MODELLING AND SIMULATION OF HYBRID RENEWABLE ENERGY SYSTEM USING NEURO-FUZZY BASED MPPT

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IN
Power System

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(Kuldeep Kaur Makhija, 2K16/PSY/08)

ABSTRACT

For the social and economic growth and in order to enhance the living standards of human among the invention of energy, it is observed that nearly all energy is applied. In order to advance the human life and assure routine necessities of the human such as lightning, food processing, comfort capacity and communication, are met correctly by energy, as energy is much significant factor in helping the productive procedures. In the environment, a significant characteristic of global warming is carbon content, which may be decreased to a large extent by utilizing renewable sources of energy. Sunlight is the major significant renewable sources of energy which is utilized through the solar PV mechanism. Since sunlight is freely available, this mechanism is much desired.

The Maximum Power Point Tracking Controller (MPPT) is the mechanism that constructs the photovoltaic modules to run at optimum rate and extort more energy out of it. Using MPPT in order to attain the maximum effectiveness, several paradigms are proposed from time to time. MPPT paradigms should be efficient as well as must have a fast convergence. This report proposes an artificial- intelligence-based solution to interface photovoltaic (PV) array with a resistive load and to deliver maximum power to the load. The maximum power delivery to the load is achieved by MPPT controller which employs adaptive neuro-fuzzy inference system (ANFIS). The proposed ANFIS-based MPPT offers an extremely fast dynamic response with great accuracy. The system consists of photovoltaic module, boost converter and ANFIS controller to control the duty cycle of boost converter switch. Later, the solar system is hybridized with the wind energy system as the hybrid renewable energy system gives a very versatile scope of renewable energy system. The entire proposed system has been modeled and simulated using MATLAB/simulink software. The simulation results show that the proposed ANFIS MPPT controller is very efficient, very simple and low cost. The conventional tracking MPPT mechanisms have a major demerit of being slow.

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LIST OF ABBREVIATIONS

MPPT	Maximum Power Point Tracking
P&O	Perturbation and Observation
INC	Incremental Conductance
PV	Photo Voltaic
DC	Direct Current
FLCIC	Fuzzy logic controller Intelligent Control
ACO	Ant colony Optimization
ANN	Artificial Neural Network
SCCC	Short Circuit Current Control
OCVC	Open Circuit Voltage Control
PSO	Particle Swarm Optimization

CHAPTER 1

INTRODUCTION

1.1 Overview

To attain the current requirement of power as resources offered through the nature the power sector are searching for novel resources these days. In the environment the significant characteristic for the global warming is the carbon content that may be decreased to a larger amount through utilizing renewable sources of energy. The sunlight is the major significant renewable resource of energy that is used through the solar PV mechanism. For the inexpensive accessibility of the sunlight and the solar panel of the PVR basic arrangement this mechanism is much desired. In the PV panels various forms among the work required to manage the deliberation mechanism of PV panels are illustrated in this study. The Maximum Power Point Tracking Controller (MPPT) is the mechanism that constructs the photovoltaic modules to run at optimum rate and extort more energy out of it. In the power point in order to attain the maximum effectiveness the several paradigms were deliberated. As the MPPT paradigms are efficient but also have some demerits that they are very slow. The Incremental Conductance (INC) and Perturbation and Observation (P&O) are the mechanisms of the MPPT paradigm that are also introduced in this study [1].

From time to time the requirement of the energy has enhanced. For the social and economical growth and in order to enhance the living situations of human among the invention of energy it is observed that nearly all energy is applied. In order to advance the human life and assure the routinely requirements of the human such as lightning, food processing, comfort capacity and communication has been met correctly by the energy as the energy is much significant factor in helping to the productive procedures. From 1850 the utilization of the fossil fuels has been enhanced. From earlier the location of the fossil fuels such as oil, gas is very dominant that directs to quick development in the emission of the carbon dioxide. For comfort and productivity of the human welfare the transformation of the energy has been considered.

Human is dependent on the energy so in the human prosperity the continuous supply of energy has an important role.

