar industry, which in turn has intensified the need for measurement solutions for testing of various components of solar powered systems. Measurement solutions come in two main format complete turn-key solutions and test-system building blocks that must be fitted together and wrapped in software. They cater to the requirements during research and development, manufacturing processes, deployment of the system on ground and finally maintenance of the system. At present typical values for solar cell efficiencies are 6-8% for amorphous cells, 10-15% for thin film cells, 13-14% for poly crystalline silicon cells, 17-18% for mono crystalline silicon cells and 30% or more for concentrating systems. The best theoretical values for efficiencies are 20-28% for normal cells. [3]

There are three main types of solar cells: *mono-crystalline silicon, poly-crystalline silicon, and thin film materials.* The different cell technologies represent different energy conversion efficiencies and manufacturing approaches in trying to reduce the cost of photovoltaic generated electricity. The photovoltaic technology is constantly evolving in the direction of better conversion efficiency and lower cost. Each solar cell can generate a predetermined voltage and current under manufacturing and physical constraints. [18]

4.1.1*Mono-Crystalline Silicon:* Solar cells made of mono-crystalline silicon (mono-Si), also called single-crystalline silicon are quite easily recognizable by an external even coloring and uniform look, indicating high-purity silicon. [16]

Figure4.1: Mono-Crystalline Silicon Solar Cell.

Mono-crystalline solar cells are made out of silicon ingots, which are cylindrical in shape. To optimize performance and lower costs of a single mono-crystalline solar cell, four sides are cut out of the cylindrical ingots to make silicon wafers, which is what gives mono-crystalline solar panels their characteristic look.

Mono-crystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. The efficiency rates of mono-crystalline solar panels are typically 15-20%. These solar panels have lived the longest and space-efficient also. Since these solar panels yield the highest power outputs, they also require the least amount of space compared to any other types. Mono-crystalline solar panels produce up to four times the amount of electricity as thin-film solar panels.[16]

4.1.2 ***Poly-Crystalline Silicon:*** Polycrystalline silicon consists of small grains of mono-crystalline silicon. Cube-shaped ingots can be made directly by casting molten poly silicon, which are then cut into wafers similar to mono-crystalline wafers. Poly-Crystalline solar cell is produced from metallurgical grade silicon by a chemical purification process, called Siemens process. This process involves distillation of volatile silicon compounds, and their decomposition into silicon at high temperatures. An emerging, alternative process of refinement uses a fluidized bed reactor. The photovoltaic industry also produces upgraded metallurgical-grade silicon (UMG-Si), using metallurgical instead of chemical purification processes. When produced for the electronics industry, polysilicon contains impurity levels of less than one part per billion (ppb), while polycrystalline solar grade silicon (SoG-Si) is generally less pure. [18]

Figure 4.2: Poly-Crystalline Silicon Solar Cell.

The process used to make polycrystalline silicon is simpler and cost less. The amount of waste silicon is less.

Polycrystalline solar panels tend to have slightly lower heat tolerance than mono-crystalline solar panels. This technically means that they perform slightly worse than mono-crystalline solar panels in high temperatures. Heat can affect the performance of solar panels and shorten their lifespan but this effect is minor. The efficiency of polycrystalline-based solar panels is typically 13-16% because of lower silicon purity.

4.1.3 ***Thin film:*** A thin-film solar cell is a second generation solar cell that is made by depositing one or more thin layers or thin film of photovoltaic material on a substrate, such as glass, plastic or metal. Depositing one or several thin layers of photovoltaic material onto a substrate is the basic gist of how thin-film solar cells are manufactured. They are also known as thin-film photovoltaic cells (TFPV). The different types of thin-film solar cells can be categorized by which photovoltaic material is deposited onto the substrate:

- Amorphous silicon (a-Si)
- Cadmium telluride (CdTe)
- Copper indium gallium selenide (CIS/CIGS)
- Organic photovoltaic cells (OPC)

Figure 4.3: Thin Film Solar Cell.

Film thickness varies from a few nanometers (nm) to tens of micrometers (µm), much thinner than thin-film's rival technology, the conventional, first-generation crystalline silicon solar cell (c-Si) that uses wafers of up to 200 µm. This allows thin film cells to be flexible, lower in weight, and have less drag or friction.

Depending on the technology, thin-film module prototypes have reached efficiencies between 7–13% and production modules operate at about 9%. [18]

4.2 Solar Panel:

Solar panels or more technically photovoltaic (PV) panels are a solar electric system's enabling component. Panels are made of wafers or cells of semiconductor material that use sunlight (photons) and the photovoltaic effect to generate direct current (DC) electricity. A solar panel is made up numerous series and parallel combinations of identical individual cells to generate the desired power output (current and voltage). Panels are assigned a power rating in watts based on the maximum power they can produce under ideal sun and temperature conditions. The rated power output is used to help determine how many panels are needed to meet the electrical load demands. Multiple panels combined together are called solar arrays. [3]

Figure 4.4: Solar Panel.

4.3 Solar Arrays:

A solar array is a loosely defined term referring to a group of photovoltaic solar panels or cells that convert sunlight to electricity, arranged and linked in such a way as to operate as a single unit. The term can also refer to a similar set of reflecting mirrors used for directing and focusing sunlight onto such a group of photovoltaic units. A solar array can be relatively small, such as a group of panels on the roof of a single family home, or very large, such as an array covering several acres, containing hundreds or even thousands of individual panels. [17]

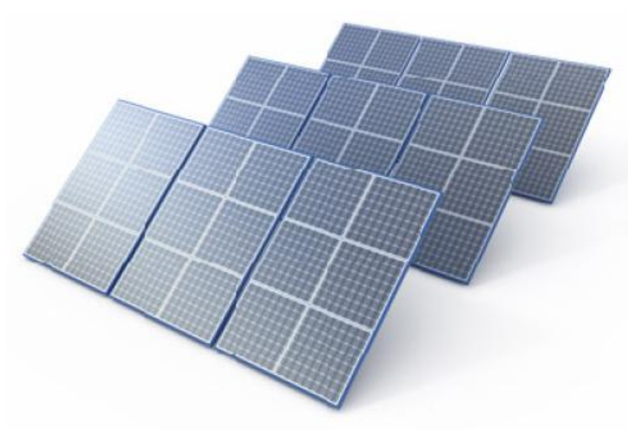


Figure 4.5: Solar Array.

In the strictest sense of the term, even some individual solar panels are technically solar arrays. A typical solar panel is made up of several photovoltaic cells linked together and bound, or contained, within a single unit. The word array is not generally used in this manner, however, and a solar array is usually regarded as a group of solar panels, which can vary widely in size and shape.

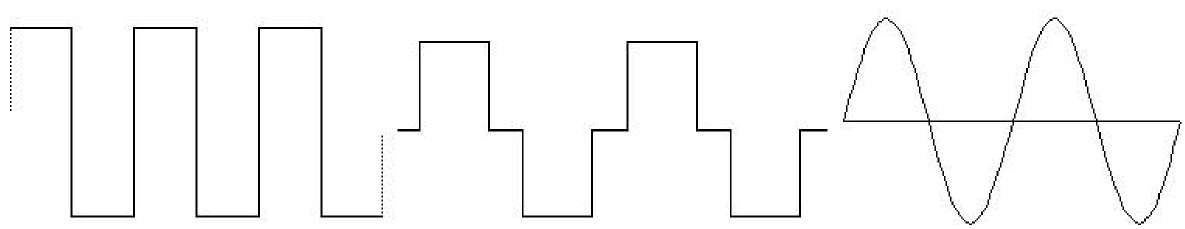
4.4 Inverter:

An inverter is an electronic device which inverts DC energy (the type of energy found in batteries) into AC energy (the type of energy that is produced by the power company and is found in your home). Household appliances such as refrigerators, TVs, lighting, stereos, computer etc., all run off of AC electricity. [14]

A solar inverter, or PV inverter, or Solar converter, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical BOS–component in a photovoltaic system, allowing the use of ordinary AC-powered equipment. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection. [50]

Depending on the output waveform there are three types of inverter:

i. Square wave inverter
ii. Modified sine wave inverter
iii. Sine wave inverter



(a) Square wave inverter (b) Modified sine wave inverter (c) Sine wave inverter

Figure 4.6: Different Types of Inverter.

4.4.1 ***Square wave inverter:*** The output of this inverter is square wave. It produces 220V+-10% and 50Hz. The input DC voltage of this inverter may be 12, 24 or 48 Volt. Although the efficiency of this inverter is high (70% to 95%), it produces very high harmonic distortion.

4.4.2 *Sine wave inverter:* This inverter produces a sine wave output. The output AC voltage range is 220V+-10% and the input DC voltage may be 12, 24 or 48 Volt. The main advantage of this inverter is its low harmonic distortion.

4.4.3 *Modified sine wave inverter*: A modified sine wave inverter has a non-square waveform that is a useful rough approximation of a sine wave for power translation purposes. Most inexpensive consumer power inverters produce a modified sine wave rather than a pure sine wave.

4.4.4 *Solar Inverters:* Solar inverters are among the type of inverters for home that are energy efficient as they do not require a separate source for generating power. The solar energy is collected during the daytime and used at time of need after being converted into electrical energy. Some basic types of solar inverters are [51]

i. Stand-alone inverters
ii. Battery back-up inverters
iii. Grid tie inverters
iv. Hybrid Inverters

Some of the benefits of solar inverters are: They are easy to install as the construction is simple and light. This home inverter type is also highly efficient as the other types of inverters. Do not require special fans for cooling purposes as they are convection cooled.

4.4.4.1 *Stand-alone inverter:* Stand-alone inverter or off-grid inverter is designed for remote stand-alone application or off-grid power system with battery backup where the inverter draws its DC power from batteries charged by PV array and converts to AC power. Stand-alone inverters provide variety of size and output waveform depending on your applications. For the best output, the pure sine inverter is required. It suits for solar home system, rural electrification, village electrification in remote area where the utility grid is not available.

4.4.4.2 *Battery back-up inverters*: A battery backup system consists of an inverter and one or more batteries. The inverter is responsible for converting the power stored in the batteries into a form that we can be used. It is also responsible for keeping the batteries fully charged at all times.

4.4.4.3 *Grid tie inverters:* Grid connected inverter or grid tie inverter is designed specifically for grid connected application that does not require battery backup system. Grid connected inverter or grid tie inverter converts DC power produced by PV array to AC power to supply to electrical appliances and sell excess power back to utility grid. With a range of sizes available, we provide grid tie inverter to suit your needs, from small residential solar system to large commercial solar system.

Grid interactive inverter is designed for residential, commercial and industry applications. The inverter can operate on both grid-tied and stand-alone off-grid operations. When utility power is normal the inverter can operate as grid tie inverter which converts DC power generated by PV panels into AC power for supplying to load and feed the excess energy back to utility grid line. When utility power is not available, the inverter can operate as backup power source to supply power from PV panels and battery. Grid interactive system provide clean, reliable backup power in the event of a utility power failure. It can reduce energy consumption and save the utility cost, while maintaining the ability to use the renewable energy source during power outage.

4.4.4.4 *Hybrid inverter:* Hybrid inverter or hybrid power inverter is designed for hybrid power system that combines solar array with diesel generator and other renewable energy sources such as wind turbine generator, hydro generator, etc. Hybrid inverter can operate as either a stand-alone inverter or a grid tie inverter. It is connected to battery bank, the utility grid lines, diesel generator and the house appliances. It suits to use for remote village electrification or remote island electrification to provide continuous reliable power at remote locations.

Inverter is a critical component used in any PV system where alternative current (AC) power output is needed. It converts direct current (DC) power output from the solar arrays or wind turbine into clean AC electricity for AC appliances. Inverter can be used in many applications. In PV or solar applications, inverter may also be called solar inverter. To improve the quality of inverter's power output, many topologies are incorporated in its design such as Pulse-width modulation is used in PWM inverter. [51]

4.5 Charge controller:

A charge controller is basically a voltage or current regulator to keep batteries from overcharged by solar panels or over discharged by loads and controls how voltage and current is applied to the battery. Thus, It regulates power coming from the solar panels going to the battery. Most panels for 12 volt system put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries used in solar systems need around 14 to 14.5 volts to get fully charged. So, a charge controller handles this task sensing voltage and connecting/disconnecting panels or loads. [21]

Specific control method and algorithm vary among charge controllers but they have basic parameters and characteristics. Two basic methods exist for controlling or regulating the charging of a battery from a PV module or array –

i. Shunt Regulation
ii. Series Regulation

4.5.1 ***Shunt Regulation:*** The shunt-interrupting controller completely disconnects the array current by shunting (shorting the array) when the battery reaches the voltage regulation set point. When the battery decreases to the array reconnect voltage, the controller connects the array to resume charging the battery. This cycling between the regulation voltage and array reconnect voltage is why these controllers are often called 'on-off' or 'pulsing' controllers. Shunt-interrupting controllers are widely available and are low cost, however they are generally limited to use in systems with array low currents due to heat dissipation requirements. In general, on-off shunt controllers consume less power than series type controllers that use relays, so they are best suited for small systems where even minor parasitic losses become a significant part of the system load.

4.5.2 ***Series Regulation:*** This type of controller works in series between the array and battery, rather than in parallel as for the shunt controller. There are several variations to the series type controller, all of which use some type of control or regulation element in series between the array and the battery. While this type of controller is commonly used in small PV systems, it is also the practical choice for larger systems due to the current limitations of shunt controllers.

In a series controller design, a relay or solid-state switch either opens the circuit between the array and the battery to discontinuing charging, or limits the current in a series-linear manner to hold the battery voltage at a high value. In the simpler series interrupting design, the controller reconnects the array to the battery once the battery falls to the array reconnect voltage set point. As these on-off charge cycles continue, the 'on' time becoming shorter and shorter as the battery becomes fully charged.

Because the series controller open-circuits rather than short-circuits the array as in shunt-controllers, no blocking diode is needed to prevent the battery from short-circuiting when the controller regulates.

There are 4 set points in a charge controller: [21]

i. Voltage Regulation (VR) set point
ii. Array Reconnect Voltage (ARV) set point
iii. Low voltage Load Disconnect (LVD) set point
iv. Load Reconnect Voltage (LRV) set point

4.5.3 ***Voltage Regulation Set Point (VR):*** This set point is the maximum voltage a controller allows the battery to reach. At this point a controller will either discontinue battery charging or begin to regulate the amount of current delivered to the battery. Proper selection of this set point depends on the specific battery chemistry and operating temperature.

