“SOME STUDIES ON HYBRID POWER SUPPLY FOR DISTRIBUTED GENERATION BY RENEWABLE ENERGY SOURCES”

DISSERTION

Submitted to Partial Fulfilment of The Requirements

For The Award Degree of Master of Technology

In

Power System

Submitted by

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2K12/PSY04

Under the supervision of

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DELHI TECHNICAL UNIVERSITY

(FORMERLY DELHI COLLEGE OF ENGINEERING) 2014

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I, **DarpanChalia**, Roll No. 2K12/PSY/04 student of **M. Tech. (Power System)**, hereby declare that the dissertation/project titled **"Some studies on hybrid power supply for distributed generation by renewable energy sources"** under the supervision of Mr. J. N. Rai, Associate Professor, Department of Electrical Engineering Department, Delhi Technological University in partial fulfillment of the requirement for the award of the degree of Master of Technology has not been submitted elsewhere for the award of any Degree.

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ACKNOWLEDGEMENT

I would like to thank my honourable guide **MR. J. N. RAI,**Associate Professor, Department of Electrical Engineering, Delhi Technological University (formerly Delhi College of Engineering). It would have never been possible for me to take this project to completion without his innovative ideas and his relentless support, encouragement and patience. I consider myself fortunate to have had a chance to work under his supervision. In spite of his hectic schedule he was always approachable and took his time to discuss my problems and give his advice and encouragement.

I would like to express my deep gratitude to Prof. Madhusudan Singh, Head, Department of Electrical Engineering for providing his support during my project.

I am also very thankful to the entire faculty and staff members of the electrical engineering department for their help and cooperation.

I would also like to thank my batch-mates and friends who encouraged and helped me in completing the thesis work.

Finally, I express my deep sincere thanks to my Parents my brother and sister who motivated and encouraged me for higher studies, without which it wouldn't have been possible.

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DECLARATION

I, hereby declare that the work being presented in this Project Report entitled **"Some studies on hybrid power supply for distributed generation by renewable energy sources"** is an original piece of work and an authentic report of our own work carried out during the period of 4th Semester as a part of our major project.

The model developed and results presented in this report is an outcome of the work carried out during the above said period and is also compiled as thesis for my Major Project for completing the requirements of Master's Degree of Examination in Power System Engineering, as per Delhi Technological University curriculum.

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ABSTRACT

Electrical energy is provided worldwide by cable or overhead transmission lines. However, power systems are still needed to locations which are isolated or far from electrical energy suppliers. Renewable energy resources in micro-grid power systems are interesting topics of recent research as environmental pollution and scarcity of energy resources come to the fore. Moreover, power systems which have renewable sources of energy are becoming popular need of green energy. A micro-grid electricity power system on a local scale usually using renewable source of energy satisfies both problem of isolation and power quality, benefits not available from conventional utility grid system, but also serves a customer with multiple load locations. In this present situation the development of intelligent system that integrate Eco-friendly energy resources such as wind, photovoltaic system, and fuel cell for green energy using MATLAB is design & tested for its reliability and cost effectiveness under different environment condition.

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CHAPTER 1

INTRODUCTION

The fast increase in the demand for electric energy requires more installation of power plant for generation of electrical energy. The energy capacities from fossil fuels have been extremely consumed day by day and their reserves have been rapidly depleted compared to the other resources. Recently there is a focus on renewable energy utilization and alternative energy to conserve the non renewable sources. Among these wind, solar and fuel cells are growing in importance and gain the interest of energy researches in renewable resources. After 1978s, the cost of electrical energy provided by wind energy has been significantly dropping. These cost reduction are due to development of new technologies which are higher efficient and highly reliable wind turbine. Non renewable sources for electricity generation has several disadvantage: it causes emission of carbon dioxide and green house gases which causes global warming pollution which is major concerned of today world and it is costly due to transport facilities to the rural areas and several transmission losses. The necessity to supply an economical, feasible and environmental harmless alternative option of renewable green energy source is very significant. As green renewable energy resources such as solar, wind and fuel cells have gain great favourable acceptance as substitute for conventional expensive and scare non-renewable energy resources. Individually renewable green energy is presently in functioning at numerous places although wind and hydrocarbon variations &stochastic nature. Isolated green energy hybrid operation may not be efficient or feasible in terms of economic, efficiency and supply consistency unless an efficient and robust stabilization of AC-DC interface system and effective control scheme are successfully implemented.

The decreasing cost of generating electrical energy Rs/kWh renewable energy sources, especially fuel cells due to the industrial development of the membrane and electrolyte technology where as the wind energy dependent on environmental conditions. Therefore, successful approach is to ensure renewable energy

multiplicity and effective utilization by uniting more than one renewable energy source to form an integrated hybrid energy grid to coordinate each other during excess load to supply electrical energy without failure thus improves system reliability. As considering geographically difficulties for establishing power plants in term of cost and transportation, the integrated green energy system is producing desired alternative solution for rural and isolated island. In this project, a hybrid renewable green energy system incorporates a combination of solar, wind and fuel cell energy sources. A system using such various combinations has the maximum advantages of capacity, diversity in supply and stability of system that may offer the strengths of each type. The main goal of integrated green energy system is to provide electrical supply for remote communities. As today world, in remote areas or island electrical energy is generated by micro grids or diesel generator which has their own advantages like low cost and abundantly available etc. So, by hybrid integrated green energy pollution we provide pollution free and provide electricity at comparatively low prices. Fuel cell technology is still limited to dispersed electric generation and hybrid electric vehicles.

1.1 PROJECT DETAILS:

Project title: "***Some Studies on Hybrid Power Supply for Distributed Generation by Renewable Energy Sources***".

1.1.1 OBJECTIVE:

The objective of this project is to developing an intelligent system that can integrate renewable resources including wind turbine system, photovoltaic system and fuel cell as a backup system to provide continuous electricity to a considered local area load without failure thus improves the system reliability. This kind of system helps in meeting the energy needs away from the depletion of the fossil fuels, or facing the potential hazards of Nuclear Setups and also reducing harmful emissions compared to conventional back up sources. This renewable energy source utilisation also helps in reducing the greenhouse gas emissions into the atmosphere as the global warming is a serious issue of the modern world.

1.1.2 SCOPE:

Energy is the backbone of technology and economic development. From the beginning, the growth of society has been upgraded by a steady growth in generation and our use of better quality exo-somatic energy. If the availability of this energy were to turn down drastically it could have serious impact for civilization and the human population it supports. However this energy generation should not be harmful for the environment and yet be sufficient to meet all our needs. Hence a system that provides energy through renewable resources helps in generating the green energy continuously with negligible operating & maintenance cost stands as welcome idea to meet this energy requirement.

1.2 LITERATURE REVIEW:

When going to start new project first question born in my mind is, from where to start, what are the available methods of ac voltage control, what topology I should use, how can I make my design more efficient etc.

For this I have referred many IEEE papers, magazines and books. One can say that the human race is now out of time. The function of our present industrial civilization is fully dependent on access to a tremendous amount of energy of different types of fossil fuels that are exhaustible and at the same time pollutant of environment. So to save the human life from the permanent damage done by fossil fuels and to continue the industrial growth we have to stop the use of fossil fuels like coal, oil, gas, nuclear and try to develop alternative energy resources and try to develop sufficient energy so that the energy requirement of the human can be achieved. [1].

The sun is the main source of energy. The heat of the sun can be used in solar panels to heat water or generate electricity by use of photovoltaic cells. Solar is an emerging technology for clean energy but alone it cannot cope up with current demand of world energy but can be integrated with some other energy is the ideal effort to meet the requirement. [4]

The use of a commercial web cam as the sensor element does not present most of these disadvantages like high sensitivity of the different elements such as photodiode so

phototransistor to weather conditions, particularly to temperature and humidity. Alternative nature to consider is that fast deterioration extreme weather conditions and the cost of the constant maintenance that this implies. Extracting the detail from the source wind energy is free, no pollution, easy construction and efficient conversion of wind into electricity but it is not enough to come up the continuous energy demand and same cannot be used as a standalone energy source due to its dependence on weather condition.[6]

Fuel cell technology contains a variety of approaches toward remaking conventional batteries into biology-based batteries. The variety of applications in which these power cells could possibly work also suggests that fuel cell technology has a bright future.

Clean energy technology includes an outstanding variety of ideas for no fossil fuel, non-polluting power supplies. These technologies currently have an encouraging amount of support from government agencies, leaders, and universities. Not every technology will prove to be realistic due to high costs or difficult technical challenges, but certainly a number of new clean energy technologies are possible and on the horizon. Clean energies have an exciting and promising future in green technology. People outside the environmental sciences can take comfort in the realization that ideas in clean energy have been developing faster than natural resources disappear.

Micro-generation units, mostly situated at user sites, have emerged as a promising choice to meet up increasing customer needs for electrical energy with an importance on reliability and power quality and contribution to different economical, environmental and technical benefits. As one of the end of the micro grid is a renewable energy resources, with the help of them consumer can generate the adequate energy for his use. For this one can uses renewable resources like solar, wind, fuel cell and many more. Of course one can also contribute into the power system when they have some excess energy. Micro-grid is just nothing but practically controlling the generation of electricity and maintaining its use for adequate requirement so all the power system can operate reliably.

As evident from the above data it is possible to optimize combine output of the alternative renewable sources and their by achieving cost efficacy for supplying electricity to rural areas or large residential houses in urban cities. Further it is economical to use fuel cell as compare to back up power available from DG set. More research is being undertaken at various places to enable generate higher scale electricity generation through renewable sources to feed additional power so generated to the grid and thus overall cost of electricity generation through eco friendly sources can be brought down. This can be achieved by constructing the Micro-grid.

CHAPTER 2

NON- RENEWABLE ENERGY SOURCES

Evolution of world when the extreme changes are occurring on earth, the flora and fauna of our earth system got compressed and with passage of time results coal formation and natural gas. Billions year ages, compression of earth element leads to formation coal, oil and natural gas. These fuels are known as fossil fuels .They have calorific value and when they are combusted releases heat energy in useful foam. This useful heat energy can be converted to other forms of energy like

- Mechanical energy.
- Electrical energy.

These energy sources are finite and exhaustible. For recreating non renewable source of energy like coal, petroleum and natural gas it took thousands of years again. From past few years the usage of the non renewable source of energy increases and it is impossible to reproduce the resource. Rapidly usage of renewable source will be depleted in upcoming years. On burning of non renewable source produces large amount of heat energy which further can be used in various power plant to convert this heat energy into mechanical or electrical energy. By using non renewable source, we are generating electricity about 65 percent of the world electrical energy out a large quantity of heat, which can be used togenerate electricity. From early stage of generation and usage of electrical energy, the coal is earliest source of heat energy. And, from 1800AD onwards coal is highest source of heat energy. Figure 2.1 shows the Fossil fuel contribution to global energy demand.

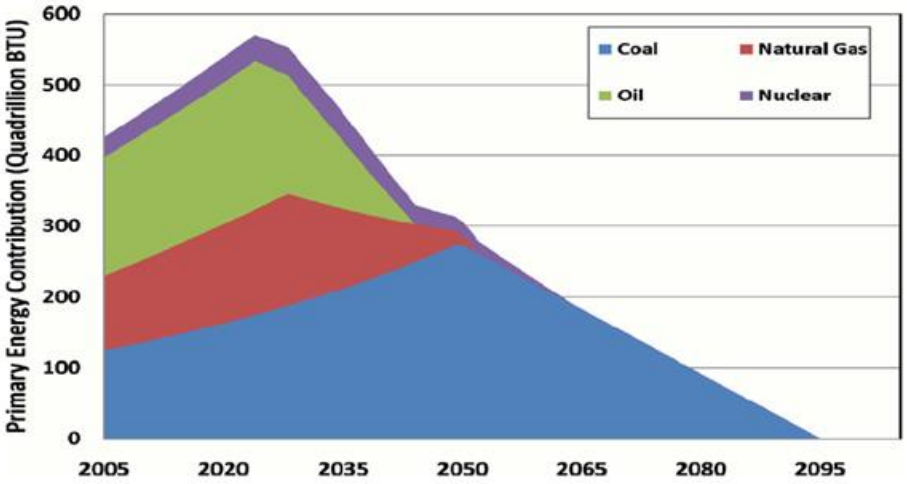

Fig: 2.1 Non-Renewable Contribution to Global energy Demand

2.1 ADVANTAGES OF FOSSIL FUELS:

The major advantages of fossil fuels are:

1. Installation:

The installation of non renewable source of energy is quite simple as compared to the renewable source of energy. The extraction of fossil fuels may have some complex phenomena but generation of electrical energy from non renewable is quite simple. As, recent developments in technology leads to minimization of installation cost.

2. Location:

These non-renewable source plant can be located at any places means not depends whether the availability of fuel near the location of power plant. The constructions of power plant are quite simple and cheap. The fossil fuels like diesel or coal can be easily transported to the location of power plant. As we compare non renewable source of energy with renewable source of energy which depends upon the availability of fossil fuel at site power plant location. Electrical energy transmission losses can be minimized by having generating power station near the load centre. These non renewable sources of energy also uses is combustion engines. So, these plants can be installed at any place irrespective of existence of fuels.