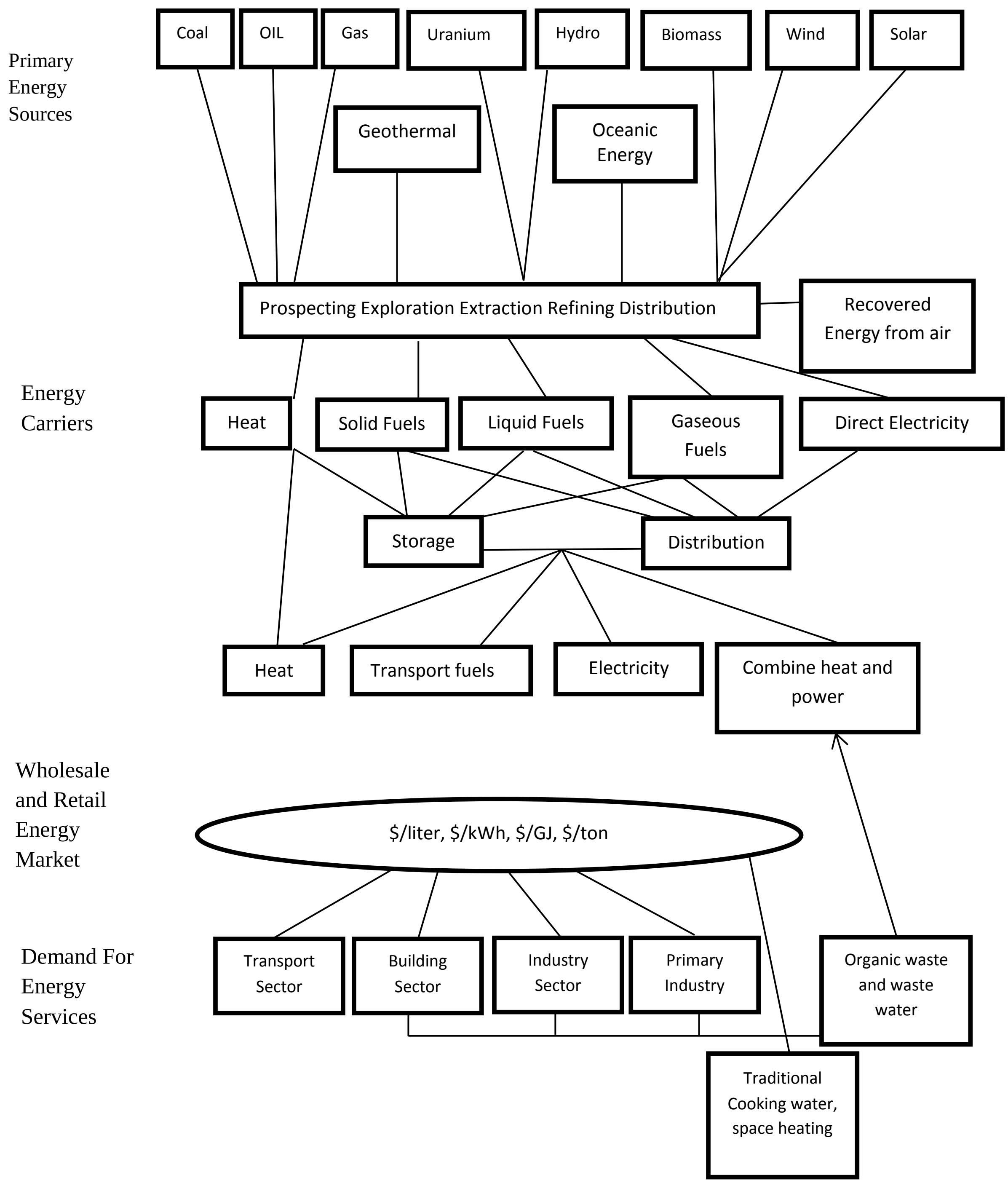

Figure 1.1 Complex Interactions between primary sources of energy and energy carriers to meet societal needs

Utilization of energy for various purposes is discussed below:

In cooking water heating, space heating and drying, 45% of the energy is utilized. For maximum temperature industrial procedure heating, 10% of the energy is utilized. In order to run the electric motors, 15% of the energy is utilized. For transportation, 30% of the energy is utilized. Due to the use of fossil fuels, 80% of the total Global emission of CO2 gas occurs. The growth in population, with its increased standard of living, demands more energy than ever. Also the demand of energy and the progress of economy occur simultaneously. From the records, it is evident that developing countries are always in demand of more energy, and with increase in demand price increases exponentially. The countries which do not generate oil, have centred on the production of the electricity in order to fulfil the domestic energy requirements after the crisis in 1973/74 and 1979/80. The possibility of demand supply disturbance of energy is still there, as the oil prices are steady. The energy supply of the world is acquiescent through 80% of the fossil fuels that is a challenge in order to utilize a low carbon emitting modern energy mechanism. The enhancement in the energy effectiveness will lead to reduction of GHG-emission.

1.1.1 Sources of Energy

On earth, naturally accessible sources of energy are classified mainly as:

1) Renewable Sources of Energy
2) Non-Renewable Sources of Energy

Renewable Sources of Energy: The renewable sources of energy are sun, rain, wind, geothermal heat etc. These sources of energy are available in abundance and does not deplete on consumption and hence are called infinite sources of energy.

Non-Renewable Sources of Energy: The energy source such as coal, petroleum etc. are the non-renewable sources of energy. These sources are also accessible naturally and they are not available in large amount because of it there is a probability that if these resources are used with cruelly, then they are ought to be drained. The non-renewable sources are also based on the geography for instance petroleum gas is mainly available in gulf regions. So the non-renewable sources are also deliberated as finite sources of energy.

In the upcoming years the energy source such as coal, natural gas, and oil is possibly to get fatigued. On the renewable sources of energy the demand of time is centred much in order to use them in a way that they comes into the entire substitute of non-renewable sources of energy. In 2012 it was reviewed that 19% of the energy was utilized and in the overview of 2013 and 2014 it was illustrated that number of utilization is increased as per renewable global status review.

There is a surprising augmentation in the utilization of the renewable sources of energy from the year 2010 to 2013 through this review a report was created that is illustrated below in the table.

Through the power sector it can be illustrated that the potential has been observed in solar energy in order to substitute the non-renewable sources of energy as it is exhausting every day and apparently the solar energy will establish its value and significance to accomplish main power necessitate in the future.