4.5.4 ***Array Reconnect Voltage Set Point (ARV):*** This set point is voltage when the array is reapplied. The greater this voltage span, the longer the array current is interrupted from charging the battery. If the ARV is too small, then the control element will oscillate, inducing noise and possibly harming the switching element. The ARV is an important factor in determining the charging effectiveness of a controller.

4.5.5 ***Low voltage Disconnect Set Point (LVD):*** This set point is voltage at which the load is disconnected from the battery to prevent over discharge. The LVD defines the actual allowable maximum depth-of-discharge and available capacity of the battery. The available capacity must be carefully estimated in the system design and sizing process. Typically, the LVD does not need to be temperature compensated unless the batteries operate below 0°C on a frequent basis. The proper LVD set point will maintain good battery health while providing the maximum available battery capacity to the system.

4.5.6 ***Load Reconnect Voltage Point (LRC):*** This set point is the voltage at which the load is reconnected to the battery. If the LRC is too small, the load may cycle on and off rapidly at low battery state-of-charge, possibly damaging the load and/or controller. If the LRC is too large, the load may remain off for extended periods until the array fully recharges the battery. With a large LRC, battery health may be improved due to reduced battery cycling, but this will reduce load availability. The proper LRC selection will depend on the battery chemistry, battery capacity, and PV and load currents.

Charge Controller Types Based on Charging Algorithm:

4.5.7 ***On/Off Control:*** This is the most basic charge controlling method which simply monitors the battery voltage and opens the array circuit, stopping the charging, when the battery voltage rises to a certain level. Similarly opens the load circuit, stopping the discharging, when the battery voltage falls to a certain level. There are hysteresis to avoid frequent connect/disconnect cycles.

4.5.8 ***PWM Control:*** This algorithm uses a semiconductor switching element between the array and battery which is switched on/off at a variable frequency with a variable duty cycle to maintain the battery at or very close to the voltage regulation set point. By electronically controlling the high speed switching or regulation element, the PWM controller breaks the array current into pulses at some constant frequency, and varies the width and time of the pulses to regulate the amount of charge flowing into the battery. When the battery is discharged, the current pulse width is practically fully on all the time. As the battery voltage rises, the pulse width is decreased, effectively reducing the magnitude of the charge current. PWM helps the battery to stay healthy and charge to the fullest capacity. [22]

4.5.9 ***MPPT Control:*** MPPT or Maximum Power Point Tracking is an algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. MPPT is actually a DC to DC Buck-Boost converter which operates the panel at maximum power point under any condition by ensuring that the multiple of V and I is maximum. MPPT controller are made using inductor, capacitor, MOSFET/IGBT and a Microcontroller that executes the algorithm. [23]

Charge Controllers are very important component of a solar system that protects the battery of a solar system. Therefore, understanding the functionality and performance of a charge controller is necessary for anyone who wishes to design a better solar system.

4.6 Energy Storage and Distribution:

4.6.1 Battery: Electric power is generated only during day time by PV panels. But we need lights at night also. So some sort of storage system has to be used with PV system. Although various types of storage systems are available in the market Batteries are commonly used in PV systems. [25]

Batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer). [26]

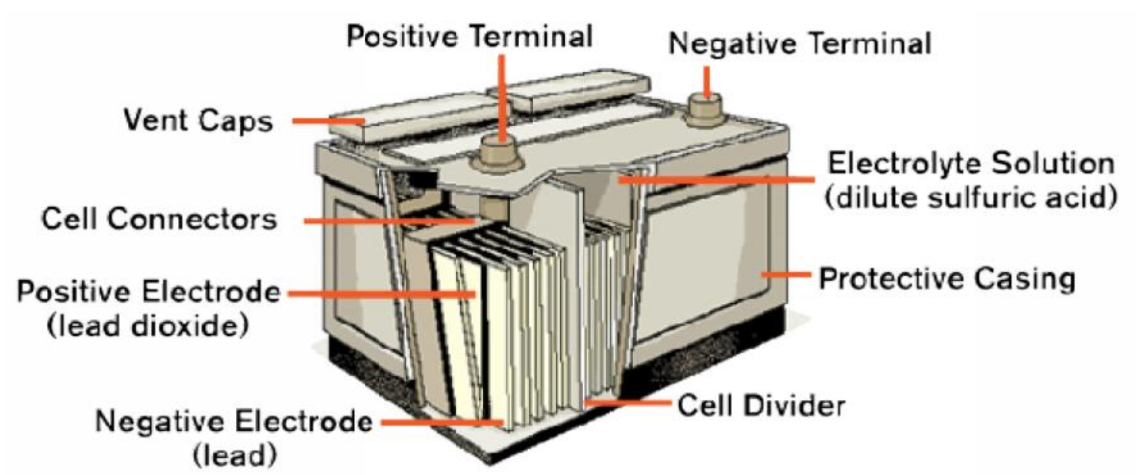


Figure 4.7: Battery (Lead-Acid).

A battery consists of a number of cells and each cell of the battery consists of (a) positive and negative plates (b) separators (c) electrolyte and d) container.

4.6.1.1 ***Charging:*** During charging, the positive active material is oxidized, producing electrons, and the negative material is reduced, consuming electrons. These electrons constitute the current flow in the external circuit. The electrolyte may serve as a simple buffer for internal ion flow between the electrodes, as in lithium-ion and nickel-cadmium cells, or it may be an active participant in the electrochemical reaction, as in lead–acid cells. [24]

The energy used to charge rechargeable batteries usually comes from a battery charger using AC mains electricity, although some are equipped to use a vehicle's 12-volt DC power outlet. Regardless, to store energy in a secondary cell, it has to be connected to a DC voltage source. The negative terminal of the cell has to be connected to the negative terminal of the voltage source and the positive terminal of the voltage source with the positive terminal of the battery. Further, the voltage output of the source must be higher than that of the battery, but not much higher: the greater the difference between the power source and the battery's voltage capacity, the faster the charging process, but also the greater the risk of overcharging and damaging the battery.

4.6.1.2 ***Discharging:*** In a battery there are two electrodes immersed in an electrolyte. When an external load is connected to these two electrodes, oxidation reaction starts occurring in one electrode and at the same time reduction occurs in other electrode.

The electrode, where oxidation takes place, the number of electrons becomes excess. This electrode is referred as negative electrode or anode. [33]

On the other hand during discharging of battery, the other electrode involves in reduction reaction. This electrode is referred as cathode. The electrons which are excess in anode, now flow to the cathode through external load. In cathode these electrons are accepted, that means cathode material involve in reduction reaction.

Now the products of oxidation reaction at anode are positive ions or cations and that will flow to the cathode through the electrolyte and the same time products of reduction reaction at cathode are negative ions or anions and that flow to anode through the electrolyte.

4.6.1.3 ***Charging and discharging rate:*** The capacity of a battery is often referred to as C A-h. Thus, if a load is connected to a battery such that the battery will discharge in x hours, the discharge rate is referred to as C/x. The charging of a battery is measured in a similar fashion. Figure 6 indicates the effect of discharging rates on the relative amount of charge that can be obtained from a lead-acid battery. Note that higher discharge rates result in less charge being available as energy to a load. At higher charging rates, a smaller fraction of the charging energy is used for charging and a larger fraction is used to heat up the battery. The battery can be fully charged at higher charging rates, but it takes more energy at higher charging rates to obtain full charge. [32]

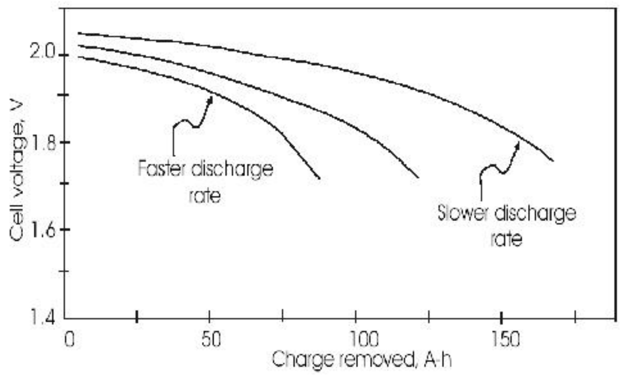


Figure 4.8: Effect of discharging rate.

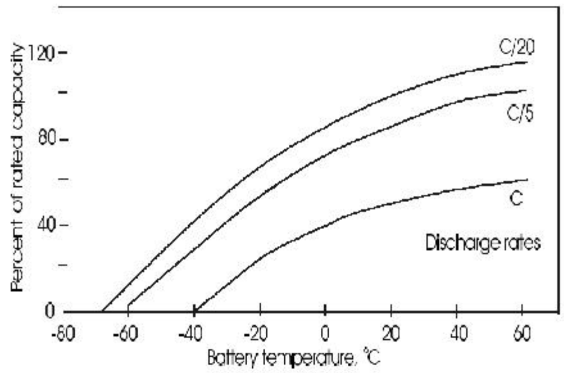


Figure 4.9: Effect of temperature and discharge rate

Since the charging or discharging current must pass through the internal (Thevenin) resistance of the battery, a power loss equal to I^2R occurs. For constant current charging or discharging, the charge delivered to or removed from the battery is given by $Q = It$. Since Q is proportional to energy storage, the energy stored is thus proportional to I, whereas the energy lost is proportional to I^2. Hence, at higher charging or discharging rates, a larger fraction of available charging energy is lost to resistive heating. This effect is compensated for somewhat by the fact that warm batteries are capable of storing more charge than cold batteries.

4.6.1.4 *Depth of Discharge (DOD):* Depth of Discharge (DOD) is an alternate method to indicate a battery's state of charge (SOC). The DOD is the complement of SOC: as the one increases, the other decreases. While the SOC units are percent points (0% = empty; 100% = full), DOD can use Ah units (e.g.: 0 = full, 50 Ah = empty) or percent points (100% = empty; 0% = full). As a battery may actually have higher capacity than its nominal rating, it is possible for the DOD value to exceed the full value (e.g.: 55 Ah or 110%), something that is not possible when using state of charge. [34]

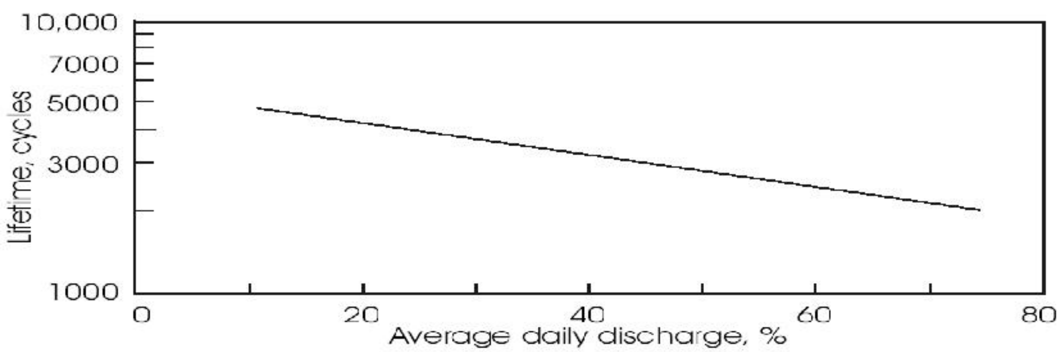


Figure 4.10: Battery lifetime in cycle's vs. depth of discharge per cycle

The depth of discharge affects the number of operating cycles of a deep discharge battery. The PV system designer must carefully consider the trade-off between using more batteries operating at shallower discharge rates to extend the overall life of the batteries vs. using fewer batteries with deeper discharge rates and the correspondingly lower initial cost.

Battery is an important component of a solar system that store electrical energy. Battery life cycle is also important for system life-time. By regular monitoring a battery give a better life-time. For that reason, every system must have to use battery monitoring sheet for battery best performance.

4.6.2 Grid: A grid-connected photovoltaic power system or grid-connected PV system is electricity generating solar PV system that is connected to the utility grid. A grid-connected PV system consists of solar panels or large arrays, one or several inverters, a power conditioning unit and grid connection equipment. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid. [36]

Grid-connected PV systems, although small compared with other power generation sources are becoming very popular all over the world. Grid-Connected PV Systems, also called utility interactive PV systems, always have a connection to the public electricity grid via a suitable inverter, because a PV module delivers only a dc power. Normally there is almost no effect of the PV system on the grid affecting power quality, load on lines, and transformers etc.

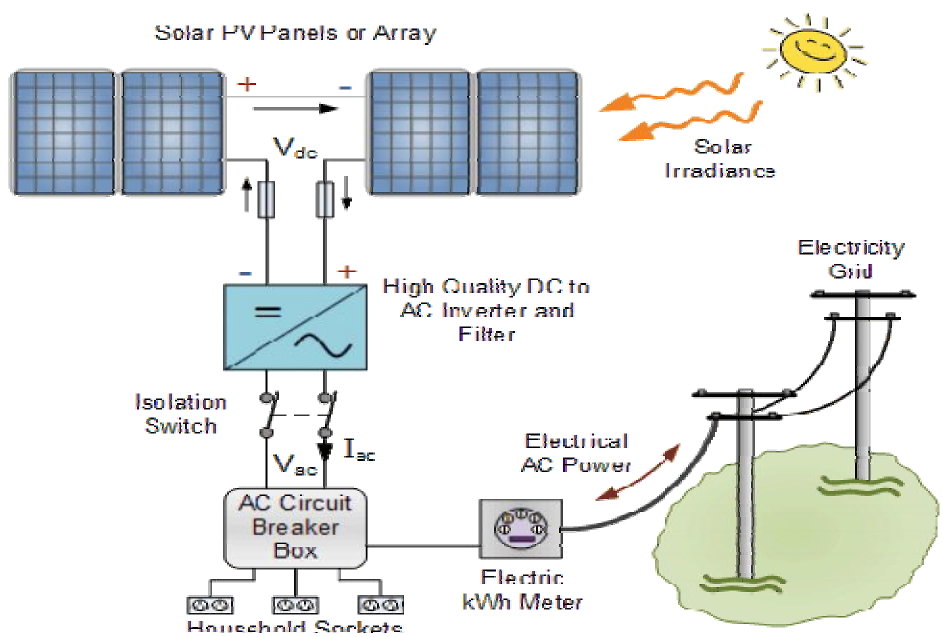


Figure 4.11: Grid-connected PV systems

Grid-connected PV systems can be subdivided into two kinds:

i. Decentralized Grid-connected PV systems
ii. Centralized Grid-connected PV systems

4.6.2.1 ***Decentralized Grid-connected PV systems:*** Decentralized Grid-connected PV systems have mostly a small power range and are installed on the roof-top of buildings (roof-top or flat-roof installation) or integrated into building facades.