3. Efficiency:

Non renewable source of energy like coal has highest calorific value. All fuels have some calorific value according to which energy is produced. The more is calorific value more better is fuel. As non renewable sources have more calorific value. By which the efficiency of non renewable source is superior. With having some drawbacks in non renewable source of energy, we are still using it because of its higher calorific value and better efficiency.

4. Stability:

The renewable plant can be respond very well to variation of load. To respond to increase in load, the power station must increases generation to respond to the load as well as when load decreases the power station must decrease the generation to minimized the cost and save our fossil fuel. The variation of load can offer change in the frequency which have diverse effect on the turbines of generator. When system parameters change, for example through the disconnection or connection of a large load or disconnection of a large generator, the power system must reach a new equilibrium state to remain stable. This is achieved by automatic controls and human operators. If after a disturbance, the system cannot return to normal condition, then it has become an unstable system. This means the system will result in a run-away or shut down situation. When we uses the renewable source of energy they cannot respond very well to variation of load is makes them very stable. Even when non renewable source of energy used in case of combustion engine, they provide more stability. Also, non renewable source of energy works even over load condition.

5. Transportation facilities:

The non renewable source of energy like coal, diesel etc are found at distant places from the generating station, so to supply the fuel to generating station we need transport facilities. The non renewable source of energy can easily transported to location of generating station. The non renewable can be stored very easily to use in over load condition. After mining of coal and petroleum can easily taken from there extracting centre to the generating station. With passage of time, the technologies developed to

easily transported natural gas to the generating station which can be used in peak load condition.

6. Availability:

From starting stages of generation of electrical energy is done by non renewable source and still now most commonly source of electrical energy are coal, petroleum and natural gas. This is because of availability of non renewable source fuel in abundance. Throughoutwholeglobe the abundance of resource are still present but increase in the consumption rate in recent years may cause depletion of these resources. As, everyone knows with increase in consumption may not last too long for the usage. But still non renewable source of energy are available and still we are using.

7. Capital cost:

Non renewable source of energy are available in abundance in almost every countries over the world. The procedure for extracting the non renewable source of energy are very expensive but operating cost is very low. Hydro electric power plant has least operating condition. For using non renewable source in refined foam, the cost increase but when fuel is prepared to use then operating cost is very less. But overall cost is very low.As we compare with the renewable source of energy like solar or wind energy resources have very less cost.

8. Limit source of power:

Since renewable source of energy depends upon availability of sunshine in case of solar power plant and speed of wind flowing in case of wind turbines. But in case of non renewable sources if we our fuel in stock we can full fill our needs. As source of power in steam power plant depends upon availability of coal resource and coal mines are being exhausted and time may come when all might be finished.

2.2 DISADVANTAGES OF FOSSIL FUELS:

The major disadvantage of burning fossil fuels is that they are environmentally damaging. The major disadvantages are:

2.2.1 Environmental aspects:

By burning of non renewable source of energy like coal, petroleum and natural gas produces carbon dioxide, greenhouse gas and different harmful components which causes various health problems and our atmosphere gets polluted. In recent years there is increase in the temperature of earth which is known as Global warming.Due to, global warming, the earth temperature increases which melts the ice bergs at poles and overall temperature of earth also increases. From ice melting, water level of the oceans increases which may cause flood in different parts of world and disturbed our eco system equilibrium.

2.2.2. Increasing Prices:

By passage of time consumption of non renewable source of energy increases which leads to increase in the cost. The consumption also leads in depletion of our recourses for example in Saudi Arabic countries have huge amount reserves of oil and natural gas which starts depleting. The group is formed to utilize and produce petroleum known as“Organization of the Petroleum Exporting Countries (OPEC)”.In this group there are 13 countries which share the 45% of oil of world oil production. Several efforts have been made to control or minimize our dependence on non renewable source of energy, so we bring down the rising price of non renewable source of energy. Hence the consumption of non renewable sources leads to the demand which causes increase in price.

2.2.3 Acidic Rain:

By burning of non renewable produce sulphur dioxide gas which is the major factor for acid rain. This acid rain has very hazards effect on environment and human being health. Acid rain damage our agriculture land and all farming land cannot able to reuse. The acidification can finished all standing crops. Even our heritage monuments have very diverse effect.The oceans water gets polluted very fast and affects the aquatic life as the oxygen level will decreases. The aquatic life cycle gets effected. The acidic rain causes skin and respiratory diseases to human being which may transfer generation to generation.

2.2.4 Limit in availability:

With increase in demand leads to more consumption of non renewable source of energy which increase in more mining of these resources which results in depletion of their amount. Being passage of time the one day may occur when these resources completely vanished. So, different organizations are set up to make less use these resources and find the alternative resources. To recreate such non renewable resources is impossible thing and took thousands of years to such resources.

2.2.5 Human Health Aspects:

There is increase in amount of harmful gases like carbon monoxide, carbon dioxide etc which causes global warming and deletion of ozone layer. The greenhouse gases produced by burning of non renewable sources lead to depletion of ozone layer. The harmful ultraviolet ray falls directly on earth without any flirtation done in stratosphere by ozone layer which causes skin cancer, increased amount of vitamin D and several DNA linked diseases can happens. The different organizations are set up to minimize the emission of carbon. The new term known as “CARBON CREDIT “also introduced in which each and every country keep taking care of carbon emission.

2.2.6 Ash Handling:

The residue remains after the combustion of non renewable source of energy results in ash and different dust particle which may cause respiratory diseases. So, we need to take care of proper disposal these particles to prevent our environment.

2.3 MAJOR POINTS OF CONCERN ABOUT FOSSIL FUELS:

One of the biggest disadvantages of non renewable sources is that they are available in fixed quantity and availability& continuously increases of cost. Following figures clearly shows the finite availability of oil, natural gases, coal and nuclear power. [1].

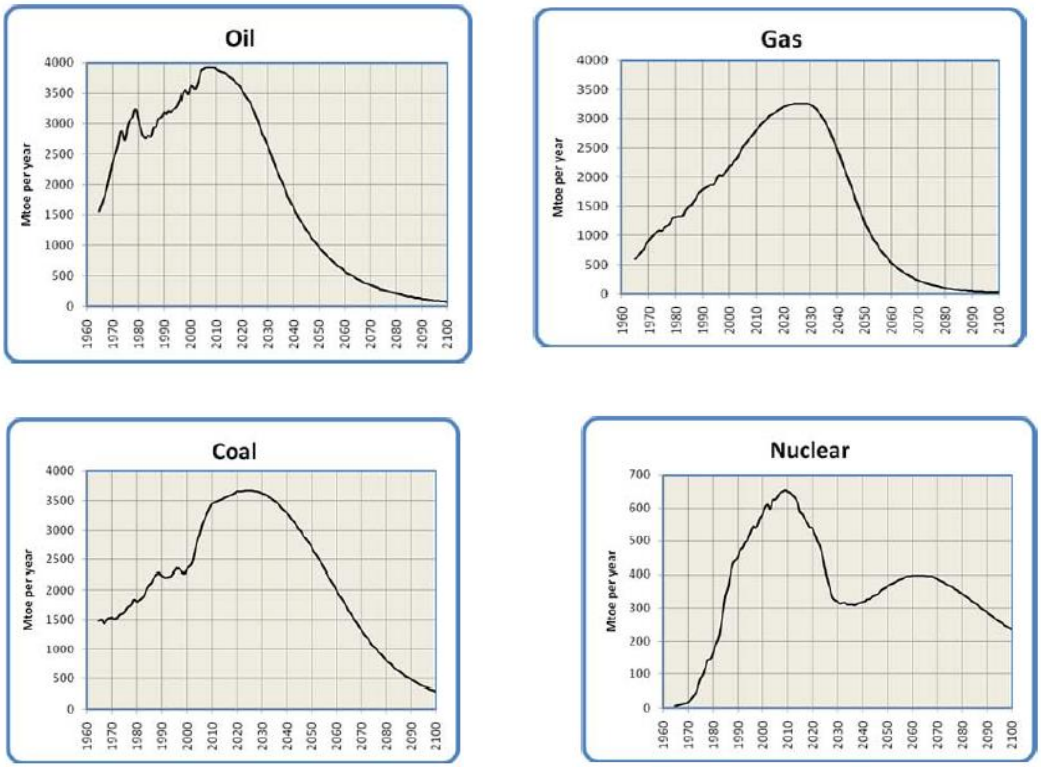

Figure 2.2 :Non-renewable energy resources availability

2.4 GROWING DEMAND OF ENERGY:

Increase in population and dependence of mankind upon energy .As day by day our life style leads to more usage of energy. The civilization and various developments always lead to requirement of energy in future. There is no doubt that dependence on energy in future always increased day by day. Among the various source of energy the electrical energy have top most preference? Electrical energy used in various applications like in agriculture, houses, industries and in transportation also. Besides its use for domestic, commercial and industrial purposes it is required for increasing defence and agricultural production. In agriculture, it is used for pumping water for irrigation and for improving the methods of production and numerous other operations. Electrical energy is convenient foam of energy because it can be generation, transmission and distribution can be done very economically and we can generate electrical energy far from the load centres and it is almost pollution free at the consumer level. Further, it can be adopted conveniently in domestic applications, industrial and agriculture fields. Electrical energy

has several merits like cheapness, convenient and efficient transmission, easy control, cleanness, greater flexibility and its versatile foam. The process of modernization, increase in productivity in industry and agriculture and improvement of quality life of people depends so much upon the supply of electrical energy that the annual per capita consumption of electrical energy has emerged as an accepted yardstick to measure the prosperity of a nation. Through at present about three-fourth of total energy is still used in non electrical which have different advantages and disadvantages. For generation of electrical energy we have non renewable fuels like coal, diesel, natural gas etc and renewable source of energy like wind, hydro, solar etc. With increase in demand the consumption non renewable sources increase which have several demerits as mentioned above.

It is expected that the electrical energy demand will continue to go up for many years to come, even in developed countries. With development of technologies the carbon emission from the non renewable source of energy is capturing and reusing to beneficial foam. Whole world investments increasing in clean renewable source of energy.Figure 2.6 shows the close relationship between global energy consumption, world GDP and global population and imply that an overall increase in the energy supply has supported the increase in population [2].

Due to combustion of non renewable source of energy results in emission in carbon dioxide which increase the carbon level of atmosphere. The carbon dioxide emission results in increase the temperature of earth. Following graph shows the carbon dioxide emission and temperature changes.

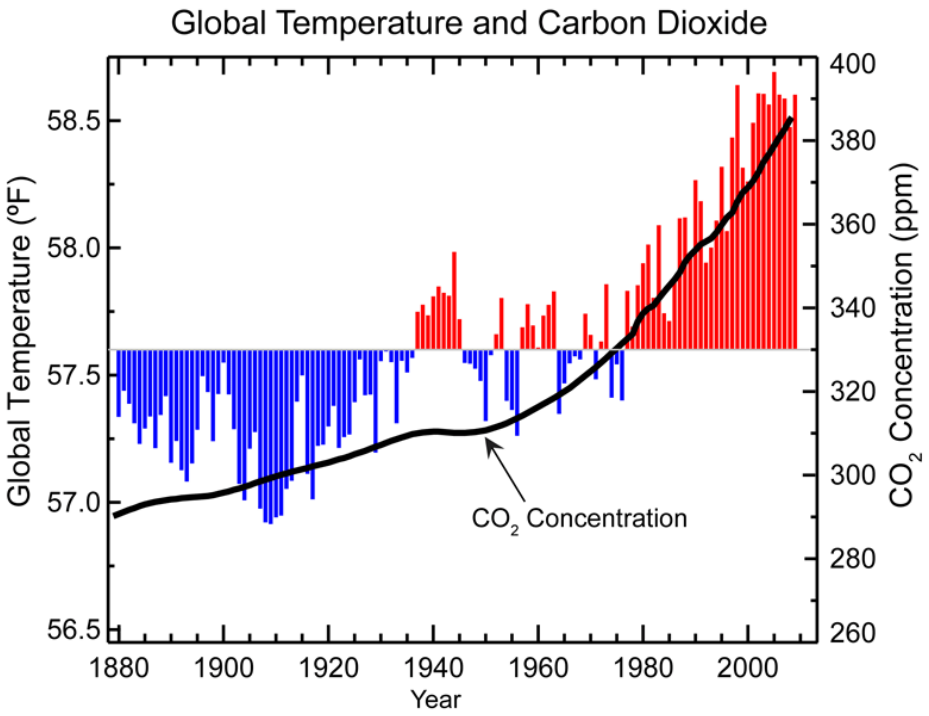

Figure 2.3 Global energy consumption, world GDP and global population

If all countries set their targets to minimize the carbon emission and full fill their committeemen results better and clean environment.By carbon emission, the temperature of increased by 0.5^{o}c every year. So, in upcoming years the temperature of earth increased drastically. Effects of global warming are very harmful and starts noticeable in these areas:

- Weather condition.
- Oceans levels.
- Quality of food.
- Human being health.