Table 1: Necessary global indicators for renewable energy

S. No	Energy Resources (GW)	2010	2011	2012	2013
1	Renewable power installed capacity with hydro	1250	1355	1470	1560
2	Renewable power installed capacity without hydro	315	395	480	560
3	Solar PV installed capacity	40	71	100	139
4	Wind Power installed capacity	198	238	283	318
5	Concentrating Solar Thermal Power Installed Capacity	1.1	1.6	2.5	3.4

1.2 AIM and Approach

Aim: The Maximum Power Point Tracking Controller is the mechanism that constructs the photovoltaic modules to run at optimum rate and extort more energy out of it. In the power point in order to attain the maximum effectiveness the several paradigms are deliberated. As the MPPT paradigms are efficient but also have some demerits that they are very slow. The Incremental Conductance (INC) and Perturbation and Observation (P&O) are the mechanisms of the MPPT paradigm that are also introduced in this study. The conventional tracking MPPT mechanisms have the biggest demerit that while tracking they are slow down or already slow in nature because of the ripples or errors are generated and the usage effectiveness is also decreased in the mechanisms. In order to overcome this issue we utilize the PO paradigm and to track the power needed adaptation and also to generate the efficient outcomes.

Approach:

1. To update the MPPT exiting model while introducing ANFIS based MPPT controller for effective outcomes.
2. To design hybrid approach that coupled together Solar and Wind based energy system.
3. To analyze the proposed model in terms of different parameters.

1.3 Literature Review

This chapter contains the study or research done by many authors in the field of maximum power tracking, Wind mechanism, solar mechanism and MPPT tracking mechanisms and many more. Through analyzing this research or study it becomes very helpful and simple to generate a novel mechanism. So the Literature review plays an important role in the projected mechanism.

1. **B. Pakkiraiah et. al.** in this paper the author had projected several sorts of PV mechanisms, power source for PV mechanism, MPPT paradigm, several sorts of controllers, harmonics reduction filters, power electronic converter usage for the principle of controlling. On the development of PV mechanism and the consequence on the effectiveness of the PV mechanism was focused in this work by the author.

2. **Arfaoui Jouda et. al.** in this paper the author had illustrated the fuzzy logic controller in order to observe the maximum power point of boost-based PV mechanism and among sudden irradiation and temperature situation how this mechanism enhance PV mechanisms response. Among the optimization of scaling factors of fuzzy controller the effectiveness of the controller enhanced in this work and introduces the Particle Swarm Optimization Algorithm that is optimization mechanism. Through numerical simulation the PSO paradigm had utilized in this paper in order to tune the scaling factor in order to observe the control presentation of the fuzzy-MPPT and afterward optimized FLC is utilized to the DC-DC Boost converter. In order to improve the effectiveness of the PV mechanism the optimization of the fuzzy-MPPT strategy was focused in this work by the author.
3. **M. Nabipour et. al.** in this paper the author had surveyed the comparison the traditional MPPT mechanisms and MPPT control mechanisms on the basis of adaptive fuzzy logic. Through observing the Maximum Power Point of the PV module the presentation was optimized the "antecedent-consequent adaptive1"indirect fuzzy based –MPPT mechanism was projected. The projected mechanism that was Antecedent-consequent adaptive1 indirect fuzzy based scheme was quick, soft as its membership function was tuned synchronously and on the traditional MPPT mechanism the strength was verified.
4. **Nuno Miguel Martins da Rocha et. al.** in this paper the author had projected a mechanisms in order to observe and control the PV cell temperature in a way that the operating point of the PV cell residues in the vicinity of MPP in order that there is no necessitation to utilize several MPPT paradigm to the DC-DC converter.
5. **Sabir Messalti et. al.** in this paper the author had projected a couple of enhanced ANN MPPT mechanisms. On the basis of the variable and fixed step size a couple of ANN MPPT mechanisms were occurred. In order to generate the data that produces the ANN model a mechanism that is Perturbation and Observation paradigm was utilized. To construct the neural network MPPT controller the couple of steps, online step and offline step were also illustrated in this paper. Initially, to attain the optimum neural network MPPT controller several neural network parameters were qualified. Afterward, the optimum neural network controller was used by the PV mechanism.

The simulation results were demonstrated by the MATLAB and SIMULINK in order to examine the presentation of the fixed and variable step size ANN-MPPT mechanism.

6. **Ali El Yaakoubi et. al.** in this paper the author had illustrated that the squirrel cage induction machine had utilized the fuzzy logic control to attain the maximum power from the turbine of the wind. The optimal rotational speed was resulted in the optimal power and the approach to attain it was recommended in this work. Through utilizing the Simulink/MATLAB the functional review of the MPPT-FLC was simulated that offered the concept regarding the capacity of project in order to attain the maximum power from the wind.
7. **T.S Balaji et. al.** in this paper the author had illustrated the hybrid source of energy was formed by a couple of renewable sources of energy and its capacity to offer the huge power. In order to decrease the unnecessary components a minimum cost power converter had illustrated in this paper. Through linking to the converter the electricity was produced by utilizing the wind energy or solar energy. By applying a fuzzy logic the power of 30KW was offered by the wind/solar energy attained in the Hybrid modal. In order to offer the load voltage of 300 V and load current of 0.1 KA by the help of the strength of the hybrid system. In order to attain the maximum power under incremental conduction paradigm the utilization of fuzzy logic among photo voltic array was projected in this paper.
8. **Akanksha Shukla et. al.** in this paper the author had projected a mechanism in order to resolve a couple of main demerits of the PV mechanism, minimum energy alteration effectiveness and maximum initial cost. In order to extort the more energy from PV cell the MPPT mechanism was utilized. On the spot of the maximum energy the PV cells had to be operated. The simulation results had demonstrated by the MATLAB that illustrated the maximum energy alteration and among the boost converters the MPPT was monitored and the Perturb was simulated.
9. **Gyorgy D. Szarka at. al.** in this paper the author had projected a mechanism in order to recover the less energy restriction of PV mechanism by applying the MPTT that was the maximum power transfer tracking. This mechanism could boost the minimum energy and could operate among no external input. Through enhancing the load

current waveforms peak to peak mean ratio among the power conditioning mechanism the power generation was improved.