Energy storage is not necessary in this case. On sunny days, the solar generator provides power, e.g., for the electrical appliances in the house. Excess energy is supplied to the national grid. During the night and overcast days, the house draws its power from the grid. In this way, the electricity grid can be regarded as a large "storage unit". In the case of a favorable rate-based tariff for PV electricity, as in force in some countries, it is more advantageous to feed all solar electricity into the grid. [37]

4.6.2.2 ***Centralized Grid-connected PV systems:*** Central Grid-connected PV systems have an installed power up to few MW range. With such central photovoltaic power stations it is possible to feed directly into the medium or high voltage grid. Mostly central photovoltaic power stations are set on unused land, but in some cases an installation on buildings, mostly on the flat roof of greater buildings, is also possible. [38]

The grid connected PV systems are ideal for loads which vary in proportion to the irradiation. Typical loads are air-conditioning, refrigeration and pumping. Other significant loads can be timed to operate when PV power is likely to be available.

CHAPTER: 05

SERVER CONFIGURATION

CHAPTER: 05

SERVER CONFIGURATION

5.1 Introduction:

A server is a computer program or a device that provides functionality for other programs or devices, called "clients". This architecture is called the client–server model, and a single overall computation is distributed across multiple processes or devices. Servers can provide various functionalities, often called "services", such as sharing data or resources among multiple clients, or performing computation for a client. A single server can serve multiple clients, and a single client can use multiple servers. A client process may run on the same device or may connect over a network to a server on a different device. Typical servers are database servers, file servers, mail servers, print servers, web servers, game servers, and application servers.

The purpose of a server is to share data as well as to share resources and distribute work. A server computer can serve its own computer programs as well; depending on the scenario, this could be part of a quid pro quo transaction, or simply a technical possibility. [52]

5.2 Linux Operating System:

Operating systems are computer programs. An operating system is the first piece of software that the computer executes when you turn the machine on. The operating system loads itself into memory and begins managing the resources available on the computer. It then provides those resources to other applications that the user wants to execute. [53]

Linux is the best-known and most-used open source operating system. As an operating system, Linux is software that sits underneath all of the other software on a computer, receiving requests from those programs and relaying these requests to the computer’s hardware. [54]

For this study of server configuration I used a Linux based Operating System named CentOS and its version was *CentOS 6.3*. CentOS (abbreviated from Community Enterprise Operating System) is a Linux distribution that attempts to provide a free, enterprise-class, community-supported computing platform which aims to be functionally compatible with its upstream source, Red Hat Enterprise Linux (RHEL). In January 2014, CentOS announced the official joining with Red Hat while staying independent from RHEL, under a new CentOS governing board.

5.3 Sever Configuration.

For this server configuration below services need to configure sequentially. [49]

- Web Server: A Web server to display network graphs created by PHP and RRDTool.
- PHP: A script module to create graphs using RRDTool.
- PHP-SNMP : A PHP extension for SNMP to access data.
- MySQL Server: A Database server to store cacti information.
- NET-SNMP : A SNMP (Simple Network Management Protocol) is used to manage network.
- RRDTool : A database tool to manage and retrieve time series data like CPU load

5.3.1 Web Server Configuration:

```
[root@www ~]#  yum -y install httpd

#Removal of welcome page
[root@www ~]#  rm -f /etc/httpd/conf.d/welcome.conf

# Removal of default error page
[root@www ~]#  rm -f /var/www/error/noindex.html

# Create a link for Perl
[root@www ~]#  ln -s /usr/bin/perl /usr/local/bin/perl
```

5.3.2 PHP Server Configuration:

```
[root@www ~]#  yum -y install php php-mbstring php-pear
[root@www ~]#  /etc/rc.d/init.d/httpd restart
Stopping httpd: [ OK ]
Starting httpd: [ OK ]
```

5.3.3 MySQL Server (Database) Configuration:

```
[root@www ~]# yum -y install mysql-server
[root@www ~]#  /etc/rc.d/init.d/mysqld start

Initializing MySQL database: Installing MySQL system tables...
OK
Filling help tables...
OK
```

5.3.4 Dag RPM Repository Configuration:

For many useful packages need to install and configure YUM.

```
[root@dlp ~]#  wget http://dag.wieers.com/rpm/packages/RPM-
GPG-KEY.dag.txt
[root@dlp ~]#  rpm --import RPM-GPG-KEY.dag.txt

[root@dlp ~]#  rm -f RPM-GPG-KEY.dag.txt
```

Repository Location:

```
[root@dlp ~]#  vi /etc/yum.repos.d/dag.repo

# create new
[dag]
name=Dag RPM Repository for Red Hat Enterprise Linux
baseurl=http://apt.sw.be/redhat/el5/en/$basearch/dag/
gpgcheck=1
enabled=0
```

5.3.5 SNMP Configuration:

```
[root@www ~]#  yum --enablerepo=dag -y install cacti* net-
snmp* rrdtool
[root@www ~]# vi /etc/snmp/snmpd.conf

# create new
rocommunity public


[root@www ~]#  /etc/rc.d/init.d/snmpd start
Starting snmpd:   [  OK  ]

[root@www ~]#  chkconfig snmpd on
```

5.3.6 MySQL Database Configuration:

We just installed MySQL we still have to set a password for MySQL server. We also have to create a new database and Table for graph server and create a new user account:

```
# mysqladmin -u root password MYPASSWORD
```

MySQL server now has a password, let's login and create a database and user account:

```
# mysql -u root -p
Enter password: MYPASSWORD

Welcome to the MySQL monitor.  Commands end with; or g.
Your MySQL connection id is 3
Server version: 5.1.69 Source distribution

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affiliates. Other names may be trademarks of their
respective
owners.

Type 'help;' or 'h' for help. Type 'c' to clear the current
input statement.

mysql> create database cacti;
Query OK, 1 row affected (0.01 sec)

mysql> grant all on cacti.* to cacti@localhost identified
by 'MYPASSWORD';
Query OK, 0 rows affected (0.00 sec)

mysql> flush privileges;
Query OK, 0 rows affected (0.00 sec)

mysql> exit
Bye
```

We have a new database called 'cacti' and a username called 'cacti'. The database is there but it's still empty. We'll import a file from the Cacti installation into the database. First we need to find out where it is located:

```
# rpm -ql cacti | grep cacti.sql
/usr/share/doc/cacti-0.8.8a/cacti.sql
```

In my case it's in the folder above. We'll import this SQL file into the database:

```
# mysql -u cacti -p cacti < /usr/share/doc/cacti-
0.8.8a/cacti.sql
```

This will fill the database…now we need to edit the database configuration file of cacti so that it uses the correct database name and username:

```
# vi /etc/cacti/db.php
```

Another location:-

```
# vi /var/www/cacti/include/config.php
```

I'll use vi as the text editor. Below you will find the part that we are looking for:

```
/* make sure these values refect your actual database/host/user/password */
$database_type = "mysql";
$database_default = "cacti";
$database_hostname = "localhost";
$database_username = "cacti";
$database_password = "cacti";
$database_port = "3306";
$database_ssl = false;
```

Make sure it reflects my database name and username/password. When it's done save the file and exit vi. We still have to configure Apache server.

5.3.7 Apache Configuration:

We can change the Apache configuration to choose what IP addresses / subnets are allowed to connect. You can do this by editing the following file:

```
# vi /etc/httpd/conf.d/cacti.conf
```

This is the part we are looking for:

```
<Directory /usr/share/cacti/>
        <IfModule mod_authz_core.c>
                # httpd 2.4
                Require host localhost
        </IfModule>
        <IfModule !mod_authz_core.c>
                # httpd 2.2
                Order deny,allow
                Deny from all
                Allow from localhost
        </IfModule>
</Directory>
```

I will change "**Allow from localhost**" to "**Allow from 192.168.0.252**" so that I can access Cacti from **192.168.0.0/24** IP Network:

```
Allow from 192.168.0.252/24
```

If anyone installing Cacti for a production environment then it's better to make things a little bit more secure by only selecting a certain range of IP addresses like this:

```
Allow from 192.168.1.0/24
```

If anyone wants to allow all network he should be configure as "**Allow from all**".

```
Allow from all
```

Once configuration or change is done, need to save configuration and exit vi. And always need to restart Apache like below:

```
# service httpd restart
```

MySQL and Apache are now up and running. The last thing to do is enable a Cronjob. This allows Cacti to collect information from devices.

5.3.8 Cron Configuration:

By default Cron will collect data from devices every 5 minutes but the cron job is disabled by default. I need to enable it:

```
# vi /etc/cron.d/cacti
```

I 'will find the line below:

```
#*/5 * * * * cacti /usr/bin/php /usr/share/cacti/poller.php > /dev/null 2>&1
```

Need to remove the # so that it looks like this:

```
*/5 * * * * cacti /usr/bin/php /usr/share/cacti/poller.php > /dev/null 2>&1
```

Save changes and exit vi editor. We can now access the web installer.

5.3.9 Cacti Configuration:

We can access the GUI from our web browser using "**`http://192.168.0.252/cacti`**". It will have different locations like "**`http://localhost/cacti`**", and "**`http://MY-IP-ADDRESS/cacti`**" It will look like below pictures and have steps of installation:

Step 01: *Browse* ***`http://192.168.0.252/cacti`***

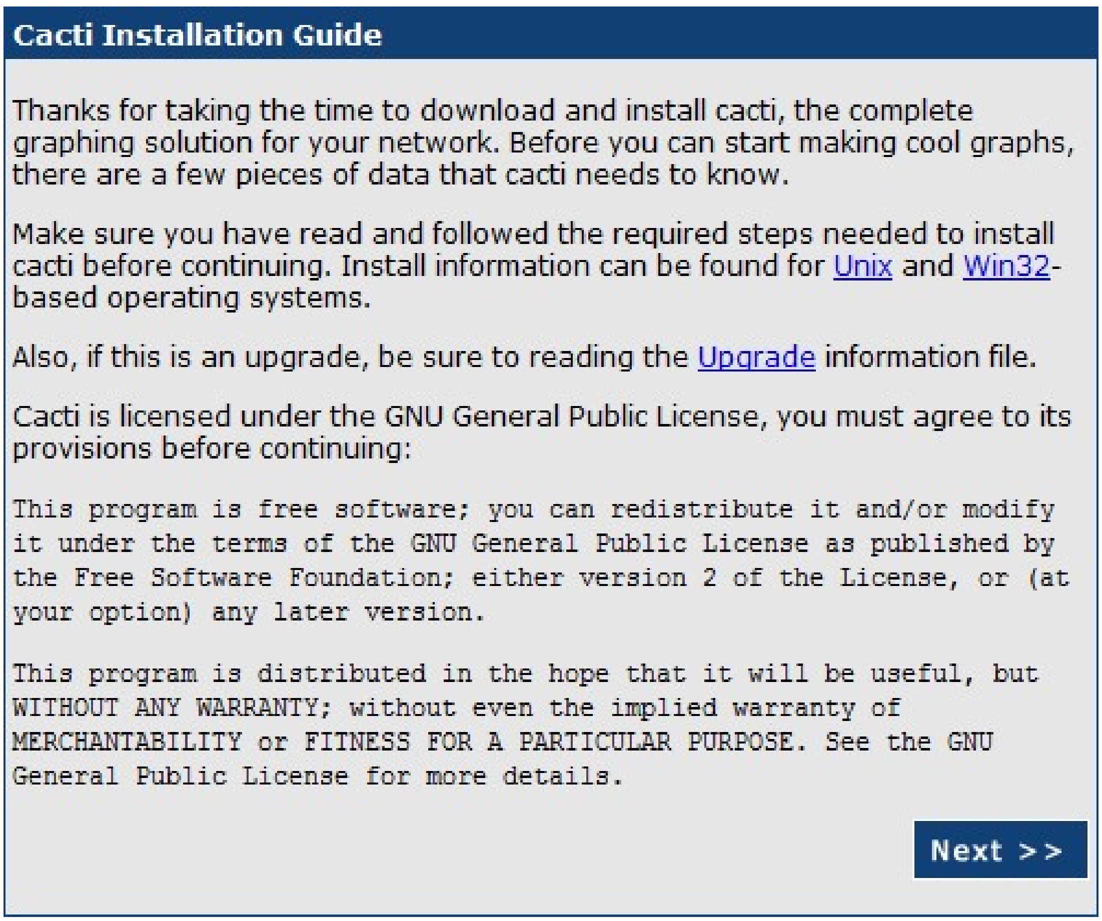

Figure 5.1: Cacti Installation Step 01

Step 02: *Go to the next*

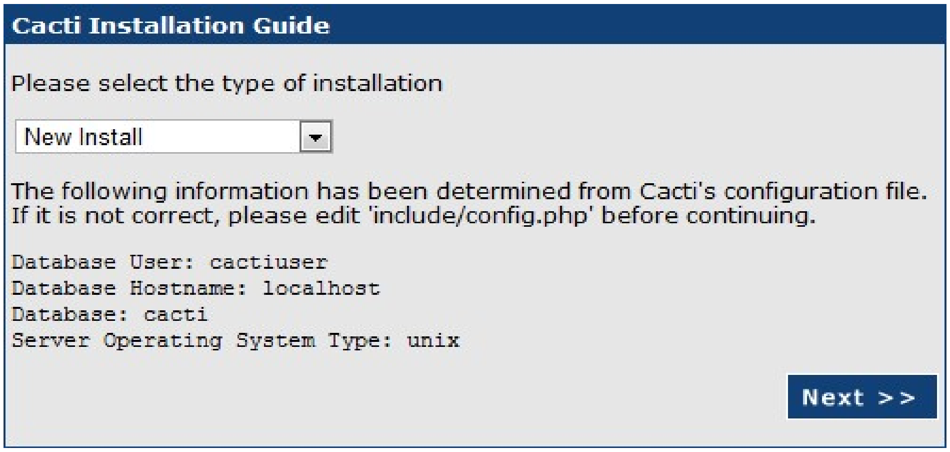

Figure 5.2: Cacti Installation Step 02

Step 03: *Click* **'Finish'.** *It's all OK with default because all are installed by RPM packages.*