CHAPTER 3

RENEWABLE ENERGY RESOURCES

This global requirement pertaining to power minimal capital they offer. These supplies connected with non renewable cause of power just like coal, petroleum and natural gas are classified as the conventional options for power, are now being eroded swiftly. Consequently there is requirement to connect with regular search for different change options for power which might be renewable and non-polluting. There is certainly good prospective to be able to record power from the movements connected with drinking water and wind. This purchases pertaining to the installation of most of these renewable power equipments are generally higher originally, inside longer work, that they will show to be an advantage for life-long.

3.1 ADVANTAGES OF CLEAN ENERGY RESOURCES:

3.1.1 Reduced Pollution:

Collectively labelling renewable energy resources as nonpolluting would be inaccurate; environmental and aesthetic costs are associated with building and operating renewable energy facilities. Renewable resources, though, present fewer environmental problems than fossil fuels. There is no elimination of carbon dioxide, carbon monoxide, sulphur dioxide and nitrous emissions in wind, solar and hydro power plants. Carbon dioxide emissions from biomass -- organic waste that can be used as a fuel -- create no net emissions when new plants take up the carbon Skin tightening and emissions coming from biomass -- natural and organic squander that can be used as a gas -- develop no net emissions while fresh facilities use up your as well as.

3.1.2 Environmental Policies:

For aesthetic, health and economic reasons, national, state and municipal governments have increasingly sought to protect the environment. While reducing soil, water and air pollution produces long-term benefits, and the costs associated with cleaning up pollution can be staggering, industrialized economies must also consider how

regulations can negatively impact economic growth, especially in the short term. An industrialized company also needs to consider precisely how regulations can easily badly effects economic increase, in particular temporarily. Environmentally friendly methods can easily fill your chasm in between ecological protection and economic increase. For example, the U.S. Environmental Protection Agency identifies coal-burning power plants as a major source of the compounds that lead to acid rain.

3.1.3 Stable Supply:

In 2010 According to the U.S. Energy Information Administration the United States roughly imported 1 million barrels of oil per day from Mexico and Saudi Arabia, which is nearly twice that from Canada. Political and social events often create shock waves through energy markets as risks to the supply are assessed. Associating energy prices with abundant renewable resources reduces exposure to the riskiness of depending on a delectable energy resource that must be imported to meet demand. Additionally, the need to continually locate and secure new nonrenewable energy deposits places the economy of the supplier and the consumer in jeopardy. The non delectable nature of renewable energy resources and the capacity for domestic production --- the U.S. has a great solar and wind power potentialwithin its borders --- provide a more stable supply system.

3.1.4. Regional Development:

The utilization of renewable energy resources is still cannot be centralized but nonrenewable can be centralized. Areas which are not developed canincrease their capital on local renewable resources which will help them in promoting the development which was previously restricted to areas having greater access with large infrastructure needed to support fossil fuel power plants. Other industries can benefit from the switch to renewable. The tourism industry, which is the major source of income in regional growth, mainly in developing nations, is affected by the environmental damage due to worldwide use of non renewable energy sources. Sadly, that transmitting of energy is costly. It should be produced locally, which can impair an area's desirability. Renewable energy resources, on the other hand helps the tourism by providing the energy requirements protecting the

aesthetic qualities required to entice travellers. It also minimizes the amount of emissions and pollution created in the process. Additionally, renewable resources, especially decentralized ones, tend to create more jobs than their nonrenewable counterparts, which further boost regional employment. [1]

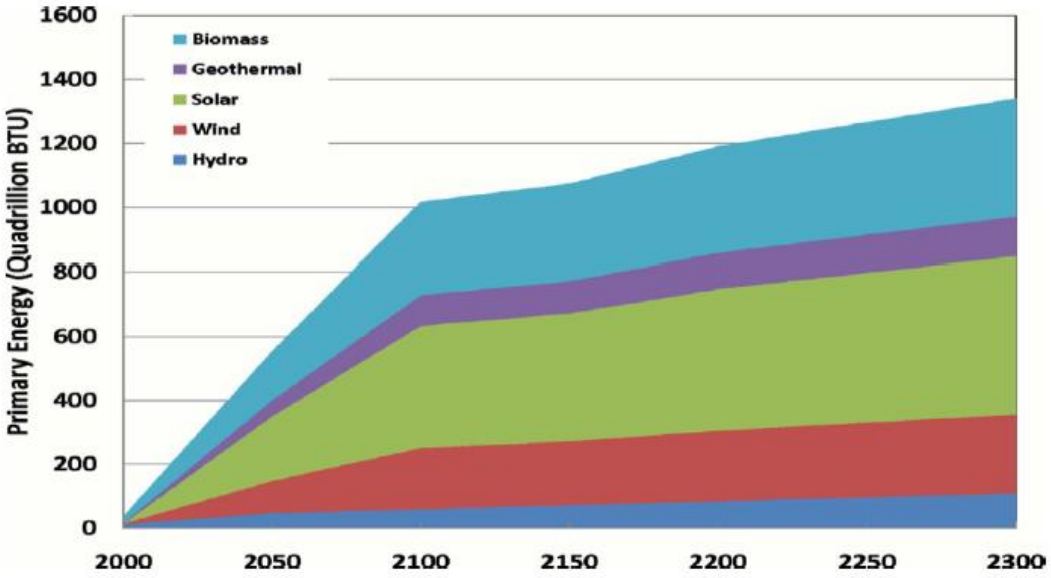

Figure 3.1 Uses of renewable energy sources v/s time

3.2 RENEWABLE ENERGY POTENTIAL OF INDIA:

Recently India is emerging as one of the biggest destinations for investors from developed countries. It is now the 11th largest economy in the world, fourth in terms of purchasing power. As we can see from the above figure, Renewable resources are going to be the major player in generation of electricity in near future. So let's check the renewable energy potential in India. Table No. 2.1 shows the renewable energy potentials of India.

Source/Technology	Potential Availability	Potential exploited
Biogas plant	14 Million	2
Biomass-based power	16.000 MW	Marginal
Efficient woodstoves	125 Million	19 Million

Solar Energy	5*10^14 Whr/year	--
Small Hydro	10,000 MW	250 MW
Wind Energy	20,000 MW	250MW
Ocean Thermal	45,000MW	--
Wind Energy	20,000MW	250MW

Table 3.1: The renewable energy potentials of India

3.3 WIND ENERGY:

3.3.1 Introduction:

In a conventional grid, the capacitor banks or FACTS devices like STATCOM etc are used to provide the demand reactive power by the load system. Due to the rapid development in power electronics components, control system and wind turbine technology; an application of wind turbine generators is possible to support the grid during voltage dips. The variable speed complete decoupled wind farms can provide the controllable reactive power to the grid. In this study, wind far. The wind farms system distribution at the point of common coupling. The air energy of atmosphere in motion is known as wind energy driving sailboats are using this as a source of energy for thousands of years for grinding grain and pumping water. The first ever known electricity generating such type of windmill operated was a simple battery charging machine installed by James Mathews in England. Wind is known as non conventional energy source because the air will blow as extensive as sun shines.

Earlier Wind energy used in sail, vessels, water pump, grinding grain. Availability of Wind energy is almost equal to twice the world energy consumption from conventional resources.

At different places, different fluxes of sunlight which cause the atmospheric temperature differences due to which winds are generated as air masses tends to move from hotter to cooler region there by regenerating wind. Basically kinetic energy of wind velocity is converted in to the electricity. Due to unequal expansion due to sun light heating of

atmosphere and therefore unequal densities of air of different region wind energy generated. When temperature of atmosphere increases warm air starts to expand and it moves up word by cool denser air immediately above. The land mass tend to which flow in surrounding areas causing a wind.

Generally in night time air over the water is tend to heat up more quickly as compared to rand masses and vice versa during day time. Wind energy production depends up on the amount of heat received which depends upon the angle of regions diametrical plane to the sun as well as on clouds and pollutants in the air above. As, the height increases the wind speed is increase. The 80% of wind installed wind energy capacity is in 5 countries are India, Germany, Denmark, USA and Japan.Resorting to non-conventional sources of energy like a wind is to be anticipated in charge to meet the massive energy requirements of the world. Additional grid power required by onsite power energy generation by means of small wind electric generators is a shows potential option at semi-urban and at the same time as rural windy areas. The possibility for micro-generation by means of wind electric systems in India is extended up to the 90,000 MW. In spite of a huge potential, diffusion of miniature wind turbines as sources of onsite production has been very comprises. In disparity to large grid connected wind turbines, whose souk as well as machinery is modified, the market as well as technology of wind electric generators is silent in emerging stage. This shows that there are quite a lot of possibilities which have restricted widespread deployment of this very helpful form of electrical energy generation.

Power generation phenomenon by wind energy:

Wind turbines converts kinetic energy of wind to rotator mechanical energy. The wind turbine blades are rotated by flowing wind on the down sides of blade of the wind turbine. The small amount of low pressure is built during wind flowing period which causes to rotor to turn by pulling the blades to it. And this is known as lift on the front side of the blades. The wind force is actually very much weaker then the force of lift and which is called drag. The combination of force of lift and drag causes rotor to spin like a propeller. Turning shaft is mounted on a hub which is attached to the rotor of turbine.

Gear transmission box connected to the turning shaft which increases the turning speed. Then gear transmission box is attached to generator which converts the mechanical energy to electrical energy and hence electricity is, thus obtained electricity can depending up on the users need either ac or dc. DC can be converted by during brushless dc generator connected to wind mills rotor.

Turbine	**Rotor diameter**	**Power O/P**
Small	1-16m	10-50m
Medium	16-50m	50-500m
Large	50-130m	500-1000m

Table 3.2 : Types of wind power plant

3.3.2 Modern Wind-Power Technology:

There are two major kinds of wind generators:

- Vertical-axis
- Horizontal-axis

3.3.2.1 Vertical-axis wind turbines (VAWTs):

Vertical axis wind turbines are usually less found. There are few VATWTs currently un-commercial production is similar to Darrieus turbine, which looks like an egg beater as shown in Figure 3.2 Vertical-Axis wind turbine Vertical axis wind mills are also called the cross-wind axis machines. Here, the axis of rotation is perpendicular to the direction of the wind. It has been found that the vertical type of wind mills, are lighter in weight and cheaper in cost. Further they are single directional and do not require a heavy shaft to support the rotor.

A horizontal axis propeller type machine having two or three blades is considered more suitable for power generation. The ratio of peak rated wind velocity to average wind velocity is an important parameter which governs the overall performance of the wind mill system. For a generator of a given rated power, a low peak to average velocity ratio requires a large rotor wind mill while a high peak to average velocity ratio requires a small

rotor wind mill. A large rotor mill is more expensive but gives greater average output and, therefore, a balance between the two is necessary.

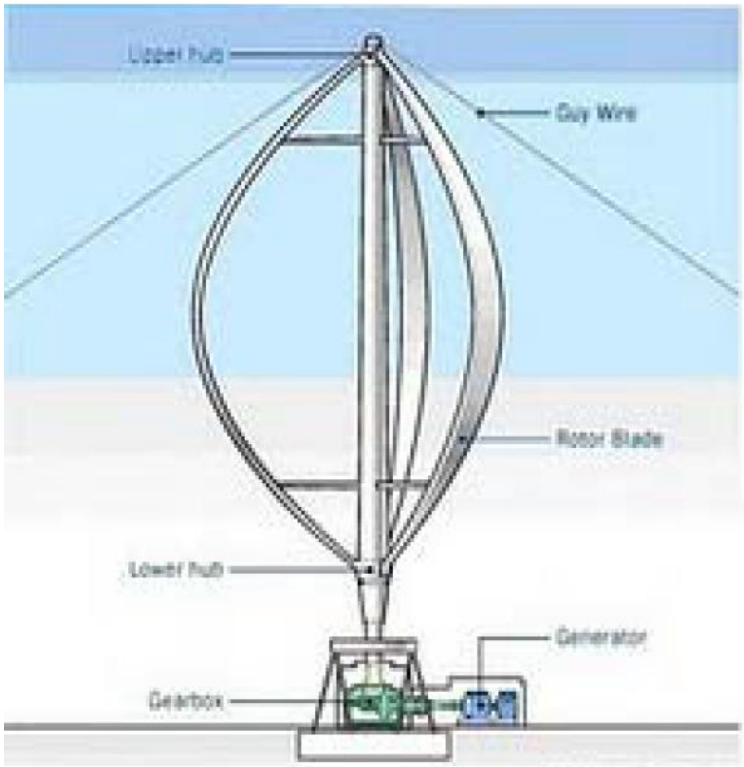

Fig: 3.2 Vertical-Axis wind turbines

Due to ground intervention slower, lower elevation means slower wind speed. So VAWTs are in general less resourceful than HAWTs. On the upside, all apparatus is at ground level for effortless installation mechanism and servicing; but that way a generously proportioned pawmarks for the turbine, which is a immense unconstructive in cultivation areas. VAWTs may be used for small-scale turbines and for pumping water in rural areas and irrigation purpose for cultivation for farming land but all commercially produced; utility-scale wind turbines are horizontal axiswind turbines (HAWTs) as shown in Figure 3.3

3.3.2.2 Horizontal-axis wind turbines:

As implied by the name, the horizontal axiswindturbinesshaft is placed horizontally, parallel to the ground. Horizontal axis windare also called the wind-axis machines. The axis of rotation of such machines is parallel to the direction of wind. The

machines are available in several designs. Depending upon the number of blades used these may be single bladed, double bladed, triple bladed multi-bladed or bicycle multi-bladed. Depending upon the orientation of the blades with respect to the wind direction these may be classified as upwind and downwind.