10. **Kumaresh V. et. al.:** In this paper the author had illustrated the effectiveness of the MPPT paradigm to remove the minimum power and effectiveness restriction of the solar cell and also demonstrated the various MPPT paradigms. In this paper the practical applications of the MPPT paradigms were illustrated in order to improve the power of solar cells.
11. **Ram Naresh Bharti et. al.:** In this paper the author had simulated the entire operation of the solar power production in which power is generated through utilizing the solar energy. The solar energy was altered to the electric DC power by the photovoltaic mechanism. The low DC voltage that was produced through the photovoltaic mechanism was boosted by the DC-DC boost converter as illustrated in this work. The large power was offered by the boosted DC through the application of the MPPT mechanism and afterward the duty ratio of the waveform is boosted by Perturb and Observe mechanism.
12. **Priety et. al.:** In this paper the author had focused on the utilization of the renewable resources especially on the usage of the solar energy and its alteration to electric energy through the utilization of the photovoltaic cell. Because of the solar irradiation and temperature among nonlinear I-V and P-V features the problem of the fluctuation of the maximum power acquired through solar energy alteration was also demonstrated in this paper. The various MPPT mechanisms were offered in this paper in order to resolve the similar problems and the differences within the several MPPT mechanisms that had been surveyed by the author in this work.
13. **Pawan D Kale et al.: I**n this paper the author had illustrated the problem of the complexity to follow the maximum power because of the various factors and had introduced the concepts and mechanisms in order to resolve the complexity. In the tracking speed and correctness the effectiveness of the open circuit and slope detection tracking mechanism was verified. This is also verified that this mechanism was much power effective mechanism.
14. **Chandni Sharma et. al** in this paper the author had focused on enhancing the PV power of the mechanism output power through examining various MPPT

mechanisms among their elaborative studies. The simplicity, convergence speed, digital or analogical execution, necessitation of sensors, cost efficiency and other features were the major factors over these various MPPT mechanisms had been analyzed.

15. **Raju P et. al** in this paper the author had introduced the Hybrid power systems (HPS) among the MPPT controller in order to improve the output power of the PV mechanism. The author had centered on the utilization of standalone power mechanism and its efficient applications in the rural regions.
16. **Rashid Al Badwawi et al.** in this paper the author had centered on the solar and wind hybridized power and confronts in order to construct the totally fledged energy source. About the hybrid power mechanism, voltage variation and frequency variation were the main concerns that were illustrated in this paper by the author. In order to eliminate the flaws the appropriate deliberation, advance response control facilities, hybrid mechanism optimization mechanisms were projected in this work. In order to construct the hybrid mechanism to work at its peak power the author had centered much on the advancement of the overall architecture. In this paper a couple of mechanisms grid-connected and standalone hybrid mechanism were measured and surveyed.
17. **Anil Kumar Kashyap et al.** in this paper the author had a couple of factors, Quick Reaction and High tracking Accuracy as the main deliberation necessitation in MPPT control to improve its power and operated to its optimum level. In order to enhance the power of the PV mechanism the usage of the MPPT paradigm was also illustrated in this paper. The author had surveyed the Hybrid power mechanism and centered on the standalone power mechanism and its finest appropriateness for the rural regions.
18. **Parveen Shukla et. al.** in this paper the author had examined several maximum power point tracking mechanism based on its three classifications that were as: Power Signal Feedback method, Hill Climb Search and Tip Speed Control mechanism. This work analyzed the MPPT mechanisms over the turbine mechanism to construct it quick and improved for wind energy alteration and its capacity in order to attain the optimal operating point for maximum power transfer

19. **S. Marmouh et. al.** in this paper the author had projected the Wind Energy Conversion System (WECS) to extort the maximum power for broad array of wind speed. The Permanent Magnet Synchronous Generator (PMSG) was contained in this mechanism over which the MPPT control paradigm was utilized. Through the AC-DC-AC converter the stator of PMSG made linked to the grid. Through influencing the Grid Side Converter (GSC) the DC link voltage flow was assured within a couple of convertors. Through the practical implementation the simulation results were demonstrated.
20. **Xiangjun Li et. al.** had introduced the control technique in hybrid wind/photo voltaic system so that it has minimum number of fluctuations and also introduced regulation of battery SOC under various situations. For the analysis of the introduced system the Matlab and Simulink simulation software were used. The analysis results had revealed that the circuit was optimum. During analysis the computation was done to determine the amount of improvement in fluctuating output signal.
21. **D.P Hohm et. al** had analyzed the output of three different types of efficient algorithms and also determined the efficiency of MPPT. Microprocessor-controlled MPPT and PV array simulator were used in order to find the difference and similarity among different algorithms, the comparison result had shown that P&O method were highly efficient as compare to other and crossed the value of 97% . Author reviewed various MPPT techniques and shown the best MPPT algorithm.
22. **EL. Talnbany et. al.** Author had compared various AI-MPPT techniques. Author had determined the best MPPT algorithm. With these techniques the source resistance can be matched with the load input resistance so that the maximum amount of power can be transmitted. Information had received from various types of AI techniques so that the optimum method can be suggested.