Figure 5.3: Cacti Installation Step 03

Step 04: *Input **'admin'** for username and password and Login.*

Figure 5.4: Cacti Installation Step 04

Step 05: *It's necessary to change password after login. Change and Save it.*

Figure 5.5: Cacti Installation Step 05

Step 06: *This is the main page of graph server's GUI.*

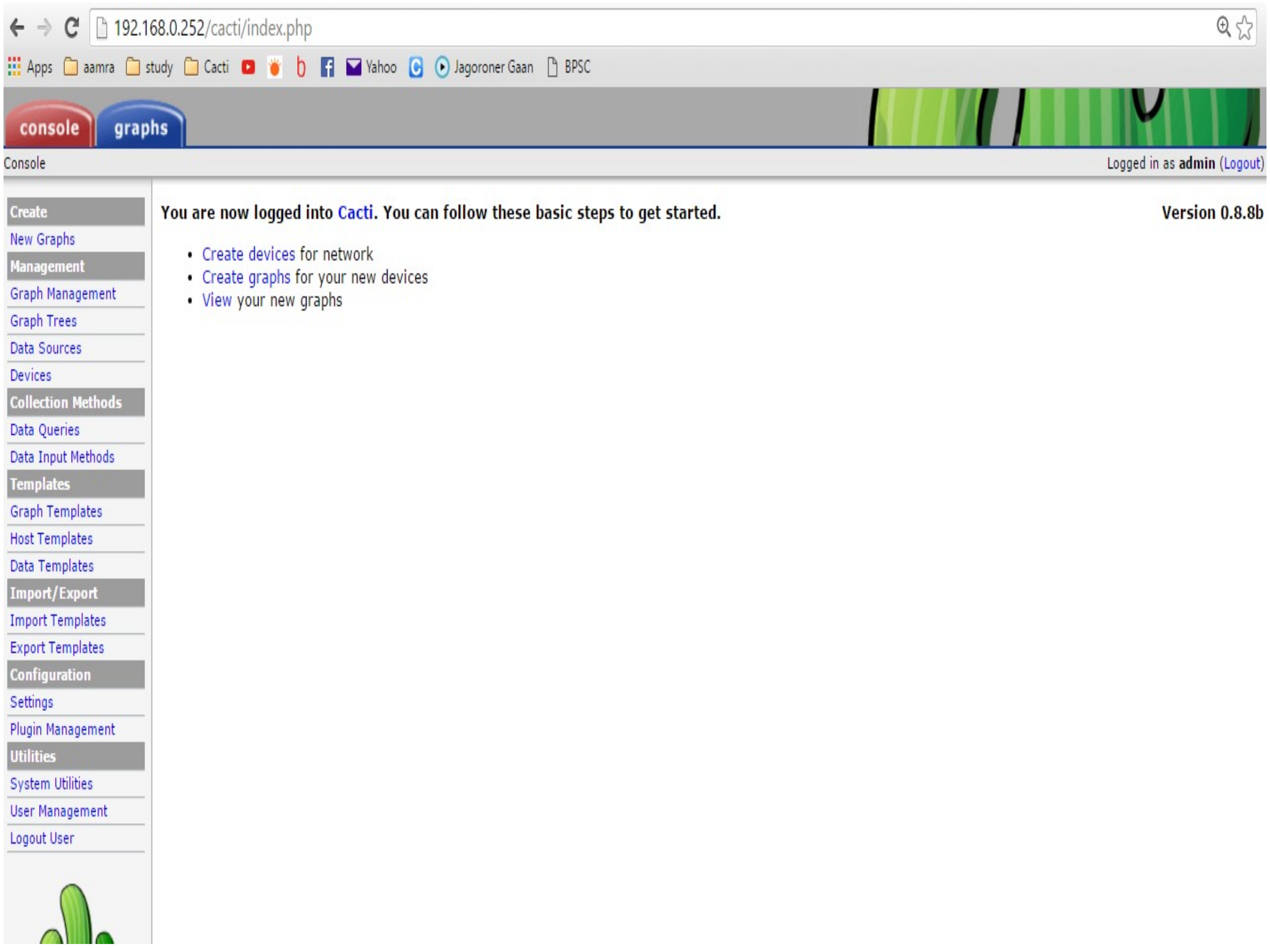

Figure 5.6: Main page graphical view of graph server (Cacti).

CHAPTER: 06

NETWORKING AND STATION ADDING PROCESS

CHAPTER: 06

NETWORKING AND STATION ADDING PROCESS

6.1 Introduction:

Networking is the construction, design, and use of a network, including the physical (cabling, hub, bridge, switch, router, and so forth), the selection and use of telecommunication protocol and computer software for using and managing the network, and the establishment of operation policies and procedures related to the network.

6.2 Network Design for the study:

For the study there are two ways of network design such as physical network and logical network.

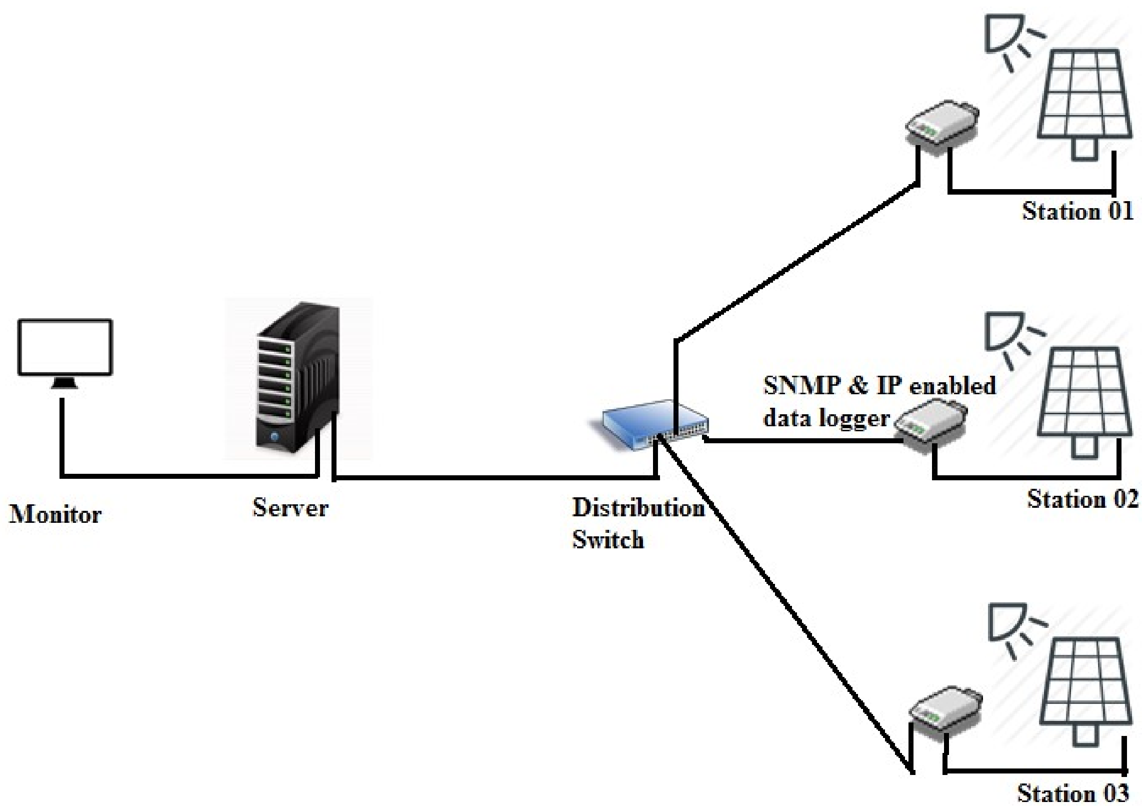

Figure 6.1: Diagram of the study Network

6.2.1 Physical Connection: In the physical part of the system design combines with Solar Photovoltaic (PV) panels which categorized as *Stations (Like station 01, station 02, station 03).* Panels are connected with a data logger by wiring. Every single panel is connected with single data logger that's why each panel (station) will provide actual and specific information of data. Data loggers are connected with a distribution Switch by Ethernet RJ45 connector. There UTP (Unshielded Twisted Pair) cable is used for communication.

Distribution switch has different number of Ethernet ports. Here I used Dell Latitude LB-MDP8 series switch. We can easily connect different number of stations which we need to monitor. Switch is finally connected with a Server which stores collected data from stations and view as a graph and data sheet. A desktop Computer configures as a Server. For connection switch and server there also used UTP cable with RJ45 connector. Server can easily monitored and view with a Monitor.

a) Switch b) UTP Cable b) RJ45 Connector

Figure 6.2: Connection Equipments (Switch, UTP cable and RJ45 connector).

For complexity of power (PV) plant and Data Logger with IP & SNMP supported problem it was not easy to collect data. In this study I used two Laptops and a Desktop Computer for collecting voltage data and get into the server.

6.2.2 Logical Connection: For the logical part of the study, I configured a graph and data server named Cacti. The server has a static IP Address for communication with own network. The IP Address of the server was 192.168.0.252 and subnet mask 255.255.255.0. Server has allowed a Private Network (192.168.0.0/24) for this study. Server has several services running and they are Web service, Apache, MySQL, RRDTool, SNMP and PHP.

Simple Network Management Protocol (SNMP) is used which is a protocol for collecting and organizing information about managed devices on IP networks and for modifying that information to change device behavior. Web Service shows graphical web page and MySQL is a database service that can store data which we achieved from stations.

Data logger is also an IP based and SNMP supported device which connected with panel load and provide actual voltage data from the panel. For this study I used three stations of Two Laptops and A Desktop (*problems are previously discussed*) and set IP address of 192.168.0.150, 192.168.0.151 and 192.168.0.152.

IP Address for **Server**: ***192.168.0.252***

IP Address for **Station 01**: ***192.168.0.150***

IP Address for **Station 02**: ***192.168.0.151***

IP Address for **Station 03**: ***192.168.0.152***

6.3 Station Adding steps with Server:

For graphical view of the stations status and get data server there need to add host with a standard procedure. How to add stations, steps are discussed below as graphically.

Step 01: Browse Server (`http://192.168.0.252/Cacti`) and login into server with **username** and **password**. #Go to `Console> New Graphs` and click `Create New Host`

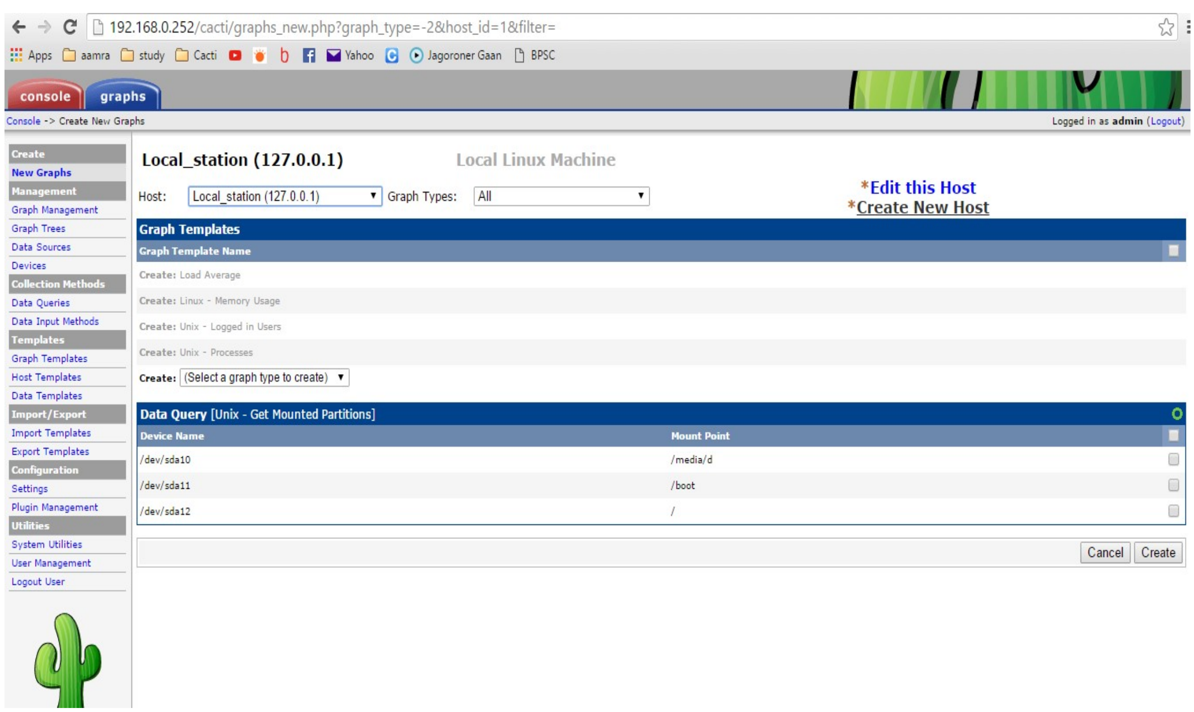

Figure 6.3: New Graph Addition

Step 02: Add Description (i.e: graph_station_01), Hostname (IP address like **`192.168.0.150`**), Select Host Template. Must select SNMP Version and SNMP Community (**`public`** is default but anyone can customize device's community name). Click **`Create`** and go to the next step.

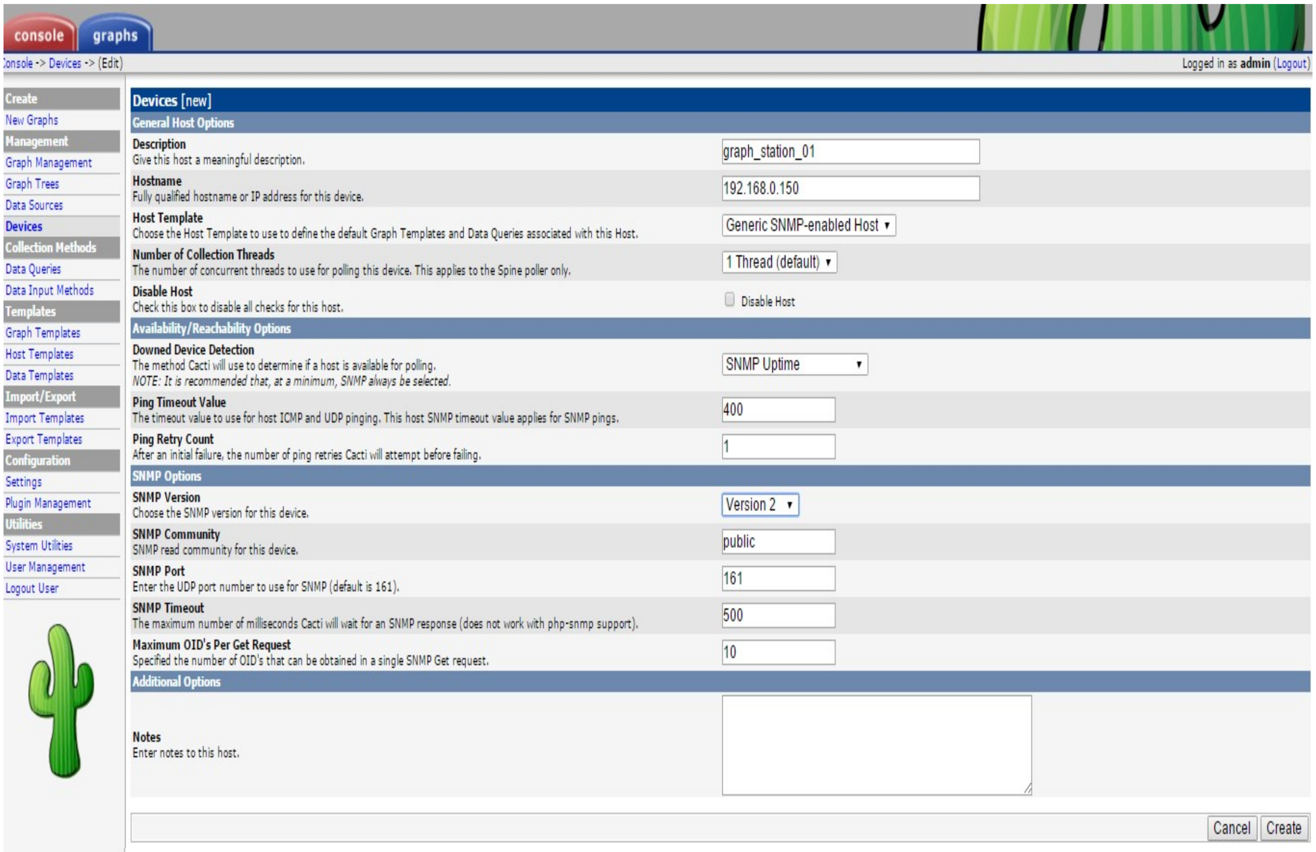

Figure 6.4: New Host Creation.