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An important consideration in wind power generations the economic flexibility of the However, wind power project may prove feasible for small power needs n isolated and remote areas. A local wind mill generator may offer a cheaper alternative in case long transmission lines are required to bring power from grids to these remote and isolated areas.

During the last three decades a few hundred small wind mills have been installed n rural areas in south India for pumping water. An 8 meter diameter wind mill was installed in village near Madurai in 1973. This wind mill is used for irrigating fields and supplying water for domestic and dairy use. This wind mill lifts 150 kg of water per minute to a height of 6 m when the wind speed is 16 km/h. A 220 V, 6 kW dc wind power plant supplied, West Germany has been installed at Central Power Research Institute Bangalore. The annual output from this power plant has been estimated to be about 15,000 kWh.

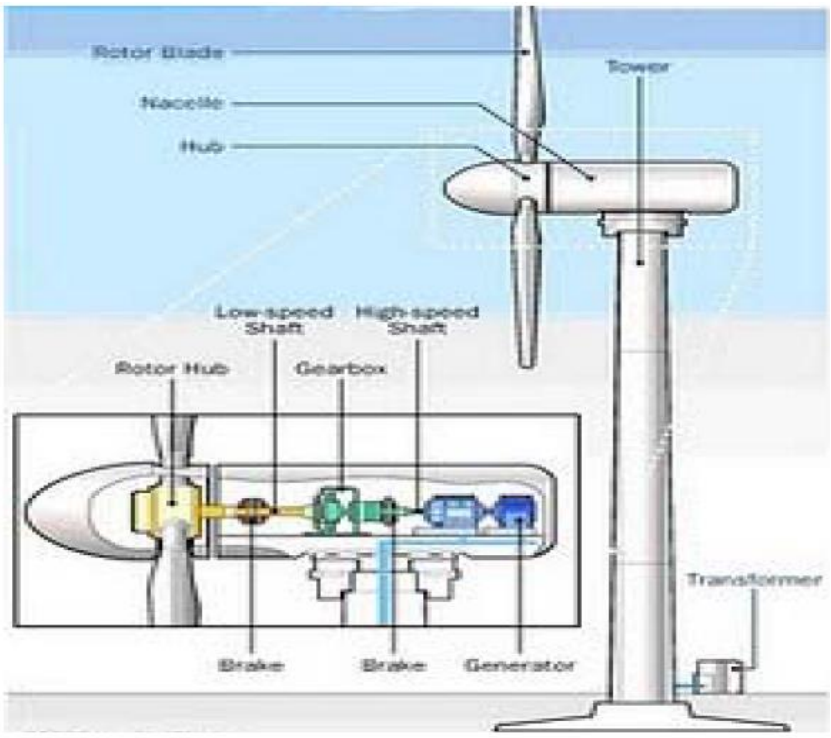

Figure 3.3Horizontal-axis wind turbines

One of the several expert committees appointed by the National Committee of Science and Technology recommends that wind mills can be used in certain parts of the country for generating electrical energy and to pump water for irrigation and drinking. Wind mills would be profitable all along the coast and in south Rajasthan, Gujarat, Maharashtra and Mysore where wind speed exceeds 10 km/h.

Though the generation of electrical energy from wind power is not likely to prove economically feasible but will certainly provide an alternative source of energy at cheaper rates for pumping water in rural areas.[14]

3.3.3 Advantages of Wind Energy:

Wind energy offer several advantages, which describe why it's the fastest-growing energy source in the world. A great research is going in this field.

- Moderate to low start up cost.
- No pollution so clean resource.
- Easy construction.

- Land below wind turbines can be used for other activities.
- Wind energy is a domestic source of energy.
- Windmills can produce electricity through the out the day as Wind flows all the day and night.
- Efficient converting of wind to electrical energy

3.3.6 Control methods of wind generator:

The main purpose of control in wind turbine systems is power efficiency and stability. Yaw control method is more focused on power efficiency. Torque control, power control and Pitch control, are involved in stability.

3.3.6.1 Yaw control:

This wind turbine ought to be synchronized together with wind streaming way to get the proper effectiveness. It could be carried out from the yaw handle that is founded on your wind way realizing considering that the wind way is actually altered while using the time. This yaw handle is actually executed because of the yaw handle actuator. This handle method flowchart connected with yaw handle is as demonstrated throughout.The control program flowchart of yaw control is as shown in Figure 3.5.[12]

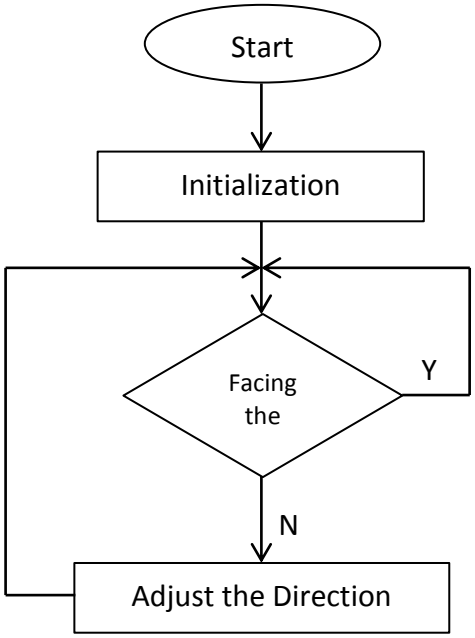

Figure 3.5 Flowchart of yaw control

3.3.6.4 Torque control:

Torque handle is significant point inside method. That serves around the electromagnetic power generator torque. This is a strategy to handle rotational velocity. Damping is additionally key that is mixed up in torque handle technique. This particular torque handle aids to make the machine secure by preserving rotational velocity [11].

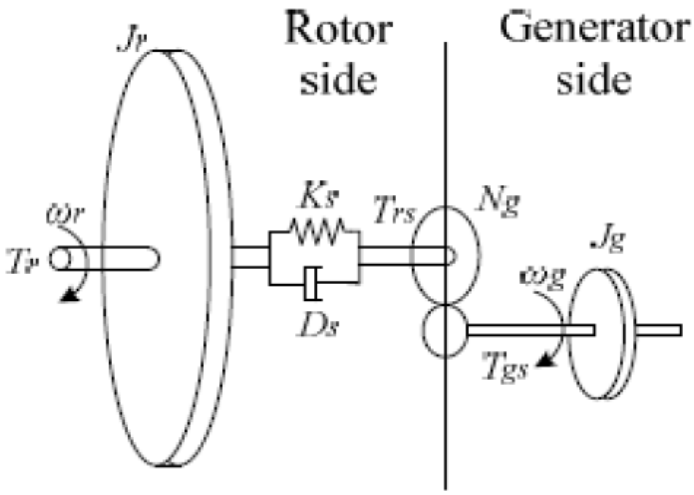

Figure 3.6: Gear Transmission box with Shaft

3.3.6.5Grid Control:

As explained above, grid parameters, voltage and frequency are to be kept very close to nominal value. The following commands 5 steps load disconnection plans to keep frequency stable:

- Grid frequency Action < 49.8 Hz - Alarming all the personals, Activation of all not yet operated power plants
- Grid frequency Action< 49.0 Hz Disconnection of 10-15% of load with delay.

- Grid frequency Action < 49.0 Hz Disconnection of 10-15% of load with delay.
- Grid frequency Action < 48.4 Hz Disconnection of further 15-20% of load with delay.
- Grid frequency Action < 47.5 Hz Disconnection of the power from the grid.

3.4 SOLAR ENERGY:

3.4.1 Introduction:

The sun is the ultimate source of most other sources of energy. This energy can be saved using solar panels to heat water .It can be converted to electrical energy by means of photovoltaic cells. Our India is receiving about 7000 billion MW of solar energy per year. If only 1 % of this energy could be plugged at even 10 % efficiency, it would be about 25 to 30 times India's present electricity production. For various domestic purposes, generating electricity using solar panels, solar water heaters investments, solar lamps, and the likes to conserve the natural resources. Conversion of solar energy to electrical energy depends on a device called the *photovoltaic cell,* also called a solar cell. Photovoltaic cells works on the principle of energy conversion which it received from in the Sun's radiation, in the form of photons; the photons are electrons generated from a material inside the cell and these flow of electrons produce an electric current. The semiconductor materials are used for such operations like silicon which act as the best substance for this conversion of photon energy to Electric current. Solar electrical energy generation by photovoltaic cell is based on through transfer of sunlight into electrical energy is exceedingly dependable, modular, little maintenance, liberated from fuel and nearby at round about each and every one positions in India for the majority division of the year i.e. about 298 sundrenched days can be anticipated .The Photovoltaic cell equipment is growing extreme speedily. In this technology, on a higher scale there are two main set back areas for concern i.e. day and night rotation and large cost of solar equipment.

Solar energy reaching the earth in tropical zone is about 1kw/m(e2) giving approximately 5 to 10 kwh/m2. In countries within 3200km of equator, use of such energy can be economically significant. The use of solar energy is, therefore of special importance for India. Most of the areas in India receive high intensity fairly uniform sunshine for 6 to 8 hours a day and roughly 10 month a year. Solar energy is already being used in many advanced countries, both for domestic and commercial purpose such as water as heating, water distillation, drying etc. The various methods, which can be adopted for converting solar energy into electrical energy.

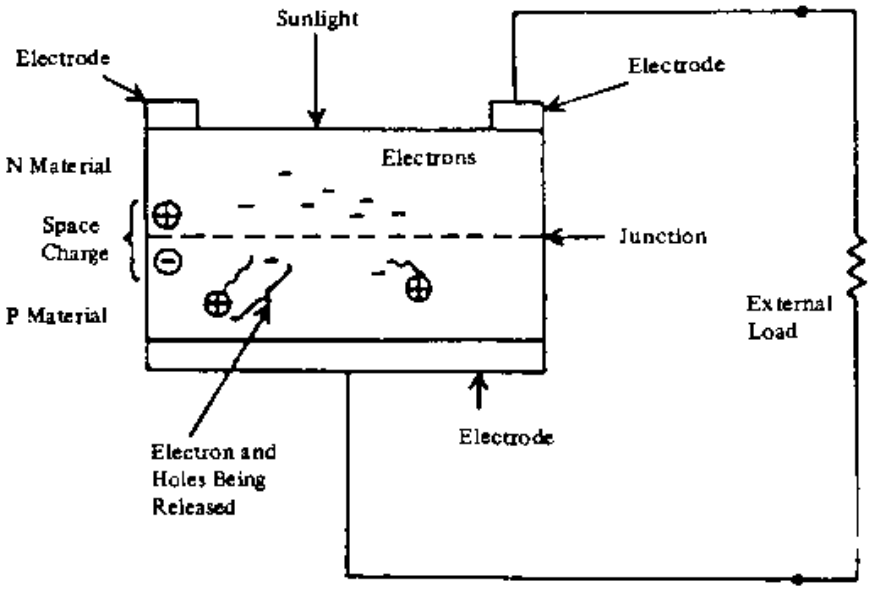

Figure 3.7 : P-N junction of Solar cell

3.4.3 Advantages of Solar Energy:

- It is free of cost.
- Easy and quick to install.
- Easy to add with other system.
- Pollution free energy.
- Noise free.
- Little damage to land.
- Photovoltaic cells have long life.

3.4.4 Disadvantage of Solar Energy:

- Installation cost is high
- need Solar energy mean the Sun at least 60percent of time
- Energy storage system required
- Need backup system of energy
- It hasshavy appearance

- Takeslongtime to complete cost40–50 years for energy savings to make up initial cost
- Manufacturing produces hazardous silicon wastes [13]

3.4.5 Solar Energy in India:

The generation of electrical energy from solar energy is a special importance for India, The reasons are:-

a) There is a need for conversion of fossil fuel resources, such as gas ,oil coal etc.

b) There is a need for reducing atmospheric and thermal pollution which are having serious detrimental effects of environments.

c) There is a need for supply of electrical energy in remote areas.

Solar energy has got the additional advantage of availability in abundance and at no cost and no problem of transportation or transmission.