1.4 Plan of Thesis

1.4.1 Present Work: As the existing techniques suffer from several issues, so a better approach is introduced in this work. Initially the existing MPPT strategy is replaced with the Adaptive Neuro Fuzzy Interference System (ANFIS) based PID controller to produce better outcomes. In ANN, if neural is not trained for any particular output then in those cases will get the static result. But in ANFIS both neural and fuzzy is combined i.e. only data is given as input and fuzzy makes their own rules. So, if in some cases fuzzy is unable to give the output then also output can be achieved through neural and vice versa. Furthermore, wind energy system is also hybridized with solar energy system. Occasionally, the power generated from solar system cannot be acquired due to non-availability of sun. Thus, wind energy system is used to make power at the unavailability of solar energy system. Consequently, hybridization of both energy systems is employed in the proposed work to make use of solar and wind simultaneously. The advanced intelligence based controller lead to the fast tracking in the system in comparison to the traditional controllers.

1.4.2 Methodology:

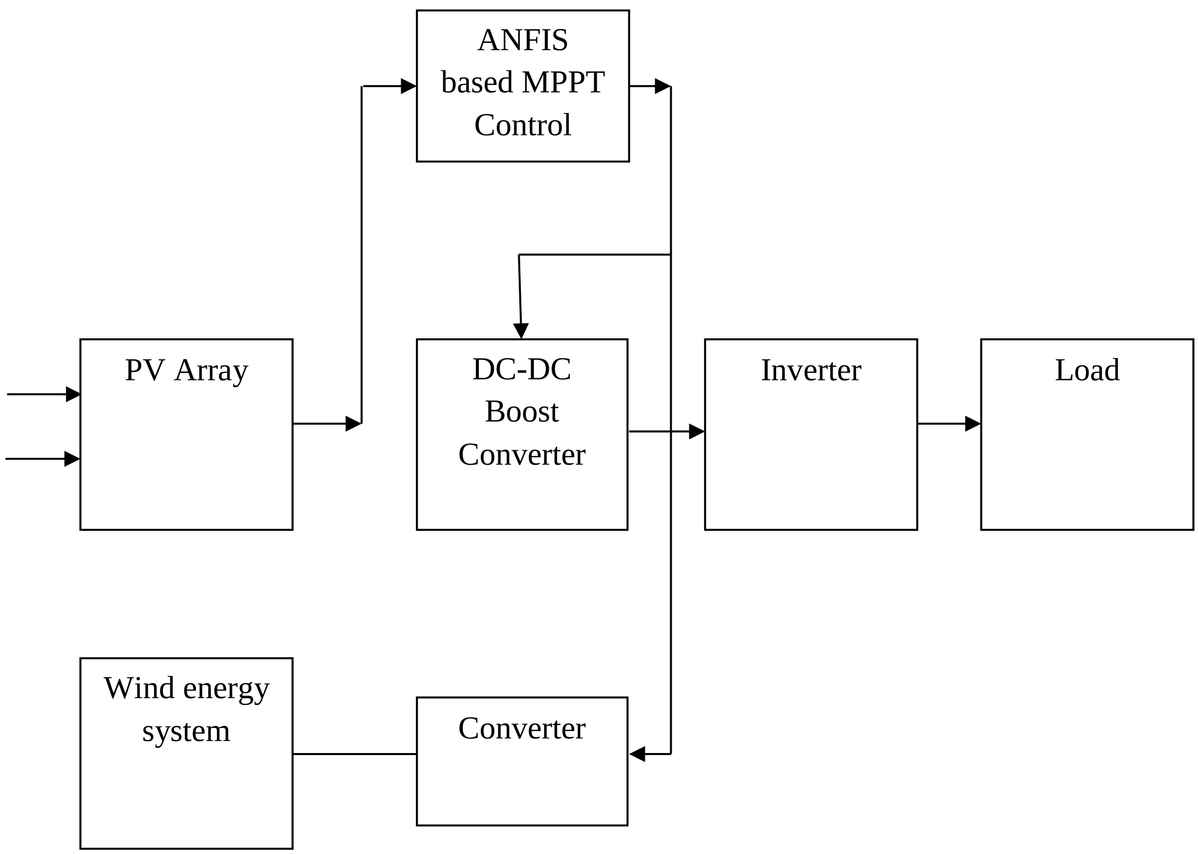

Figure 1.2 Block Diagram of Hybrid System

1.4.3 FACILITIES REQUIRED

Hardware Requirements

- Processor (Intel I, Intel II or higher)
- RAM (2 GB or higher)
- Disk Space (20 GB or more)

Software Requirements

- Operating System (Win-XP, Win-7 or any other higher version)
- MATLAB
- MATLAB Simulink Tool

CHAPTER 2

SOLAR ENERGY SYSTEM

2.1 Introduction

By applying Photo Voltaic Cells or Panels from the sunlight the electrical energy is achieved in the solar energy system and therefore is merely a renewable source of energy. Through the radiation and temperature that has large influence on the outcome of the panels the PV panels are straight forwardly affected. As enhancement in the temperature the advancement in radiation outcomes into the improvement in the currents value as the voltage remnants constant that reduced the voltage of the circuit and enhances the short circuit current in the solar radiation intensity through enhancement. The I-V and P-V curve is altered by fluctuating the temperature and irradiance that in turn alters the maximum power point. Due to the nonlinear I-V characteristics the nature of the associated load offered major effect on outcome of the power of the photovoltaic mechanism [2]. In the voltage the fluctuating P-V load caused continuous variation therefore to attain the highest power from the PV array having MPPT mechanism that improves the effectiveness of the method the constant tracking current is necessitated. Due to the solar energy the Photo voltaic mechanism operates. The configuration of the PV mechanism is illustrated below as:

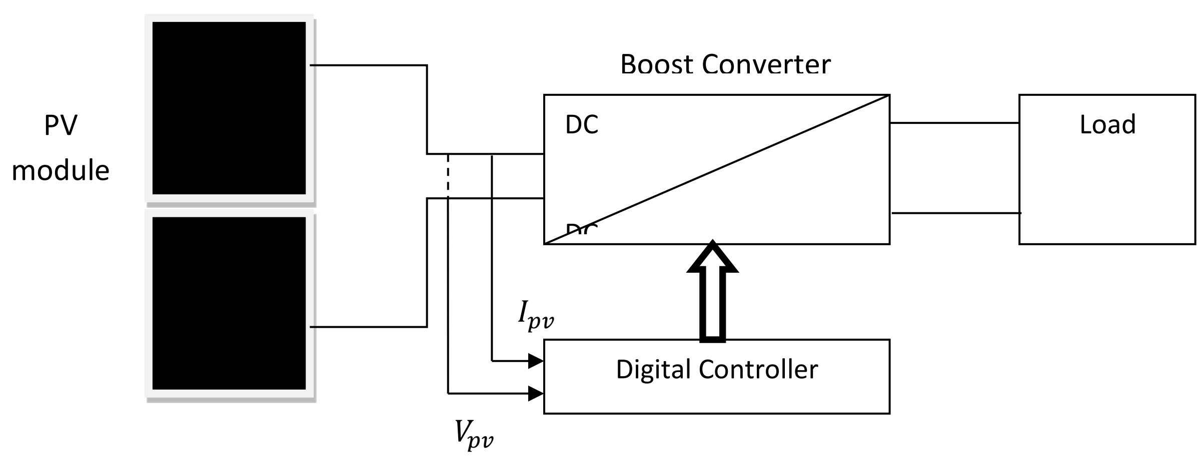

Figure 2.1 PV energy system block diagram

In the block diagram of PV energy system, I_{pv} = cell current and V_{pv} = cell voltage. From the solar energy the electrical energy is attained in the PV module. The resultant voltage is coordinated among the voltage necessity of the electrical devices in the dc-dc converter. On the basis of the accessible voltage level and the necessary one's this converter is either buck or boost or maybe buck-boost contingent. The power of the PV module is extorted by the MPPS. Through the bi directional converters the battery is charged and to the load it is discharged.

2.1.1 PV Cells

The major element of the PV mechanism is the PV cell. Through the material such as silicon and germanium the PV cells are constructed. Because of its merits the Silicon is desired on the germanium. In the semiconductor material a light ray contained the photons. Because of the breakage of covalent bonds it occurs through which the electric field is produced. As it is associated to these terminals the current in the load initiates to flow.