Step 03: In this stage SNMP enabled shows confirmation with host community name matching. Click to **`Create Graphs for this Host`**.

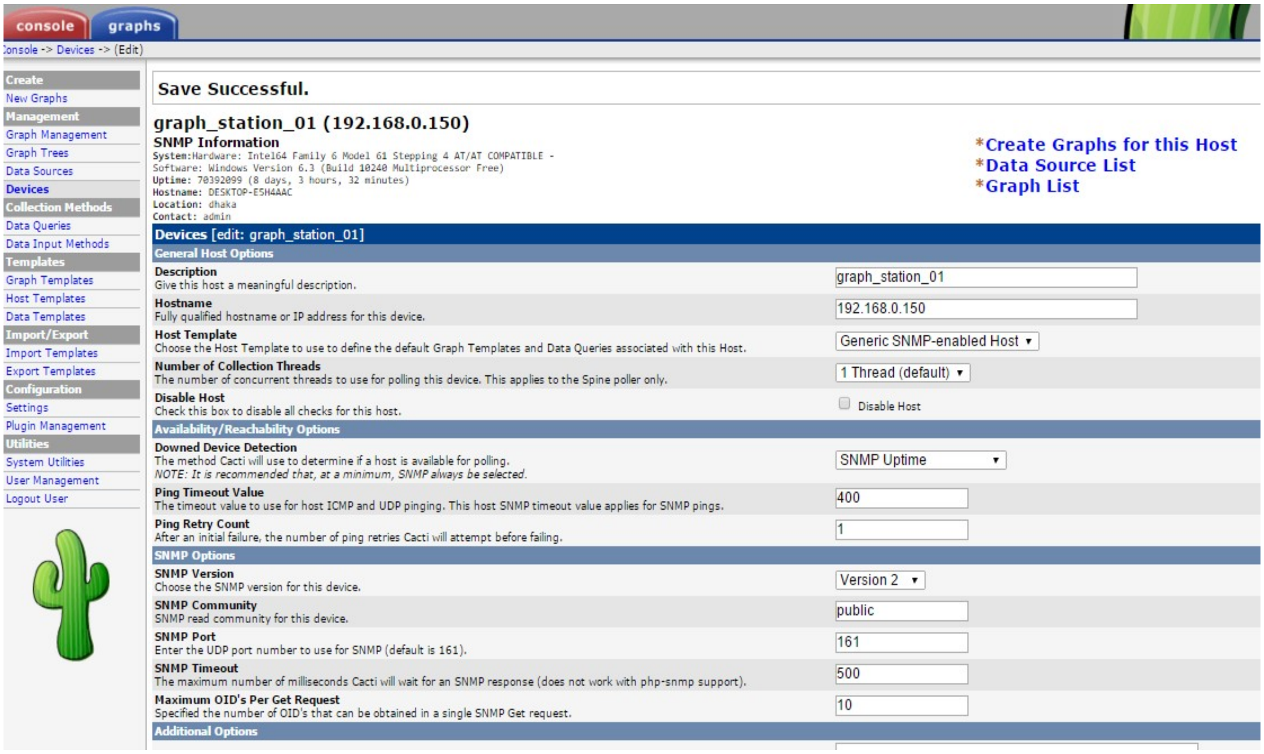

Figure 6.5: SNMP and Community confirmation.

Step 04: Go to **`Graph Trees`** and select Tree where station added

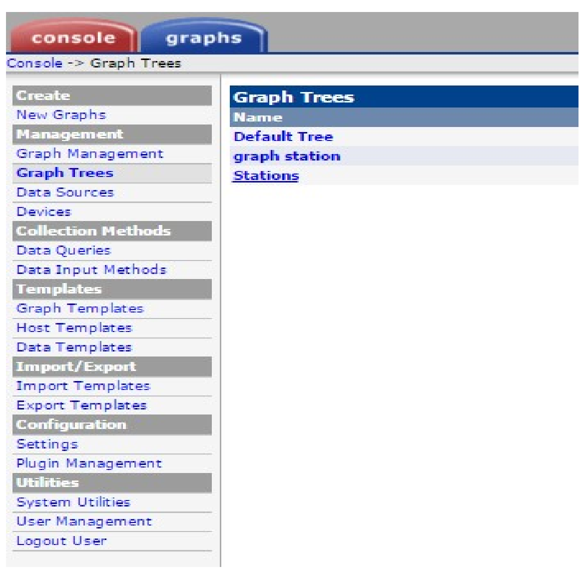

Figure 6.6: Graph adding into proper Tree.

Step 05: Go to **`Graph Trees> Station> Add`**

Select **`Tree Item Type`** as **`Host,`** Host is **`graph_station_01`** and select **`Daily(5 Minutes Average)`** this will provide ***voltage graph and data every 5 minutes interval.***

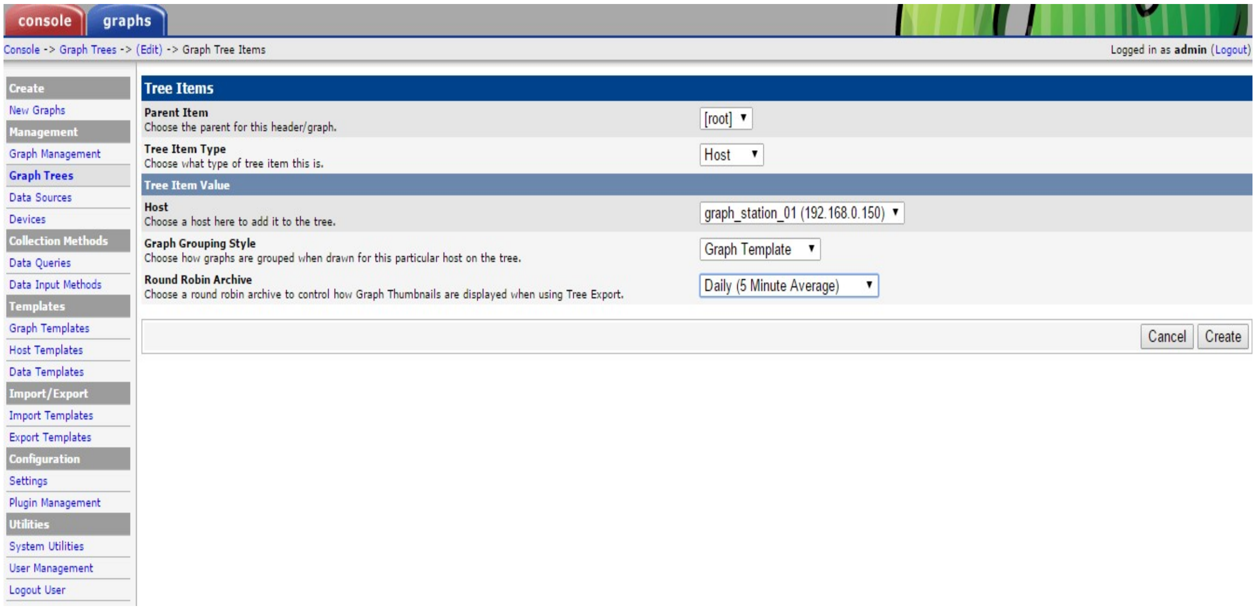

Figure 6.7: Graph adding into proper Tree.

Step 06: Finally **`graph_station_01`** is added to "**`Stations`**" tree and below view.

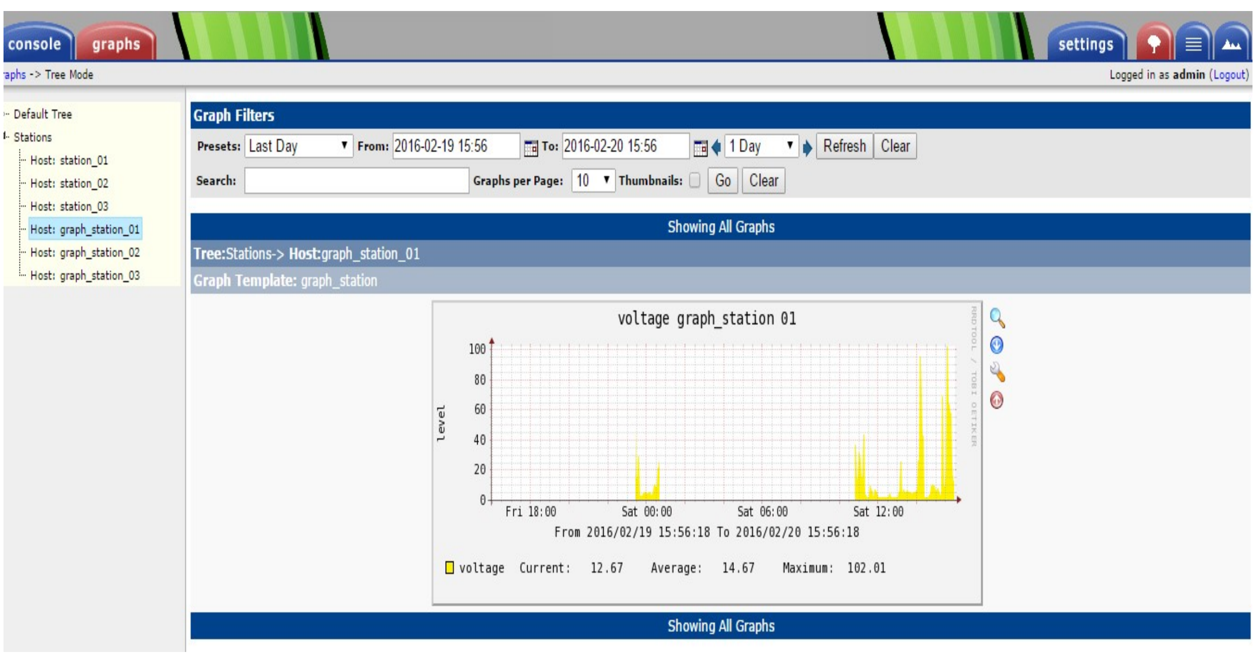

Figure 6.8: Final view of adding stations into the Server.

CHAPTER: 07

DATA ANALYSIS AND FINALIZATION

CHAPTER: 07

DATA ANALYSIS AND FINALIZATION

7.1 Data:

Data is a set of values of qualitative or quantitative variables; restated, pieces of data are individual pieces of information. Data is measured, collected and reported, and analyzed, whereupon it can be visualized using graphs or images. Data as a general concept refers to the fact that some existing information or knowledge is represented or coded in some form suitable for better usage or processing.

Analysis of data is a process of inspecting, cleaning, transforming, and modeling data with the goal of discovering useful information, suggesting conclusions, and supporting decision-making. Data analysis has multiple facets and approaches, encompassing diverse techniques under a variety of names, in different business, science, and social science domains. [55]

7.2 Data Presentation:

For this study work data is presenting below with graphical and statistical presentation for separate three voltage source stations.