Since solar energy is widely spread and so there is a need to make it available in concentrated from for which collectors used. The surface of these collectors is designed high absorptive and low emissivity. Collectors are of two types namely flat plate collectors and focusing collectors.

As the position of India is between the Tropic of Cancer and the Equator, Its average annual temperature that ranges is from 25°C – 27.5 °C which shows that India has vast solar potential.

PHOTO-VOLTAIC:

It is possible to convert solar energy directly into electrical energy by means of silicon wafer photo-voltaic cells, also called the solar cells, without any intermediate thermo-dynamic cycle. The solar cells operate on the principle of photo-voltaic effect, which is a process of generating an emf as a result of the absorption of ionizing radiation. Thus a solar cell is a transducer, which converts the sun's radiant energy directly into electrical energy and is basically a semi-conductor diode capable of developing a voltage of 0.5-1 volt and a current density of 20-40 mA/cm^2 depending on the materials used and the

conditions of sunlight. The efficiency of the solar cells is as low as 15%, but that does not matter as the solar energy is basically free of cost. The main problem faced is that cost (Rs 1,400 to Rs 7,000 per watt) of the solar cells and their maintenance. With the likelihood of a breakthrough in the large scale production of solar cells at low cost, this technology may compete with conventional methods of generation of electrical power, particularly as conventional sources of energy become scarce.

The photo-voltaic effect can be observed in nature n a variety of materials but the materials having the best performance n sunlight are the semi-conductors. In a piece of pure semiconductor like silicon, there is no free charge carrier at ordinary temperatures, but if this piece of silicon is doped with phosphorous or arsenic there will be one extra electron per atom of the impurity leading to N-type (negative type) semi-conductor. Similarly, if another piece of pure silicon is doped with boron (having one electron less than silicon) there will be deficiency of electrons (or excess of holes) leading to P-type impurities are connected by some means, a junction, at which the nature of the current carrier changes, is created. In fact, a potential energy gap (Eg) is created at the junction.

When a photon of energy ‘hv’ is allowed to fall on the P-region, it is absorbed by an electron in the valence bond. If ‘hv’ exceeds energy gap Eg, the electron will migrate to the N-region. Similarly if ‘hv’ is less than Eg in the N-region, the photon will be absorbed by a hole which will migrate to P-region.

This charge separation creates an electric field opposite to the electric field created by the diffusion of free electrons of the N-region and in case the field created by charge separation pre-dominates the electric field created by the diffusion of free electrons from N-region to P-region and holes from P-region to N-region current will start flowing the circuit Photo-voltaic cells generate a voltage proportional to electro-magnetic radiation intensity and are called as such because of their voltage generating capability.

Silicon solar cell consists of a thing slice of single crystal P-type silicon, upto 2 cm square, into which a very thin (0.5 micron) layer of N-type material is diffused. The circuit symbol often used for photo-voltaic cell.

The open-circuit output voltage characteristic of a typical photo-voltaic cell is shown , the graph is logarithmic on light intensity axis. This characteristic shows that the cell is more sensitive for low light levels, since a small change in light intensity (say from 10 to 100 lux) can produce the same increase in output voltage as a large change in light intensity (say from 100 to 1,000 lux) at a higher light intensity level. The output current of such a cell is very low and is measured in micro-amperes. Photocells can be stacked in parallel, however, in order to increase their output current capability. The conversion efficiency depends upon the spectral content and the illumination.

The photo-voltaic cells can be operated satisfactorily over a wide range of temperature (say from – 100 to 125o C). The temperatures variations have little effect on short-circuit current but affect the open-circuit output voltage considerably. These variations may be of the order of a few mill volts per ^{o} C output voltage.

The advantages of such devices are their ability to generate a voltage without any bias and their extremely fast response i.e. these devices can be employed as energy convertors directly.

Multiple-unit silicon photo-voltaic devices may be used for sensing light n applications such as reading punched cards in the data-processing industry.

Gold-doped germanium cells with controlled spectral response characteristics act as photo-voltaic devices in the infrared region of the spectrum and may be used as infrared detectors.

The solar cells are extensively employed as a source of power for space aircrafts and the advances in solar cell technology have found their way into many earth-based applications.

The group of series-parallel connection of solar cells operated to increase the capacity of system. Several cells are required to be connected in series to give the required output voltage and several of such series-connected groups are to be connected in parallel to provide the necessary output current.

To systems namely roof top array system and satellite system for generation of electric power from solar cells are being considered.

Roof Top Array System:

This system s an earth-based solar cell system mounted on roofs. The main difficulty is the problem of energy storage since this system will work when there is sun shine. The various possible alternatives for energy storage are:

a) Electro-chemical storage, but batteries of adequate capacity that can withstand frequent charging and discharging for several years are yet to be developed.

b) Hydro-storage n which water is pumped uphill when power is abundant and allowed to flow through hydro-generators at a time of peak demand. This possibility is suitable only to a few regions of the country.

c) Mechanical storage in high speed flywheels.

d) To store energy in the form of hydrogen, this could be re-converted into electricity in fuel cells. Hydrogen is obtained by the electrolysis of water by the output of the solar cells.

A more long range system that would also avoid the need for major storage of power is a space power station in synchronous orbit around the earth. A solar collector of 8 x 8 km will be fixed on the surface of the satellite. Electricity so produced will be used to produce a micro-wave beam. This micro-wave power will be transmitted to antennae on earth, and converted back into electric power. Although this system could provide large amount of power, but the problems regarding the endurance of the components, the control of large structures n space, and the safety of the micro-wave radiation, are still to be solved.

3.4.6 Control methods in photovoltaic systems:

The angle between sunlight and solar panels can significantly affect the ability of photovoltaic systems. Solar panels should be perpendicular to sunlight in order to illuminate strongly. Therefore, solar tracking systems are used to keep efficiency at a optima scale of photovoltaic systems. Solar tracking systems are devices for orienting

solar photovoltaic section toward the sun. The track of sunlight in the atmosphere varies both with time of day and the seasons as the sun moves across the sky. That's why solar photovoltaic system can easily increase the efficiency of a solar tracking system with a high accuracy. Solar tracking systems are of many types depending on its operating ways. Simplest type and mostly used in solar tracking system is the heliostat. It is nothing but a movable mirror which reflects the direction of the sunlight to a fixed place.

The correctness of the solar tracking system depends on the application. Especially, the qualities of concentrators decide a degree of accuracy. Therefore, large power plants or research facilities engage a high degree of concentrator in order to ensure high accuracy of the system. For low-temperature solar thermal applications, tracking systems are not commonly used. However, when it comes to high efficiency, solar tracking systems are indispensable elements in photovoltaic systems.

Solar tracking systems are of two types-

- Active
- Passive

In a view point of using power motor. Active one is operated using motors and gear trains and programmed by a controller responding to the solar direction. On the other hand, passive one is operated without any electric motor. Solar tracking systems are single axis or dual axis according to the number of axis. Single axis tracking systems use only one axis. For example, the solar panel is always toward south and increase or decrease the vertical angle according to the altitude of the sun. This single axis tracking system is simple and generally engaged one even though it has 30~40 % of low efficiency compared to dual axis tracking systems.

CHAPTER 4

FUEL CELLS

4.1 Working of Hydrogen Fuel Cell:

Fuel cell is device in which the chemical energy is converted directly into electrical energy. The chemical energy is the free energy of the reactants employed. The basic feature of the fuel cell is that the fuel and its oxidant are combined in the form of ions rather than neutral molecules. The first practical fuel cell was demonstrated in 1959 by Francis T. Bacin and J.C. Frost of Cambridge University.

In conventional steam power plants the chemical energy of the fuel is converted into heat energy by burning and the heat energy is, then, converted into electrical energy. The efficiency of this conversion process is limited by the limitations of Carnot cycle. In fuel cells the chemical energy of the reactants is converted into electrical energy as an isothermal process. Thus heat is not involved in the conversion process and a high conversion efficiency is possible. Another reason for the interest in fuel cells is that their efficiency and cost per kW of power are independent of size (or rating) of the fuel cell. This advantage makes the prospects of fuel cells very attractive as portable power plants for space-crafts, locomotives etc.

The other advantages of fuel cells are :-

(i) The unit is lighter and smaller and requires little maintenance because of absence of mechanical parts.

(ii) They cause little pollution and little noise.

(iii) No overhead line is required.

(iv) Fuel can be used more effectively than in a central power plant.

(v) A fuel cell gives a few times more electrical energy per unit weight as compared to a turbo-generator or storage battery.

(vi) They can become remarkable home units.

(vii) A variety of fuels such as methane, ethane, ethylene, acetylene, propane, butane, benzene, methanol, ammonia, hydrazine, LPG, biogas or coal gas can be used.

The sun is primary source of energy. Solar energy appears to be the most promising among the non-conventional source of energy. The sun's great energy release is the result of an elaborate chemical process in the sun's core – a process of thermo-nuclear fusion like the reaction in hydrogen bomb. Sun radiates energy of about 3.5*e14 kw into space and only 2*e14 kw reaches the earth. Converting even a part of solar energy at very-very low frequency can produce in far more energy than could conceivably be harnessed or utilized for power generation .Even if 90 percent of solar energy reaching the earth is lost by reflection, refraction & absorption in the outer layer of atmosphere, the quantity available at the surface is 2*e13kw ,which is equivalent to the burning of some 17 million tonne of coal. This stupendous solar energy, which is exhaustible and completely pollution free, could drive the civilization forever ,if it could be properly and economically harnessed .However ,it has got some serious drawbacks energy density per unit area is very low, it is available for only a part of the day and cloudily and hazy atmospheric condition largely reduce the energy reduce the energy received. Therefore, in harnessing solar energy for generation of electrical power large areas to collect sufficient amount of energy and means to store it will be required.

Most of the areas in India receive high intensity fairly uniform sunshine for 6 to 8 hours a day and roughly 10 month a year. Solar energy is already being used in many advanced countries, both for domestic and commercial purpose such as water as heating, water distillation, drying etc. The various methods which can be adopted for converting solar energy into electrical energy.

The generation of electrical energy from solar energy is a special importance for India, The reasons are:-

(A). There is a need for conversion of fossil fuel resources, such as gas ,oil coal etc.

(B). There is a need for reducing atmospheric and thermal pollution which are having serious detrimental effects of environments.

(C). There is a need for supply of electrical energy in remote areas.

Solar energy has got the additional advantage of availability in abundance and at no cost and no problem of transportation or transmission.

Since solar energy is widely spread and so there is a need to make it available in concentrated from for which collector's used. The surface of these collectors is designed high absorptive and low emissivity. Collectors are of two types namely flat plate collectors and focusing collectors.

These reactions produce electricity which takes place at the electrodes.

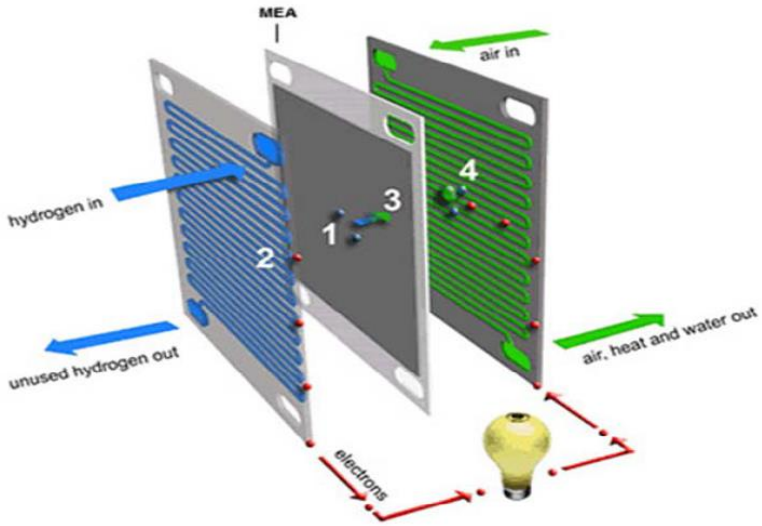

Figure 4.1 Internal Diagram of Fuel cell

Theoretically a fuel cell should be capable of generating electricity very efficiently. However the development costs are very high. It is necessary to work at high temperatures or high pressures or use costly catalysts for the reaction to take place at a speed in order to give high current densities required for an economic plant. Other drawbacks of the fuel cells are low voltage and low service life.

In spites of the limitations and drawbacks of fuel cells, development works of fuel cells are in progress at many places in USA and other countries. They are likely to have their own place in generation of electrical energy in the near future and will have revolutionary effect in spreading electricity n remote and rural areas of the world. The

development of fuel cells will be specially beneficial to India for supply of electrical energy to irrigation pumping sets in the villages and remote areas as the fuel cells as supply source of electricity will not require transmission lines for which a lot of money is needed. Indian scientists are, therefore, exploring the development and utilization of fuel cells.