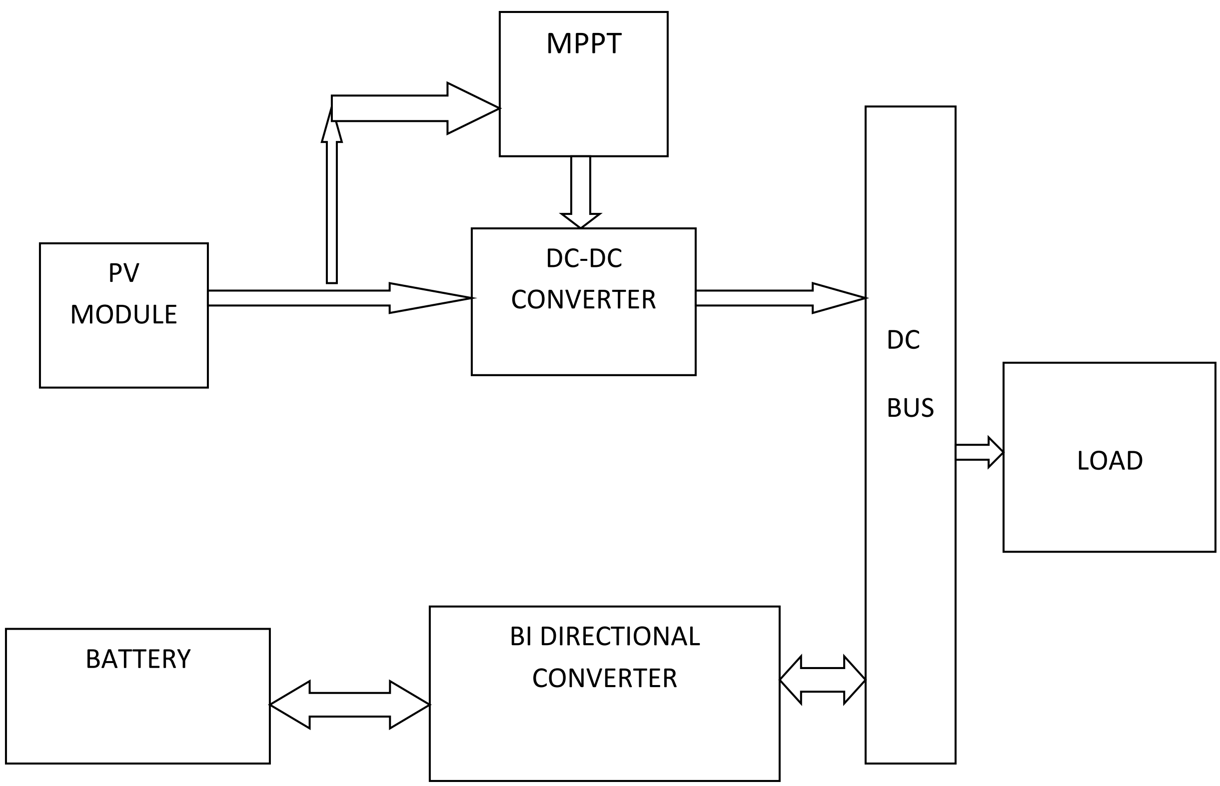

Figure 2.2 PV cell structure

2.1.2 PV Module

Through single module the produced voltage is low because of this a PV module is generated through associating more than single PV cell in series and parallel or as a grid as illustrated in figure 3. The association of the PV cell is in the parallel mode for the larger demand of the current and the association is in series mode if the demand of voltage is high. There are 36 or 76 PV cells are basically contained in the PV modules. The effectiveness of the module is decreased by the enclosement of PV Cells.

2.1.3 PV Array

A photovoltaic array is generated through the interconnection of several PV modules in either series or parallel. For trading applications the array of PV is not appropriate. In the module the association of the module in the array is similar to the association of the cells. Initially, for the desired voltage the association of the module is in series and after that the string is linked in parallel to achieve the necessitation of the current.

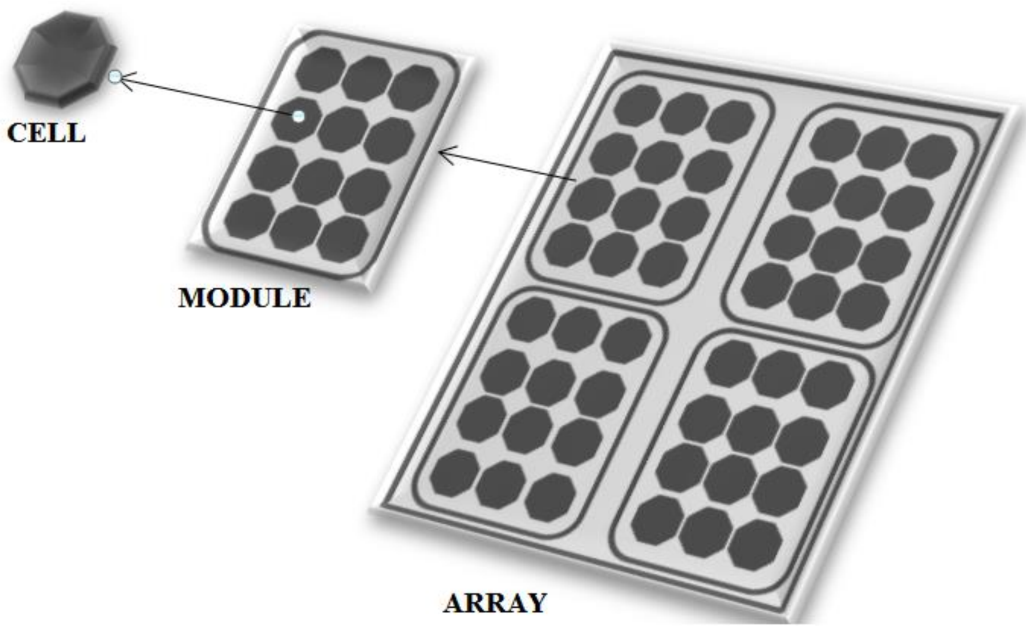

Figure 2.3 Photovoltaic System

2.1.4 Working of PV cell

As a sun beam contained photons that hit the PV cell, after that in the semiconductor the electrons find excited which in turn shifts from the conduction band to the valance band, here in the valance band electrons can move freely. Through generating a potential difference within the electrodes the negative and positive terminal is made by the movement of the electrons. The current flow during the circuit as the external circuit is associated within these terminals.

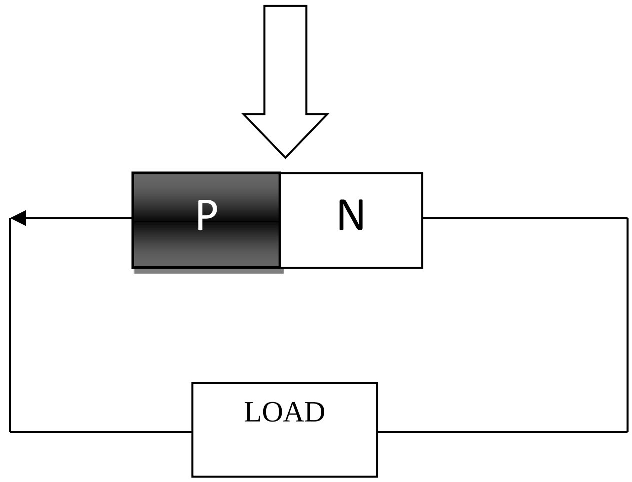

Figure 2.4 Working of PV cell

2.2 Modeling of PV Cell

In order to alter the sunlight straight forwardly to electricity does not make any terrible effect on the atmosphere through the PV cells alteration mechanism. The P-N junction diode is PV cell. A photo current source, a diode parallel to it and a resistor in series that presents internal resistance and shunt resistance illustrating the leakage current contained in the PV cell that is demonstrating in the equivalent circuit. To the load the current that is offered is expressed through the expression as below:

$$I = I_{PV} - I_0 \left[exp\left(\frac{V+IR_S}{aV_r}\right) - 1\right] - \left(\frac{V+IR_S}{R_p}\right) \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Here,