7.2.1 Station 01 Graphical Data:

Graphical view from server is below in Daily 5 minutes average

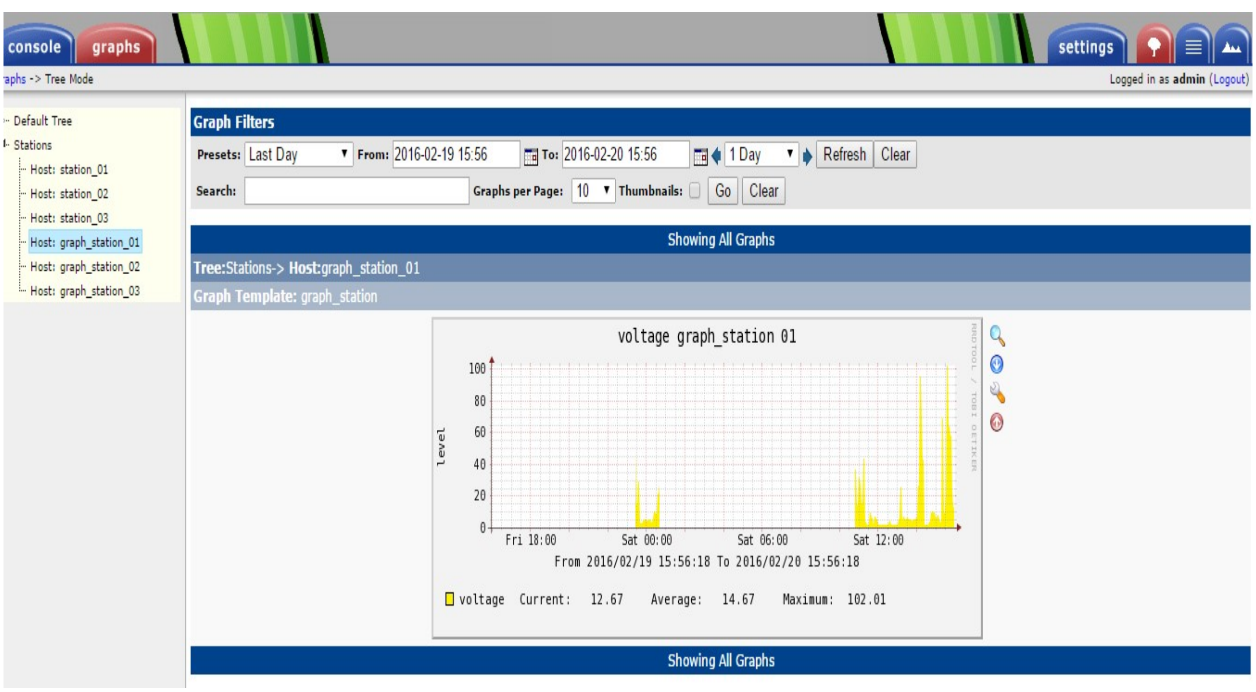

Figure 7.1: Basic data graph for ***Station 01.***

The graph with Daily 5 Minutes Average Voltage to Weekly 30 Minutes average and Monthly 2 Hours graph showing for **Station 01** (2/19/16 23:15 to 2/20/16 20:55)

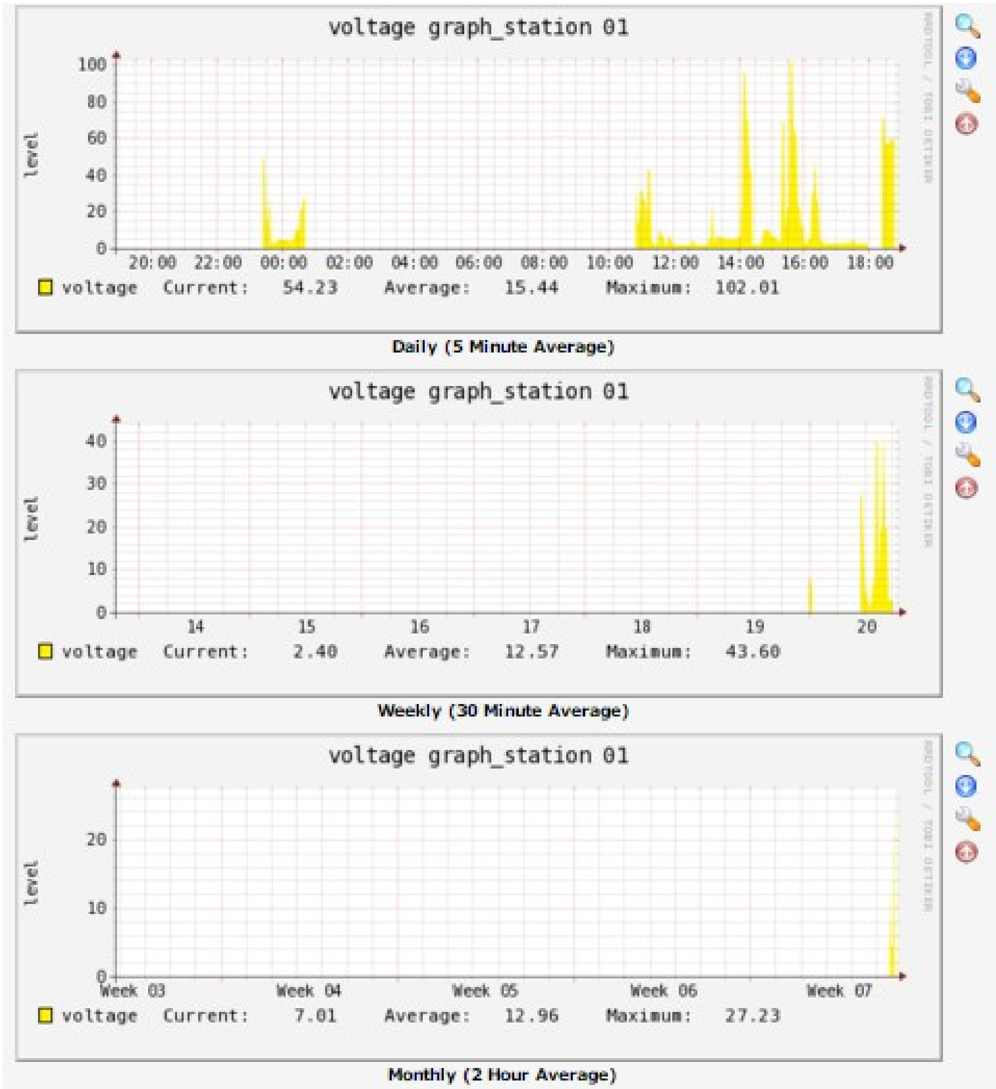

Figure 7.2: Weekly and monthly data graph for ***Station 01.***

From this graph we can see that, *Voltage level for Daily 5 Minutes Average was:*

Current: 54.23 V, Average: 15.44 V and Maximum: 102.01 V

Voltage level for Weekly 30 Minutes Average was:

Current: 2.4 V, Average: 12.57 V and Maximum 43.60 V

Voltage level for Monthly 2Hours Average was:

Current: 7.01 V, Average: 12.96 V and Maximum: 27.23 V

We can see the actual data graph for Daily 5 Minutes data graph with below graph when we can create zoom for the graph (2/19/16 23:15 to 2/20/16 20:55)

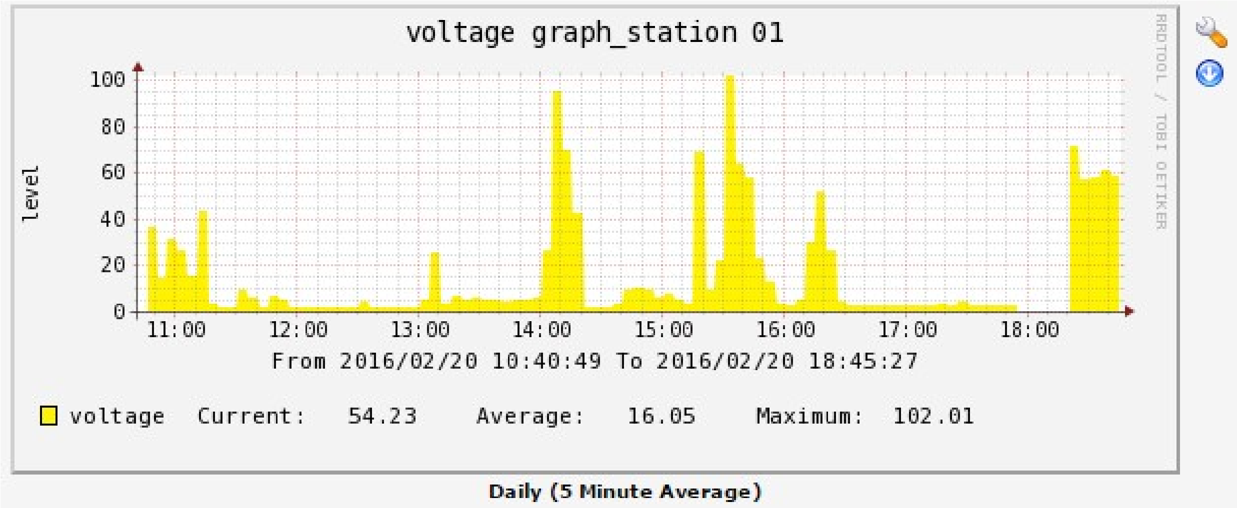

Figure 7.3: Daily 5 Minutes data graph for ***Station 01***(zooming view).

7.2.2 Station 01 Statistical Data:

In this stage we get 5 minutes duration actual data value from the station.

Title:	'voltage graph_station 01'
Vertical Label:	'level'
Start Date:	2/19/2016
End Date:	2/20/2016
Step:	300.00
Total Rows:	288.00
Graph ID:	23.00
Host ID:	6.00

Date	voltage
2/19/16 23:15	NaN
2/19/16 23:20	NaN
2/19/16 23:25	48.10
2/19/16 23:30	14.12
2/19/16 23:35	28.91
2/19/16 23:40	2.03
2/19/16 23:45	2.23
2/19/16 23:50	3.86

2/19/16 23:55	5.16
2/20/16 0:00	3.84
2/20/16 0:05	4.24
2/20/16 0:10	4.77
2/20/16 0:15	3.37
2/20/16 0:20	4.76
2/20/16 0:25	9.99
2/20/16 0:30	8.41
2/20/16 0:35	20.74
2/20/16 0:40	27.03
2/20/16 0:45	NaN
2/20/16 10:45	NaN
2/20/16 10:50	36.25
2/20/16 10:55	13.87
2/20/16 11:00	30.99
2/20/16 11:05	26.16
2/20/16 11:10	15.51
2/20/16 11:15	43.37
2/20/16 11:20	2.98
2/20/16 11:25	1.12
2/20/16 11:30	1.50
2/20/16 11:35	9.38
2/20/16 11:40	5.95
2/20/16 11:45	1.60
2/20/16 11:50	6.69
2/20/16 11:55	4.74
2/20/16 12:00	1.41
2/20/16 12:05	1.26
2/20/16 12:10	1.27
2/20/16 12:15	1.40
2/20/16 12:20	1.60
2/20/16 12:25	1.24
2/20/16 12:30	1.46
2/20/16 12:35	4.13
2/20/16 12:40	1.15
2/20/16 12:45	1.66
2/20/16 12:50	1.43
2/20/16 12:55	1.78
2/20/16 13:00	1.37
2/20/16 13:05	5.20
2/20/16 13:10	25.56

2/20/16 13:15	2.95
2/20/16 13:20	6.32
2/20/16 13:25	4.71
2/20/16 13:30	5.61
2/20/16 13:35	5.14
2/20/16 13:40	5.11
2/20/16 13:45	4.03
2/20/16 13:50	4.79
2/20/16 13:55	4.81
2/20/16 14:00	6.20
2/20/16 14:05	25.82
2/20/16 14:10	95.33
2/20/16 14:15	69.96
2/20/16 14:20	42.70
2/20/16 14:25	1.80
2/20/16 14:30	1.63
2/20/16 14:35	1.69
2/20/16 14:40	3.60
2/20/16 14:45	9.20
2/20/16 14:50	10.23
2/20/16 14:55	9.27
2/20/16 15:00	5.95
2/20/16 15:05	7.16
2/20/16 15:10	4.78
2/20/16 15:15	2.96
2/20/16 15:20	69.10
2/20/16 15:25	9.03
2/20/16 15:30	21.84
2/20/16 15:35	102.01
2/20/16 15:40	63.32
2/20/16 15:45	57.83
2/20/16 15:50	22.77
2/20/16 15:55	12.67
2/20/16 16:00	2.98
2/20/16 16:05	2.19
2/20/16 16:10	4.65
2/20/16 16:15	29.16
2/20/16 16:20	51.58
2/20/16 16:25	26.32
2/20/16 16:30	3.97
2/20/16 16:35	2.27

2/20/16 16:40	2.44
2/20/16 16:45	2.49
2/20/16 16:50	2.79
2/20/16 16:55	2.53
2/20/16 17:00	2.51
2/20/16 17:05	2.22
2/20/16 17:10	2.37
2/20/16 17:15	2.51
2/20/16 17:20	2.95
2/20/16 17:25	2.40
2/20/16 17:30	3.94
2/20/16 17:35	2.37
2/20/16 17:40	2.40
2/20/16 17:45	2.49
2/20/16 17:50	2.54
2/20/16 17:55	2.21
2/20/16 18:00	NaN
2/20/16 18:05	NaN
2/20/16 18:10	NaN
2/20/16 18:15	NaN
2/20/16 18:20	NaN
2/20/16 18:25	71.65
2/20/16 18:30	56.72
2/20/16 18:35	57.47
2/20/16 18:40	61.38
2/20/16 18:45	58.41
2/20/16 18:50	54.23
2/20/16 18:55	39.11
2/20/16 19:00	91.33
2/20/16 19:05	73.93
2/20/16 19:10	51.89
2/20/16 19:15	29.45
2/20/16 19:20	77.33
2/20/16 19:25	9.69
2/20/16 19:30	3.02
2/20/16 19:35	2.43
2/20/16 19:40	1.95
2/20/16 19:45	2.30
2/20/16 19:50	2.09
2/20/16 19:55	2.14
2/20/16 20:00	1.95

2/20/16 20:05	2.15
2/20/16 20:10	1.89
2/20/16 20:15	2.16
2/20/16 20:20	2.38
2/20/16 20:25	1.78
2/20/16 20:30	2.14
2/20/16 20:35	1.82
2/20/16 20:40	11.64
2/20/16 20:45	3.92
2/20/16 20:50	3.48
2/20/16 20:55	16.64

Table 7.1: Statistical Data for ***Station 01***(2/19/16 23:15 to 2/20/16 20:55).

7.2.3 Station 02 Graphical Data:

Graphical view from server is below in Daily 5 minutes average

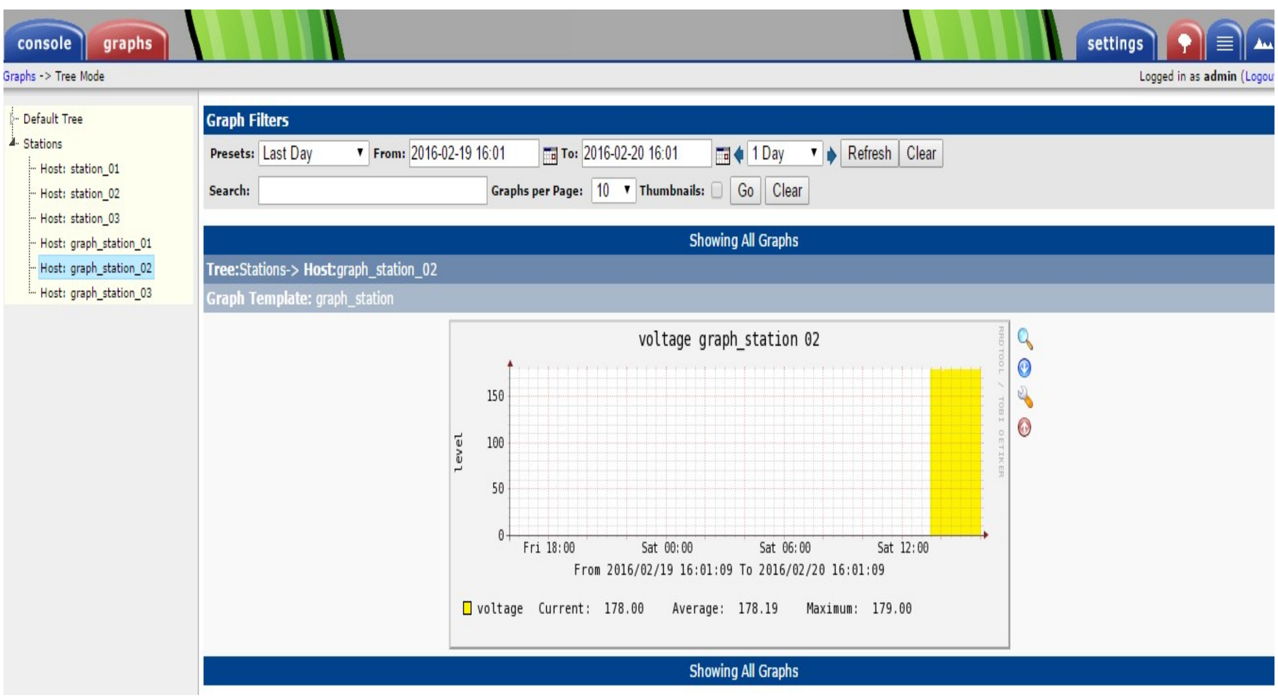

Figure 7.4: Basic data graph for ***Station 02.***

The graph with Daily 5 Minutes Average Voltage to Weekly 30 Minutes average graph showing for **Station 02** (2/19/2016 21:20 to 2/20/2016 21:15).