A fuel cell normally contains two electrodes separated by an electrolytic solution. A fuel reactant, usually hydrogen or carbon monoxide is fed into one porous electrode and oxygen or air is fed into the other porous electrode. The electrodes should be capable of passing through both fuel and electrolyte and also to conduct electrons to the terminal. The electrodes must contain a chemical catalyst that breaks the fuel compound into atoms so that they are more reactive. The most commonly used catalysts are platinum and sintered nickel. The electrodes should neither have pores of too large size to cause bubbles of fuel gas nor of too small size to cause insufficient contact between the reactant and the electrolyte. The electrolyte solution must be highly permeable to either a H^+ or OH^- ion which is produced as an intermediate product at one of the electrodes. The same ion is transferred through the electrolyte to the other electrode where it combines with the other reactant.

The working of a fuel cell using hydrogen and oxygen is explained below.

When two permeable nickel electrodes are immersed in a well conducting electrolyte (say a solution of H_2SO_4 or KOH), negative electrode is fed with hydrogen, bubbled around it through the solution and positive electrode is fed with oxygen and the electrodes are connected together through an external circuit, then for every molecule of hydrogen consumed, two electrons pass from negative to positive electrode, where they react with absorbed oxygen. The operation of fuel cell can be summarized as follows.

Reaction at negative electrode is:

$$2H_2 + 4H^+ + 4\ e^-$$

Every hydrogen molecule brought to the electrode surface is dissociated into two atoms by virtue of the catalytic properties of the surface. These enter the solution as

hydrogen ions leaving behind two electrons which pass through the external circuit to the positive electrode.

Reaction at positive electrode is:

$$O_2 + 4H^+ + 4\ e^- + 2H_2O.$$

The oxygen supplied to the positive electrode reacts with hydrogen ions from the electrolyte and the electrons to give water. Thus water is the waste product of the cell. For the above case the electrolyte is acidic and the intermediate ion is H^+.

In case of alkaline electrolyte (a typical 40% KOH solution), the intermediate ion will be OH^- and the chemical reaction in the cell will be as follows.

At cathode: $2H_2 + 4OH + 4H_2O + 4e^-$

At anode: $2H_2O + O_2 + 4e^- + 4OH^-$

So, when the electrolyte is acidic, water is formed at the anode and when the electrolyte is alkaline, it is formed at cathode.

If the electrodes are on open circuit, negative charges accumulate at hydrogen electrode. These negative charges attract potassium ions, K^+ of the electrolyte producing a double layer. Similarly the loss of electrons from the oxygen electrode results in a layers of positive charges which in turn attracts hydroxyl ions, OH^- from the electrolyte and form a double layer. These electrical double layers build up at the electrodes until the potentials are such that they inhibit any further reaction between the electrolyte and the fuel gases. An open-circuit voltage of 1.23 V at one atmospheric pressure at 25^{o}C is developed. If the circuit is closed through an external load resistance, the electrons flow from the hydrogen electrode, through the external circuit to the oxygen electrode and take part in the reactions as mentioned above. The movement of electrons constitutes a current flowing through the external load circuit. The electrons movement is from the hydrogen electrode to oxygen electrode. Thus hydrogen electrode serves as cathode and the oxygen electrode as anode.

Fuel cells can be adapted to a variety of fuels by changing the catalyst, but 'hydrox' fuel cells using hydrogen and oxygen as fuel are the most efficient and most highly developed cells. Hydrogen can be obtained from natural gas, by catalytic cracking of ammonia or hydro-carbons or as a by-product from some processes. Oxygen may be obtained from the air or from decomposition of peroxides. A fuel cell power plant generally also contains a reformer and an inverter. The reformer uses chemical processes to convert the fuel to form that can be utilised by the cell while an inverter is used for converting output direct current into alternating current.

A single 'Hydrox' fuel cell can produce an emf of 1.23 volts at one atmospheric pressure and 25^{o}C, as already mentioned. However, it is possible to create useful potentials of 100 to 1,000 volts and power level of 1 kW to 100 Mw by connecting a number of cells in series-parallel combination. The current depends upon the physical size of the cell. The output of the fuel cell varies directly with pressure, so to increase the cell output, the gas pressure is raised. The optimum size of the cell at present is about 0.027 cubic metres per kW.

Hydrox cells are of two type namely low temperature cell and high pressure cell.

Fuel cells are particularly suited for low voltage and high current applications. Apollo Astronauts going to the Moon used fuel cells to convert hydrogen and oxygen to electricity. The power cells were located in the Apollo service module and provided the primary power source to operate life, support communication, guidance and other electrical system.

One type of fuel cell considered suitable for fuel cell power generation system is phosphoric acid fuel cell that operates at a temperature of about 190^{o}C. The fuel used in this cell is high calorific value gas (with methane as the principal constituent), oxidizer is air, electrolyte is phosphoric acid and electrodes are made of carbon catalyzed by platinum. The fuel cell voltage is 0.7 V, current density 200 mA/cm^{2} and expected life 10,000 hours.

Choice of Fuel For Fuel Cells. The choice of fuel for a fuel cell is governed by cost, availability, volume, transportability etc.

Amongst the fuels used in fuel cell hydrogen is the most important. This is because hydrogen and oxygen are capable of releasing more energy per unit weight than most other oxidizer combinations. Such fuel cells are widely used in spacecraft power supplies.

Hydro-carbons (such as methane, ethane, acetylene, benzene etc.) are less reactive than hydrogen, much more difficult to oxidize and their by-products are usually undesirable.

Compromise fuels (such as methanol, ammonia, hydrazine etc.) have reactivity in between that of hydrogen and the hydro-carbons. They are easy to use. Hydrazine is highly reactive at normal temperatures and does not require any catalyst. Hydrazine is used n fuel cells employed n military systems and submarines though it is very costly and poisonous. Ammonia is much cheaper than hydrazine, is readily available and easier to handle but its reactivity is low. Fuel cells using ammonia are considered quite suitable for specialized remote, low power applications.

4.2 TYPES OF FUEL CELL:

Types of fuel cell	Application	Advantages	Limitation	Status
Proton Exchange Membrane	Cars, buses, portable power, medium to large-scale stationary power generation.	Compact design, relatively long operating life, adapted by major automakers, offer quick start-up, low temperature operation, operates at 50% efficiency	High manufacturing cost needs pure hydrogen heavy auxiliary equipments and complex heat & water management.	Mostly widely developed, experimental production.
Alkaline	Space (NASA) terrestrial transport (German submarines).	Low manufacturing &operation costs, does not need heavy compressor, fast cathode kinematics.	Larger size needs pure hydrogen & oxygen, use of corrosive liquids electrolytes.	First generation technology, gains interest due to low operating cost.
Molten carbonate	Large-scale power generation	Highly efficient, utilizes heat for co generation.	Electrolyte instability, limited services life	Well developed, semi-commercial
Phosphoric Acid	Medium to large scale power generation	Commercially available, lenient to fuels, heat for co generation	Low efficiency instability, limited services life, expensive catalyst.	Mature but faces composition from PEM
Solid oxide	Medium to large scale power generation.	High efficiency lenient to fuels, takes natural gas directly, no reforms needed. Operates at 65% efficiency.	High operating temperature, exotic metals, high manufacturing costs, oxidation issues	Least developed in cell material & stack design sets off new research.
Direct methanol	Suitable for portable, mobile & stationary	Compact design, no compressor or humidification needed, feed	Complex stack structure, slow load response operates at 20%	Laboratory proto types.

	application.	directly methanol	efficiency.	

4.3 ADVANTAGES OF FUEL CELL:

Some more features of this energy resource solar cells can be described the following:

1. Substantial proficiency change

Energy solar cells transform chemical power into energy without the combustion practice. Therefore, any energy resource cell is just not ruled by thermodynamic laws, such as the Carnot proficiency related to warm search engines, currently used by strength era. Energy solar cells can do large efficiencies in power change conditions, particularly where the squander warm in the cell will be utilised in cogeneration circumstance.

2. Substantial strength occurrences

A higher strength occurrence makes it possible for energy resource solar cells to get reasonably compact cause of electric power, beneficial in program with space limitations. In the energy resource cell system, this energy resource cell per se 's almost dwarfed by some other different parts of the system such as the energy resource reformer as well as strength inverter.

3. Silent procedure

Energy solar cells, greatly assist mother nature regarding procedure, are exceedingly calm functioning. This allows energy resource solar cells to get utilised in housing as well as built-up places where the noises pollution will be unfavorable.

4. Low-to-Zero Emissions

An energy resource cell working on pure hydrogen emits absolutely no emissions for the origin. Some standing energy resource solar cells employ gas as well as hydrocarbons as being a hydrogen feedstock, but even these types of systems make far less emissions as compared to regular strength facilities. Depending on scored facts, any standing energy resource cell strength grow results in a lot less than one whiff regarding pollution per 1, 000 kilowatt-hours regarding energy produced.

5. Reliability as well as High quality Strength

Highly trusted strength is vital to numerous companies, and also housing residential areas. Roughly U.Ersus. Companies drop $29 billion every year by laptop or computer downfalls caused by strength black outs. Information stores, finance institutions, private hospitals, markets as well as telecoms corporations just about all count on regular capacity to maintain operations.

6. Downside:

Really the only downside in the energy resource solar cells associated with the charge. The 3 essential causes tend to be

I) Substantial costs in comparison to some other power systems technologies

II) Function requires replaceable energy resource offer.

III) Fuelling energy resource solar cells continues to be an issue since the creation, travel, supply as well as storage space regarding hydrogen will be complicated. [10]

4.4 HANDLE APPROACH IN ENERGY RESOURCE CELL ENERGY

Generally, energy resource cell system has centre components of management: cause of air as well as hydrogen, drinking water administration inside heap, as well as warm administration in the heap. Lover executes any centre part in air offer, warm administration as well as drinking water administration regarding heap.

CHAPTER 5

DESIGNED MICRO-GRID SYSTEM

MATLAB is a advanced and high-performance language mainly for technical computing. It integrates

- Visualization
- Computation
- Programming

In an easy-to-use environment. It helps where problems and solutions are expressed in familiar mathematical notation. Its use include Math and computation Algorithm development simulation and prototyping Data analysis, Data acquisition Modelling,, exploration and engineering graphics , graphical user interface building . Simulation work is done in **MATLAB 7.**Here **STANDALONE** system is taken under consideration for simulation work.

5.1 SPECIFICATIONS AND REQUIREMENTS OF THE ENTIRE MICRO-GRID POWER

System

For the simulation purpose,

Selected site: Dhank, Rajkot, Gujarat.

Average load capacity in the micro grid is 200 kW,

Maximum generator capacity of a used wind turbine generator: 100 kW

Number of Wind Turbine engaged: 5 wind turbine generators

Maximum generator capacity of used photovoltaic system: 220 kW

Maximum generator capacity of fuel cell system which is backup one of the micro-grid power system: 200 kW

Maximum battery capacity is 2000 kW and its initial value is 800 kW.

5.2 SYSTEM SETTING FOR THE WIND TURBINE SYSTEM PART

The annual variability of long-term mean wind speeds at site across India shows a normal distribution with a standard deviation of 6 percent. This result plays important role in the assessment of the uncertainty in the prediction of wind farm energy production. The simulation for wind turbine generation chooses a standard deviation of 6 percent which can represent wind speed in Dhank, Rajkot.

Month	**Average Wind Speed**	**Month**	**Average Wind Speed**
January	5.9	July	8.6
February	6.1	August	7.4
March	6.5	September	7.1
April	8.0	October	5.5
May	9.1	November	5.5
June	8.8	December	5.9

Table No.5.1: Average wind speed in Dhank, Rajkot

Wind Turbine Power is expressed by the following equation

$$\mathbf{P = 0.5\rho A\, C_p\, V^3\, N_g N_b}$$

Where,

P = power in watts

ρ = air density (about 1.225 kg/m^2 at sea level, less higher up)

A= rotor swept area, exposed to the wind (m^2)

C_p = Coefficient of performance (0.59 [Betz limit] is the maximum theoretically Possible, 0.35 for a good design)

V = wind speed in meters/sec

N_g = generator efficiency (50% for car alternator, 80% or possibly more for a Permanent magnet generator or grid-connected induction generator)

N_b= gearbox/bearings efficiency (It could be as high as 95%).

Rating(kW)	30	120	200	250	550	750	1700
Annual(MWh)	50	250	400	600	1500	2500	6000
Rotor(metres)	10	18	25	35	45	55	75

Table No. 5.2: Power Rating Vs Rotor Size

In the simulation,

Wind turbines with diameter of 17 meters are selected for 100 kW capacities

Air density ρ= 1.225,

Coefficient of performance Cp = 0.35 for a good design,

Generator efficiency Ng = 0.9,

And gearbox/bearings efficiency Nb = 0.95 are chosen

5.3 SYSTEM SETTINGS FOR THE PHOTOVOLTAIC SYSTEM PART

For photovoltaic system part, the engaged photovoltaic panel is SM 110-24produced by Siemens.

Its specifications are,

Rated power is 110 watts,
The voltage at max power is 35V,
The weight is 11.5 kg,
Dimensions (Length*Width*Height) is 1321*660*40 mm. [36]

Annual average possibility of sunshine in Rajkot is 60% from the Table 5.3. The solar tracking system is assumed to work perfect.