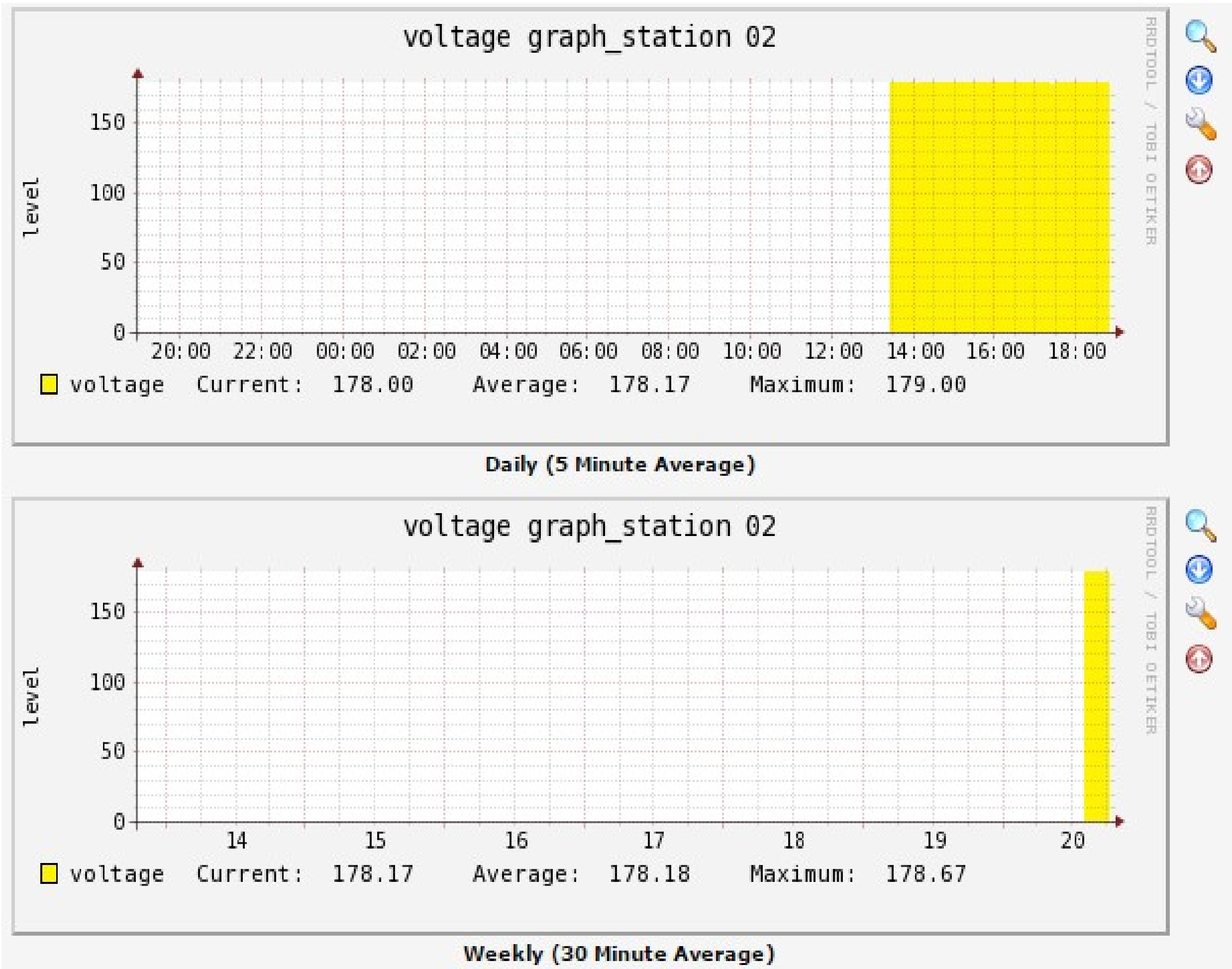

Figure 7.5: Daily and Weekly data graph for ***Station 02.***

From this graph we can see that,

Voltage level for Daily 5 Minutes Average was:

Current: 178.00 V, Average: 178.17 V and Maximum: 179.00 V

Voltage level for Weekly 30 Minutes Average was:

Current: 178.17 V, Average: 178.18 V and Maximum 178.67 V

We can see the actual data graph for Daily 5 Minutes data graph with below graph when we can create zoom for the graph (2/19/2016 21:20 to 2/20/2016 21:15)

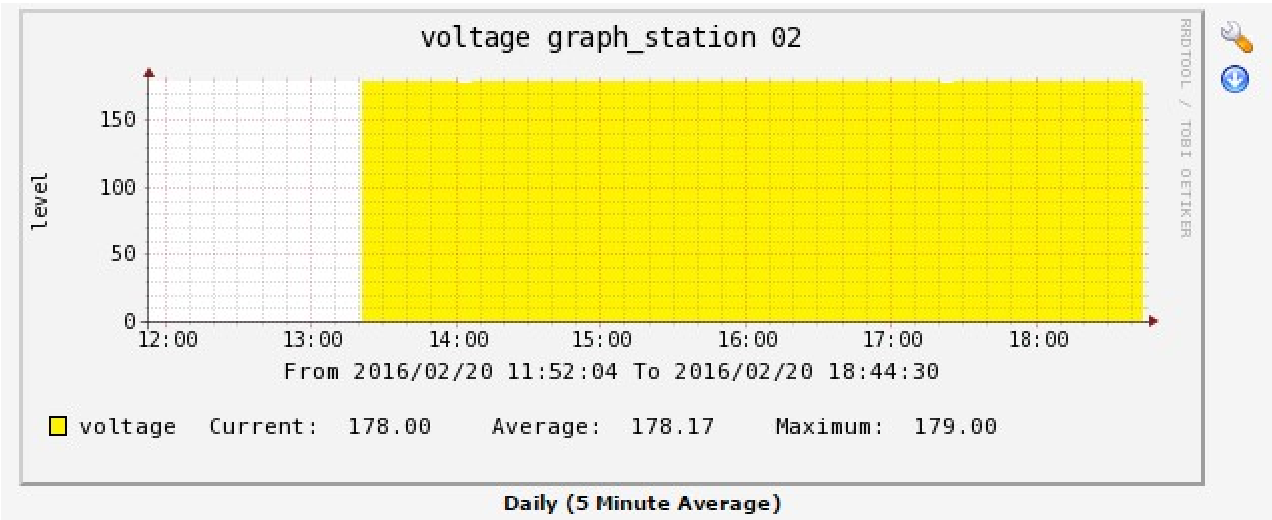

Figure 7.6: Daily 5 Minutes data graph for ***Station 02***(zooming view).

7.2.4 Station 02 Statistical Data:

In this stage we get 5 minutes duration actual data value from the station.

Title:	**'voltage graph_station 02'**
Vertical Label:	'level'
Start Date:	2/19/2016 21:20
End Date:	2/20/2016 21:15
Step:	300
Total Rows:	288
Graph ID:	27
Host ID:	7

Date	**voltage**
2/19/2016 21:20	NaN
2/20/2016 13:10	NaN
2/20/2016 13:15	NaN
2/20/2016 13:20	NaN
2/20/2016 13:25	178.01
2/20/2016 13:30	178.00
2/20/2016 13:35	178.00

2/20/2016 13:40	179.00
2/20/2016 13:45	178.01
2/20/2016 13:50	178.00
2/20/2016 13:55	178.00
2/20/2016 14:00	178.00
2/20/2016 14:05	177.00
2/20/2016 14:10	177.99
2/20/2016 14:15	179.00
2/20/2016 14:20	178.00
2/20/2016 14:25	178.00
2/20/2016 14:30	179.00
2/20/2016 14:35	178.00
2/20/2016 14:40	178.00
2/20/2016 14:45	178.00
2/20/2016 14:50	178.00
2/20/2016 14:55	178.00
2/20/2016 15:00	178.00
2/20/2016 15:05	178.00
2/20/2016 15:10	179.00
2/20/2016 15:15	179.00
2/20/2016 15:20	179.00
2/20/2016 15:25	178.00
2/20/2016 15:30	179.00
2/20/2016 15:35	178.01
2/20/2016 15:40	178.00
2/20/2016 15:45	178.00
2/20/2016 15:50	178.00
2/20/2016 15:55	178.00
2/20/2016 16:00	178.00
2/20/2016 16:05	178.00
2/20/2016 16:10	178.00
2/20/2016 16:15	178.99
2/20/2016 16:20	178.00
2/20/2016 16:25	178.99
2/20/2016 16:30	178.00
2/20/2016 16:35	178.00
2/20/2016 16:40	179.00
2/20/2016 16:45	178.01
2/20/2016 16:50	178.00
2/20/2016 16:55	178.00
2/20/2016 17:00	178.00

2/20/2016 17:05	178.99
2/20/2016 17:10	178.00
2/20/2016 17:15	178.99
2/20/2016 17:20	178.00
2/20/2016 17:25	177.01
2/20/2016 17:30	178.00
2/20/2016 17:35	178.00
2/20/2016 17:40	178.00
2/20/2016 17:45	178.00
2/20/2016 17:50	178.00
2/20/2016 17:55	178.00
2/20/2016 18:00	178.00
2/20/2016 18:05	178.00
2/20/2016 18:10	178.00
2/20/2016 18:15	178.99
2/20/2016 18:20	178.02
2/20/2016 18:25	178.00
2/20/2016 18:30	178.00
2/20/2016 18:35	178.00
2/20/2016 18:40	178.00
2/20/2016 18:45	178.00
2/20/2016 18:50	178.00
2/20/2016 18:55	178.00
2/20/2016 19:00	178.00
2/20/2016 19:05	177.01
2/20/2016 19:10	178.00
2/20/2016 19:15	178.99
2/20/2016 19:20	178.00
2/20/2016 19:25	178.99
2/20/2016 19:30	178.00
2/20/2016 19:35	178.00
2/20/2016 19:40	178.00
2/20/2016 19:45	178.00
2/20/2016 19:50	178.00
2/20/2016 19:55	178.00
2/20/2016 20:00	178.00
2/20/2016 20:05	178.00
2/20/2016 20:10	178.00
2/20/2016 20:15	179.00
2/20/2016 20:20	178.00
2/20/2016 20:25	178.00

2/20/2016 20:30	178.00
2/20/2016 20:35	178.00
2/20/2016 20:40	178.00
2/20/2016 20:45	177.00
2/20/2016 20:50	177.99
2/20/2016 20:55	178.00
2/20/2016 21:00	178.99
2/20/2016 21:05	178.00
2/20/2016 21:10	178.00
2/20/2016 21:15	179.00

Table 7.2: Statistical Data for ***Station 02*** (2/19/2016 21:20 to 2/20/2016 21:15).

7.2.5 Station 03 Graphical Data:

Graphical view from server is below in Daily 5 minutes average

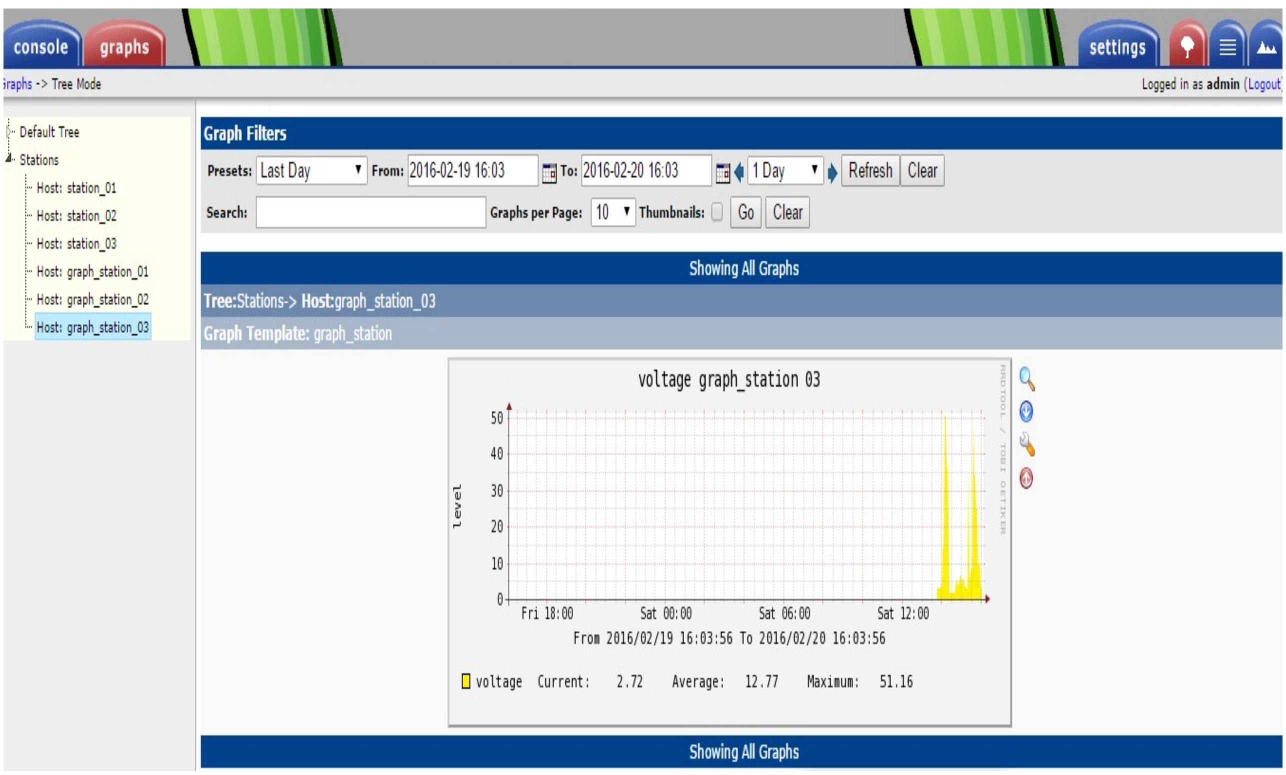

Figure 7.7: Basic data graph for ***Station 03.***

The graph with Daily 5 Minutes Average Voltage to Weekly 30 Minutes average and Monthly 2 Hours graph showing for **Station 03** (2/19/2016 21:30 to 2/20/2016 21:25)

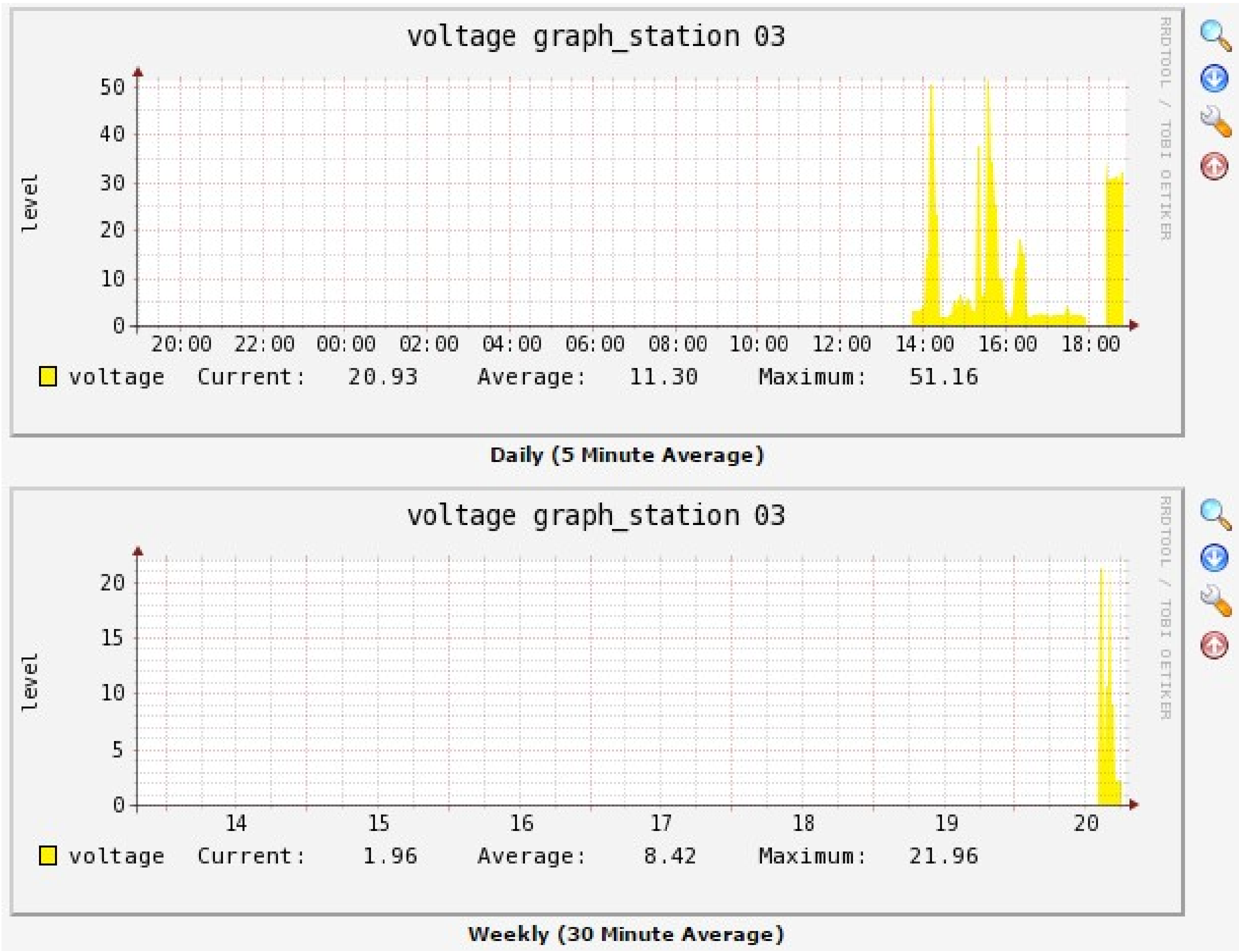

Figure 7.8: Weekly and monthly data graph for ***Station 03.***

From this graph we can see that,

Voltage level for Daily 5 Minutes Average was:

Current: 20.93 V, Average: 11.30 V and Maximum: 51.16 V

Voltage level for Weekly 30 Minutes Average was:

Current: 1.96 V, Average: 8.42 V and Maximum 21.96 V

We can see the actual data graph for Daily 5 Minutes data graph with below graph when we can create zoom for the graph (2/19/2016 21:30 to 2/20/2016 21:25)

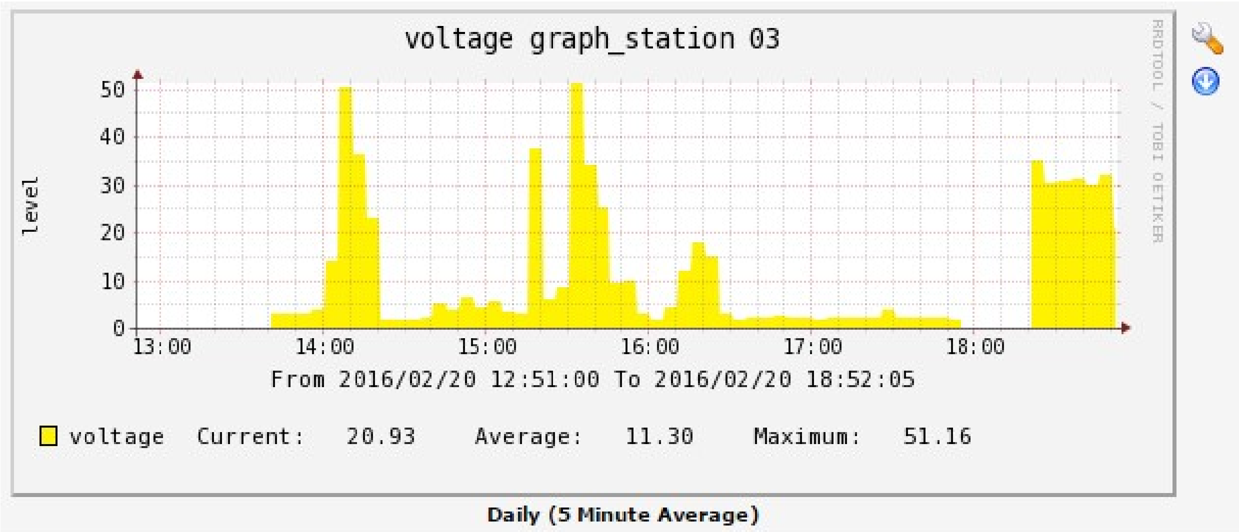

Figure 7.9: Daily 5 Minutes data graph for ***Station 03***(zooming view).

7.2.6 Station 03 Statistical Data:

In this stage we get 5 minutes duration actual data value from the station.

Title:	'voltage graph_station 03'
Vertical Label:	'level'
Start Date:	2/19/2016 21:30
End Date:	2/20/2016 21:25
Step:	300
Total Rows:	288
Graph ID:	28
Host ID:	8

Date	Voltage
2/19/2016 21:30	NaN
2/20/2016 13:40	NaN
2/20/2016 13:45	2.69
2/20/2016 13:50	3.10
2/20/2016 13:55	3.06
2/20/2016 14:00	3.55
2/20/2016 14:05	14.18
2/20/2016 14:10	50.02

2/20/2016 14:15	36.35
2/20/2016 14:20	22.89
2/20/2016 14:25	1.66
2/20/2016 14:30	1.56
2/20/2016 14:35	1.60
2/20/2016 14:40	2.12
2/20/2016 14:45	4.99
2/20/2016 14:50	3.78
2/20/2016 14:55	6.24
2/20/2016 15:00	4.01
2/20/2016 15:05	5.57
2/20/2016 15:10	3.48
2/20/2016 15:15	2.70
2/20/2016 15:20	37.55
2/20/2016 15:25	6.06
2/20/2016 15:30	8.64
2/20/2016 15:35	51.16
2/20/2016 15:40	34.04
2/20/2016 15:45	25.12
2/20/2016 15:50	9.21
2/20/2016 15:55	9.52
2/20/2016 16:00	2.72
2/20/2016 16:05	1.83
2/20/2016 16:10	4.29
2/20/2016 16:15	11.66
2/20/2016 16:20	17.80
2/20/2016 16:25	14.88
2/20/2016 16:30	2.76
2/20/2016 16:35	1.80
2/20/2016 16:40	1.96
2/20/2016 16:45	2.03
2/20/2016 16:50	2.30
2/20/2016 16:55	2.08
2/20/2016 17:00	2.03
2/20/2016 17:05	1.75
2/20/2016 17:10	1.91
2/20/2016 17:15	2.07
2/20/2016 17:20	2.02
2/20/2016 17:25	1.94
2/20/2016 17:30	3.80
2/20/2016 17:35	1.93

2/20/2016 17:40	1.96
2/20/2016 17:45	2.06
2/20/2016 17:50	2.10
2/20/2016 17:55	1.76
2/20/2016 18:00	NaN
2/20/2016 18:05	NaN
2/20/2016 18:10	NaN
2/20/2016 18:15	NaN
2/20/2016 18:20	NaN
2/20/2016 18:25	34.81
2/20/2016 18:30	30.29
2/20/2016 18:35	30.41
2/20/2016 18:40	31.01
2/20/2016 18:45	29.76
2/20/2016 18:50	31.85
2/20/2016 18:55	20.93
2/20/2016 19:00	48.25
2/20/2016 19:05	40.13
2/20/2016 19:10	28.03
2/20/2016 19:15	19.72
2/20/2016 19:20	44.78
2/20/2016 19:25	8.20
2/20/2016 19:30	2.74
2/20/2016 19:35	2.30
2/20/2016 19:40	1.87
2/20/2016 19:45	2.19
2/20/2016 19:50	1.98
2/20/2016 19:55	2.10
2/20/2016 20:00	1.83
2/20/2016 20:05	2.09
2/20/2016 20:10	1.83
2/20/2016 20:15	2.15
2/20/2016 20:20	2.29
2/20/2016 20:25	1.67
2/20/2016 20:30	2.09
2/20/2016 20:35	2.06
2/20/2016 20:40	10.91
2/20/2016 20:45	3.33
2/20/2016 20:50	2.97
2/20/2016 20:55	9.71
2/20/2016 21:00	10.69

2/20/2016 21:05	26.06
2/20/2016 21:10	17.18
2/20/2016 21:15	10.26
2/20/2016 21:20	33.49
2/20/2016 21:25	15.31

Table 7.3: Statistical Data for ***Station 03*** (2/19/2016 21:30 to 2/20/2016 21:25).

7.3 Result:

Voltage level for three Stations is different from each other.

Station 01: Date (2/19/16 23:15 to 2/20/16 20:55)

Voltage level for **Daily 5 Minutes Average** was:

Current: **54.23,** Average: **15.44** and Maximum: **102.01 V**

Voltage level for **Weekly 30 Minutes Average** was:

Current: **2.4,** Average: **12.57** and Maximum **43.60 V**

Voltage level for **Monthly 2Hours Average** was:

Current: **7.01,** Average: **12.96** and Maximum: **27.23 V**

Station 02: Date (2/19/2016 21:20 to 2/20/2016 21:15)

Voltage level for **Daily 5 Minutes Average** was:

Current: **178.00,** Average: **178.17** and Maximum: **179.00 V**

Voltage level for **Weekly 30 Minutes Average** was:

Current: **178.17,** Average: **178.18** and Maximum **178.67 V**

Station 03: Date (2/19/2016 21:30 to 2/20/2016 21:25)

Voltage level for **Daily 5 Minutes Average** was:

Current: **20.93,** Average: **11.30** and Maximum: **51.16 V**

Voltage level for **Weekly 30 Minutes Average** was:

Current: **1.96,** Average: **8.42** and Maximum **21.96 V**

7.4 Error Detection and Recovery:

From Figure 7.9 we can see that there were absent of data from 18:00 to 18:20 and it showing as NaN in statistical data sheet (Table 7.3). There was absent of data for system or other error. Also we can see the variation of data in the Figure 7.9 with different time duration. From this monitoring technique we can easily identify error report as an alarm and we can set a rapid action for recovery of the error.

7.5 Discussion:

The experiment shows that capacity of the system and data levels are different from each other. It also shows that, data level changes with time to time. It is not constant. Station 02 is showing high data level where Station 03 is lower. A solar PV system does the same because variation of radiation and environmental impacts work on it.

For a large power station we can realize that if changes single parameter of the system there is a huge change occurs. If 5W power changes every day after a week there have 35W power changes and monthly change is large. Variation of data depends on various parameters such as panel or system capacity, solar radiation, weather condition, temperature, environment and use of load.

With this system we can easily monitor all parameters of a PV system and can take action rapidly when parameter varies with normal and estimated data. Along with error detection of data values as an alarm and rapid action should be taken for maintenance.

CONCLUSION

Using IT for Photovoltaic (PV) data monitoring by the central server system we can get real time based data form one station. In this study we selected that three separate power stations produces specific data independently. The data was accurate which shows difference from other conventional monitoring techniques. We realized that, variation of voltage level was visible from each other as well as time and weather changes.

In a solar PV system solar radiation is never constant, it changes with weather, cloud, humidity, diffuse radiation, position of the sun, season changing environment, bad weather condition, dew & dust falling into the panel and so on. Most of the times we do not clean surface dust & dews of panels and panels go to decrease current level. Through this study we can monitor and identify properly how variation of voltage level changes with specific time. The graph and statistical data puts yearly based, which gather long time data for analysis about device performance. It also helps to maintenance of any part of the system.

In this system we can get actual peak value and it helps to monitor a large PV power plant. A large power plant is not easy to maintain and monitor but if we have proper information collection system than it can be easily maintained. Besides it will help a large power plant to improve revenue growth for the state along with revenue of electricity demand.

After necessary correction and improvement a centralized monitoring system can be developed for overall performance evaluation for PV power system. Due to time constant we could not complete the operation of the designed system independently but concluded that, this system is working as a basic first stage remote monitoring of operation.

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