Month	**Sunshine (%)**	**Month**	**Sunshine (%)**
January	49	July	63
February	54	August	64

March	58	September	62
April	62	October	66
May	68	November	58
June	67	December	50

Table No. 5.3: Percent of possible sunshine in Dhank, Rajkot

Month	Sunrise	Sunset
January	7:27	18:25
February	7:20	18:42
March	6:55	18:46
April	6:20	19:17
May	6:10	19:09
June	6:00	19:36
July	6:10	19:25
August	6:20	19:19
September	6:33	18:55
October	6:43	18:14
November	6:42	18:10
December	7:11	18:01

Table No.5.4: Sunrise and sunset average time in Dhank, Rajkot

5.4 SYSTEM SETTINGS FOR THE FUEL CELL SYSTEM PART

A fuel cell system is engaged as a backup generator in the selected micro-grid power system while a diesel engine generator is commonly used as a backup generator in micro-grid power systems. The output power of the fuel cell system is assumed a constant as 200kW for its operating range.

CHAPTER 6

CASE STUDY

Case Study 1: April Month.

Month Under consideration: April

PV Data:

Sunrise Time: 6:27

Sunset Time: 19:07

Percent of Possible Sunshine: 62%

Wind Data:

Average wind speed: 8 m/s

All the other system settings are common for all the cases.

Now the random wind speed is generated using MATLAB. From the above defined formulas it can be clearly concluded that total wind turbine generated power a day is:

21309 * 5 * 24= 2557.136 kWh

This power is stored to the energy storage system initially without operating load as shown in figure 6.1. However, this micro-grid system requires more than 4,800 kWh power a day according to simulation setting. So wind turbine system is not enough to provide power to the load. In other words, only if total load is supplied through the wind turbine system then it can cover the given load size for approx 8 or 9 hours as per figure 6.1. As a result, the wind turbine system which has 5 wind turbine generators is not enough to satisfy the load requirement of the micro-grid power system. Besides for long life &recharging possibility of the battery, it must not discharge below 30% of its maximum value, so this also adds to the power deficiency of the system.

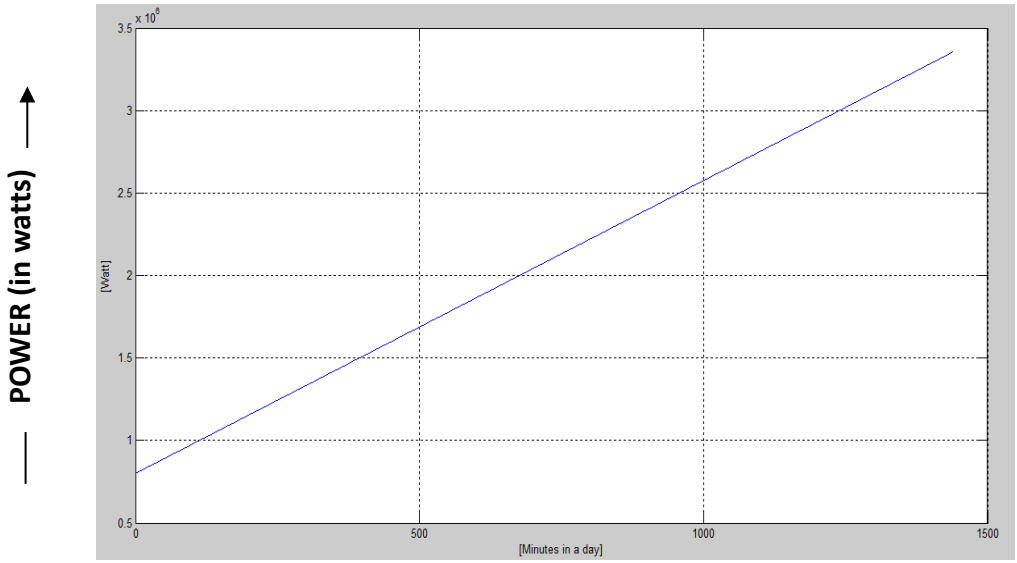

Figure 6.1: Total generated Wind power a Day.

Now if the wind turbine system and the load of 200 kW work simultaneously. Then the battery condition is shown in figure 6.2.

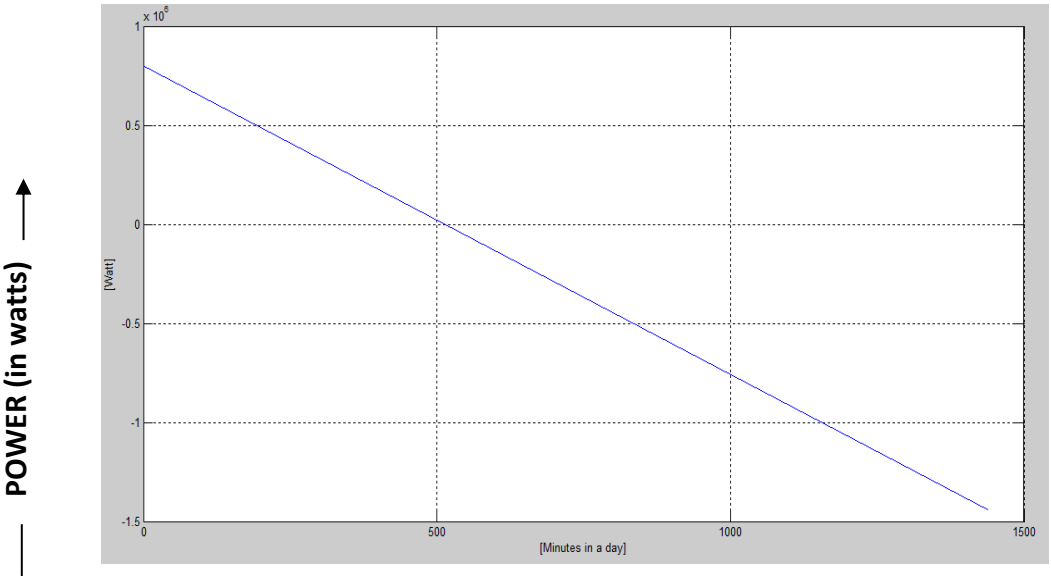

Figure 6.2: Stored power when the wind turbine system and 200 kW load are working simultaneously.

In the Photovoltaic generation part, from the **Figure 6.2**it can be concluded that the **totalgenerated photo voltaic power** a day is

2000 *110 *0.62 *0.77 * 12.6667 =1330.350 kWh.

However, this micro-grid system requires more than 4,800 kWh power a day according tosimulation setting. So photo voltaic system is not enough to provide power to the load fora day. And also for long life & recharging possibility of the battery, it must not dischargebelow 30% of its maximum value.

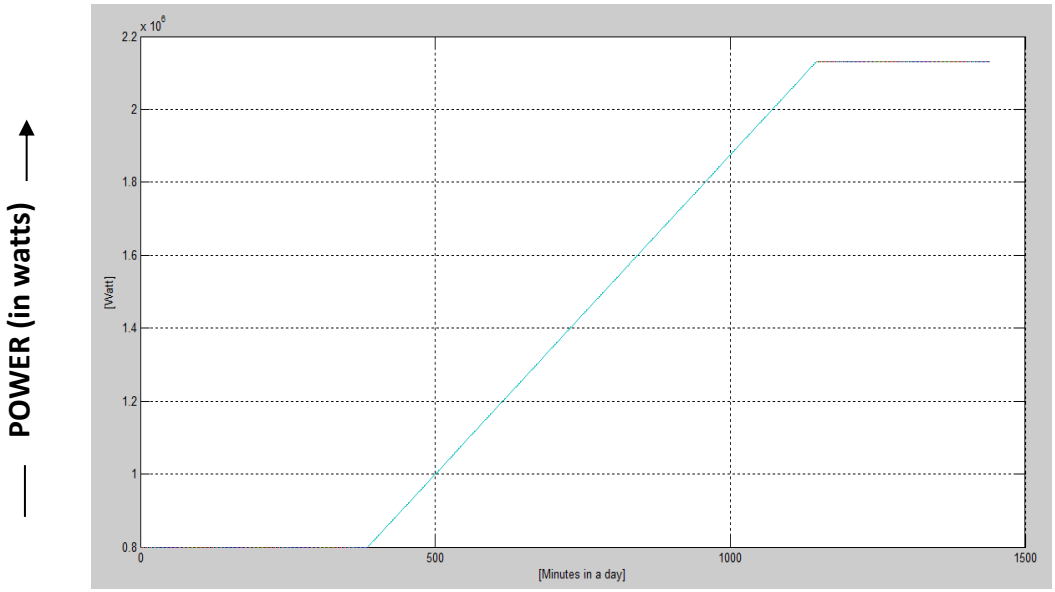

Figure 6.3: Energy generated by the photovoltaic system part.

It means that the photovoltaic generation system can only cover less than 4 hours formthefigure 6.3.As a result, the photovoltaic generation system which has 220 kW capacities is not enough to satisfy the load requirement in the micro-grid power system. Inthe next step, both the wind turbine system and the photovoltaic system are engagedwithout any intelligent control and any backup system.

From the result of figure 6.4, itonly covers about 22 hours. Therefore this combination of the wind turbine system andthe photovoltaic system is still unable to provide required power to this micro-grid powersystem.

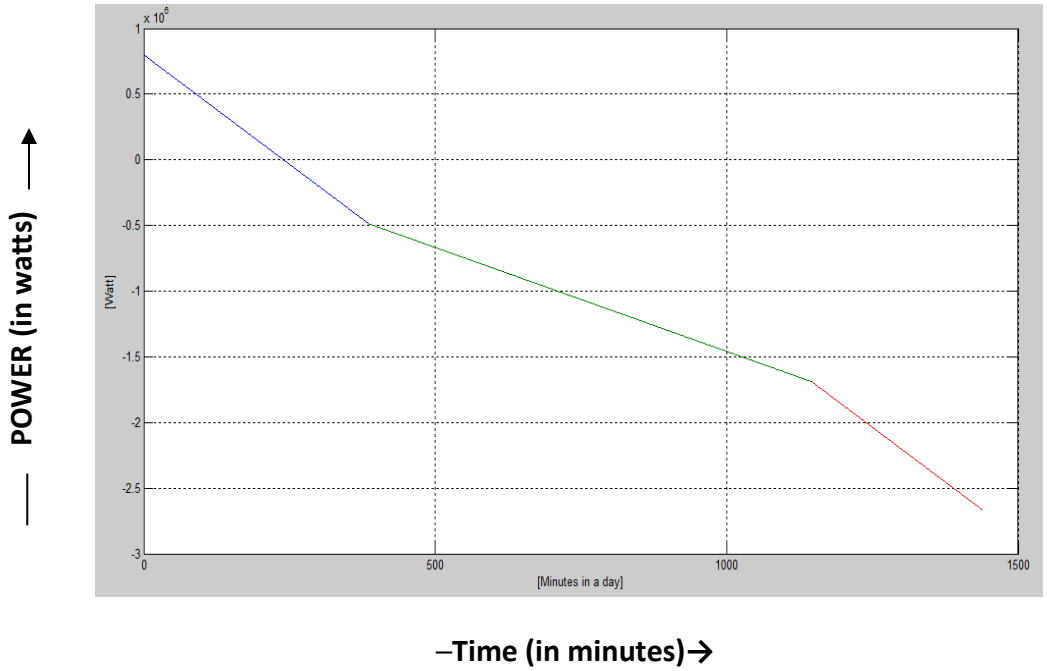

Figure 6.4: Stored power when photovoltaic system and 200 kW load are working simultaneously.

When both the wind turbine system and the photovoltaic system i. e. the micro grid working simultaneously with the load, the stored power is shown in figure .6.5

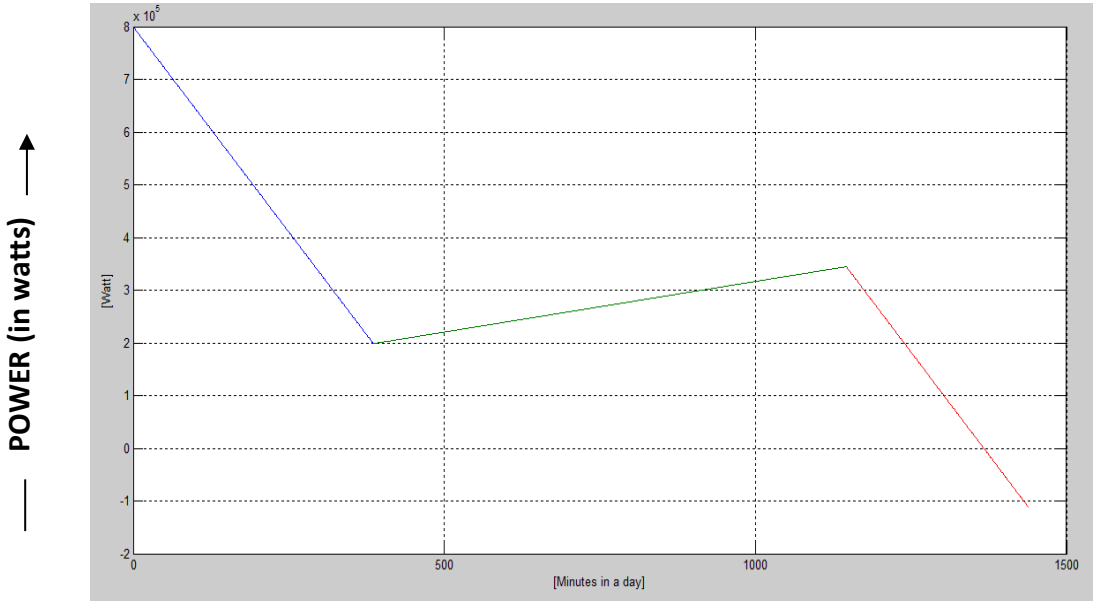

Figure 6.5: Stored power when micro-grid is working simultaneously with the load.

Finally, the micro-grid power system which is combination of the wind turbine system,the photovoltaic system, and the fuel cell backup system was designed with intelligentalgorithm shown in Figure 8.6 flowchart.

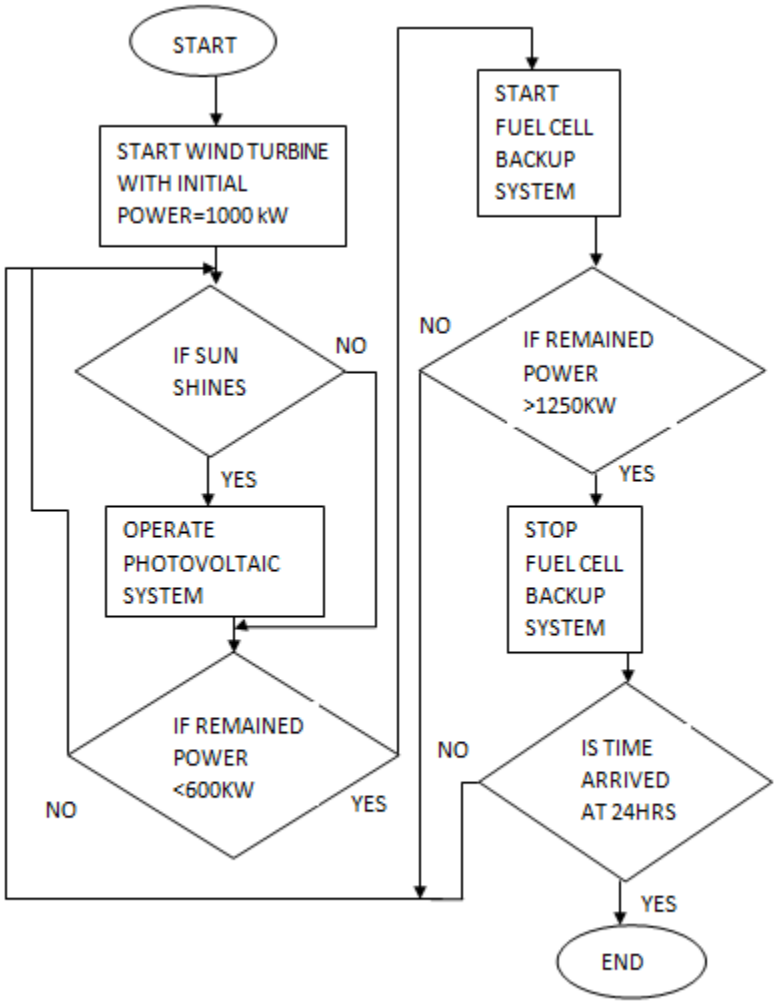

Figure 6.6: Flowchart for the designed system with fuel cell as backup.

From Figure 6.6, the micro-grid system startsthe predesigned wind turbine system part with 800 kW remained capacity of the battery.Second, it turns on the photovoltaic system part if the sun is shining. If it is night time,the fuel cell backup system is started when

remained capacity of the battery is lower than 1000 kW. The fuel cell backup system is also operated during day time when theremained capacity of the battery is less than 600 kW. The fuel cell backup system stops when the remained capacity of the system is 1000 kW. The minimum remained capacity ofthe battery (600 kW) was decided to increase the system stability. In other words, the micro-grid power system can provide power to its loads without any disconnection by preventing scarcity of remained power. Moreover, the maximum remained capacity ofthe battery (1,000 kW) can increase the effectiveness by reducing operating time of thefuel cell backup system.

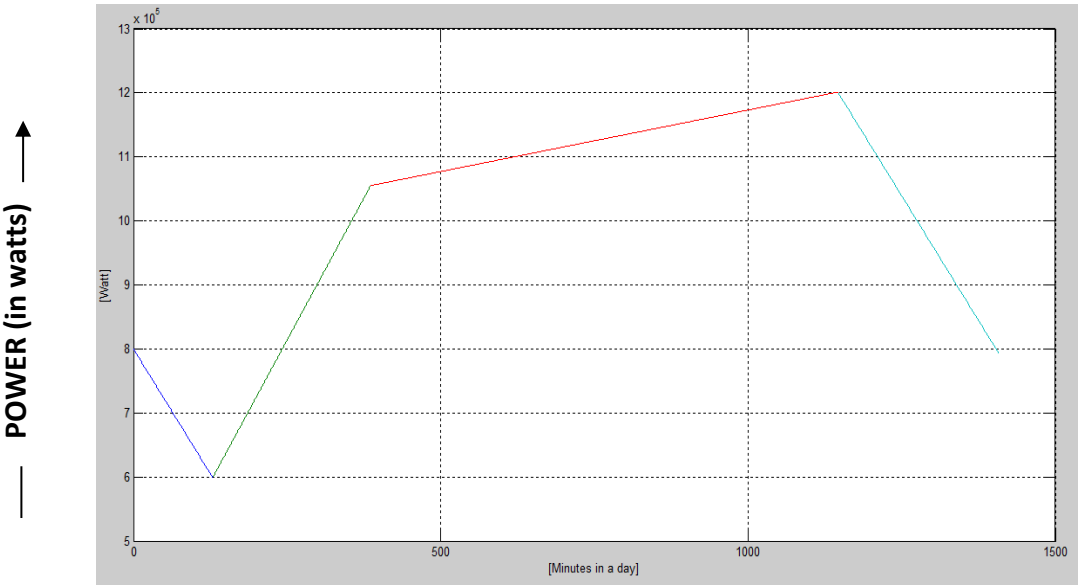

Figure 6.7: Micro-grid system working with fuel cell backup system and 200 kW load for the April month.

The result of the entire micro-grid in which wind, photovoltaic and fuel cell are integrated is shown in figure 8.7. The facts that the minimum level of power is 600 kWwhich are 30 % capacity of the battery, and maximum level of power is 1,000 kW which is50 % of the battery capacity is proved. As a result, designed micro-grid power system cancover a region which has 200 kW/hour load size for the April month.

Case Study 2: July Month.

Month Under consideration: July

PV Data:

Sunrise Time: 6:12

Sunset Time: 19:32

Percent of Possible Sunshine: 60%

Total generated solar power in sunshine hours=1422.960 kWh.

Wind Data:

Average wind speed: 8.6 m/s

Total generated wind turbine power in 24 hours= 3176.652 kWh.

For this month, only the last case, that is intelligently integrating the wind turbine system, Photovoltaic system and Fuel Cell as a backup system is considered shown in figure 6.8.

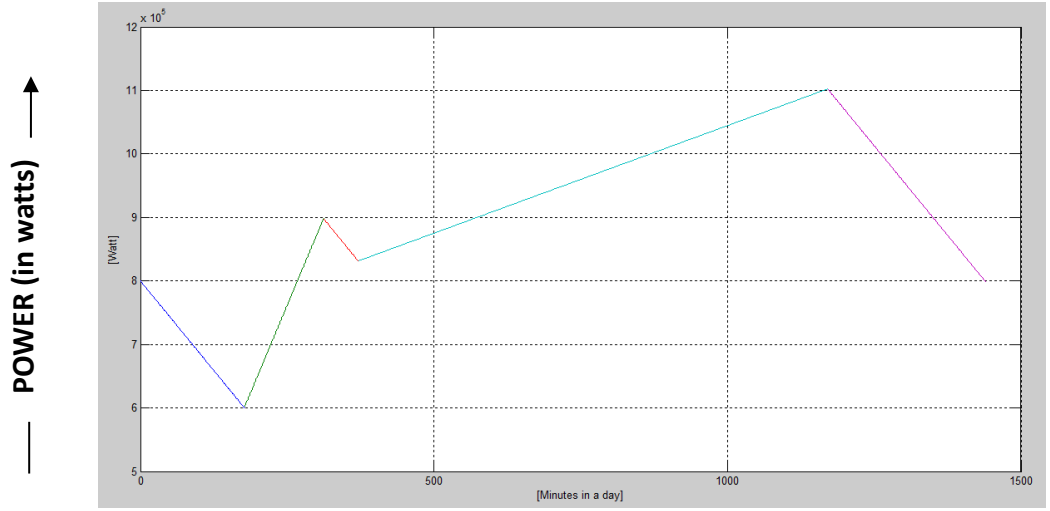

Figure 6.8: Micro-grid system working with fuel cell backup system and 200 kW loads for the July month.

From the above, it was found that intelligent system that is described can also work satisfactorily in monsoon season.

Case Study 3: Winter season.

Month Under consideration: December

PV Data:

Sunrise Time: 7:18

Sunset Time: 18:06

Percent of Possible Sunshine: 58%

Wind Data:

Average wind speed: 5.9 m/s.

The average wind data in the area, total wind power generated is equal to 1025.72 kWh.

Total photovoltaic power generated is equal to 1061.112 kWh.

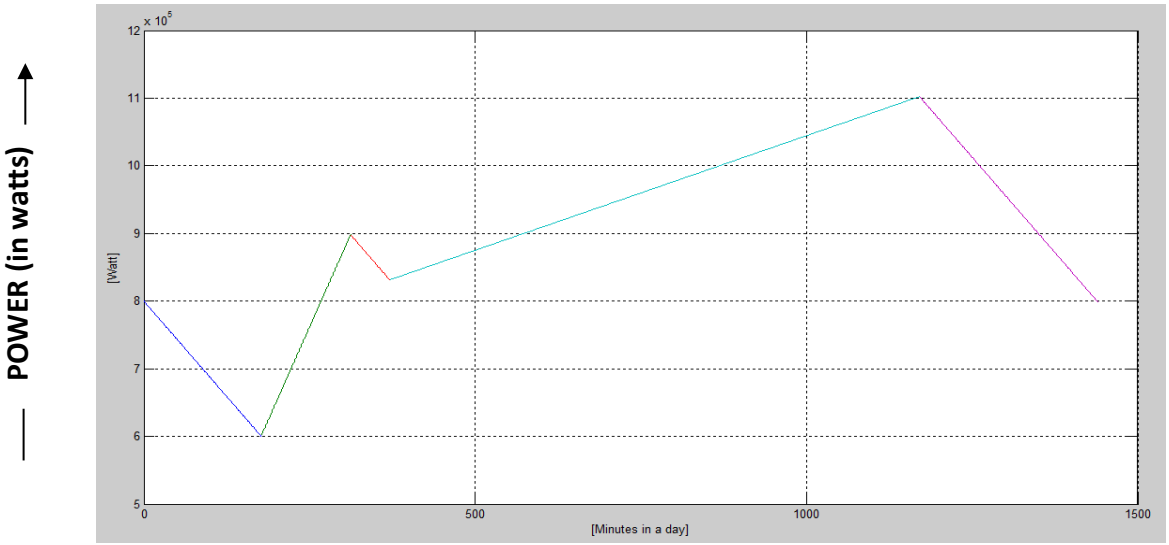

Figure 6.9: Micro-grid system working with fuel cell backup system and 200 kW loads for the December month.

From the above, it was found that intelligent system that is described can also work satisfactorily in winter season.

From the above 3 case studies, it is clear that our designed system worked perfectly in all the weather condition as it is important for the effective and widespread use of

renewable resources to be available all the year round meeting the required power needs even though they are completely dependent on the seasonal vagaries of the availability of sun and wind.

CONCLUSION

The system has been so designed that the fuel cell operates only when the power of the battery falls below 600 KW (which is minimum 30% of the total battery capacity). This helps to reduce the operating hours of the fuel cell, thus making it cost effective and ensures a better performance to have a longer operational life of the battery. This system seems to be highly Green Energy compliant as both the wind turbine and photovoltaic systems are Clean Energy sources. This kind of system helps in meeting the energy requirement without any consequences of depleting the fossil fuels, or facing the potential hazards of Nuclear Setups and also reducing harmful emissions compared to conventional back up sources. Therefore, micro-grid power systems are Environment- Friendly.

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