I_{PV}= Photo current

I_0= Reverse saturation current of the diode

V= Voltage across the diode

a= Ideality Factor

V_T= Thermal voltage

R_s= Series Resistance

R_p= Shunt Resistance

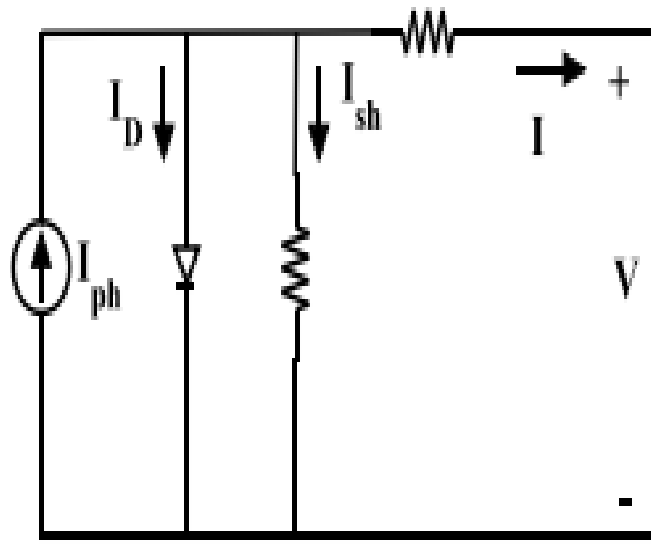

Figure 2.5 Equivalent circuit of single diode model of a solar cell

The photo current of the photo voltaic cell is presented by the equation expressed below as:

$$I_{PV} = \left(I_{PV\_STC} + K\Delta T\right)\frac{G}{G_{STC}}\text{……………………………..(2)}$$

Here,

K_I = Circuit current temperature coefficient

G = Solar irradiation in W/m2

G_{STC} = nominal solar irradiation W/m2

I_{PV_STC}= light generated current under standard test terms.

As a cubic function of temperature, the reverse saturation current fluctuates that is expressed as:

$$I_o = I_{o\_STC}\left(\frac{T_{STC}}{T}\right)^3 exp\left[\frac{qE_g}{aK}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right]\text{…………..(3)}$$

Here,

I_{o_STC} = Nominal saturation current

E_g= Energy band gap of semiconductor

T_{STC}= Temperature at standard test conditions

q= Electron charge

The following equation represents the reverse saturation current

$$I = \frac{(I_{SC\_STC}+K_t\Delta T)}{exp\left[\frac{(V_{OC\_STC}+K_V\Delta T)}{aV_t}\right]-1}\text{…………………..(4)}$$

Here,

I_{SC_STC}= Short circuit current at standard test condition

V_{OC_STC}= Short circuit voltage at standard test condition

K_V= Temperature coefficient of open circuit voltage

Several authors had been projected various developed models in order to achieve the improved accuracy. The diode model is controlled by a novel factor that is projected or established by each novel model, also not taken into account in last models either single way or another way. On the operating effectiveness of photovoltaic cells the Shunt resistance Rp fluctuation has no effect as the effective effect is constructed by the series resistanceR_S. For minimum leakage current as the shunt resistance fluctuates conversely among it much high significance of shunt resistance is utilized. The power generation of an individual cell is not satisfactory enough to accomplish the condition therefore the arrangement of PV cells is utilized. The equation of PV array is expressed as:

$$I = I_{PV}N_P - I_oN_P\left[exp\left(\frac{V+IR_S\left(\frac{N_S}{N_P}\right)}{aV_rN_s}\right)-1\right]-\left(\frac{V+IR_S\left(\frac{N_S}{N_P}\right)}{R\left(\frac{N_S}{N_P}\right)}\right)\text{…….(5)}$$

N_S= Number of series cells

N_P= Number of parallel cells

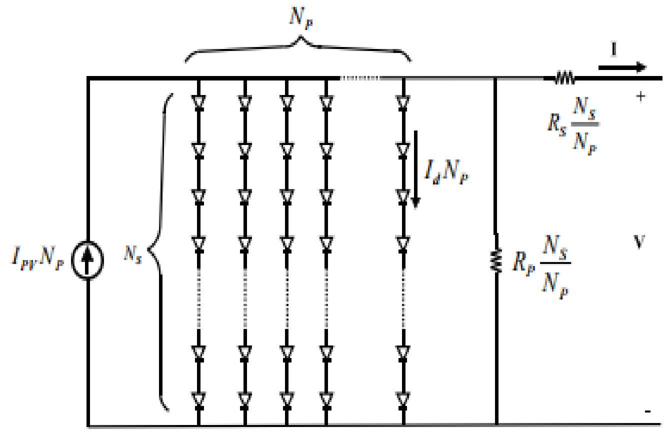

Figure 2.6 Representation of PV module

Through altering the series resistance the effectiveness of the PV cell is affected as there is no effect of alteration of shunt resistance. For the much less leakage current the shunt resistance performs as an open circuit. Then the shunt resistance is taken into an account as zero so the mathematical expression of the model is generated that is as:

$$I = I_{PV} N_P - I_o N_P \left[exp\left(\frac{V + IR_S\left(\frac{N_S}{N_P}\right)}{aV_r N_s} \right) - 1 \right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The I-V and P-V characteristics are shown below in the figures:

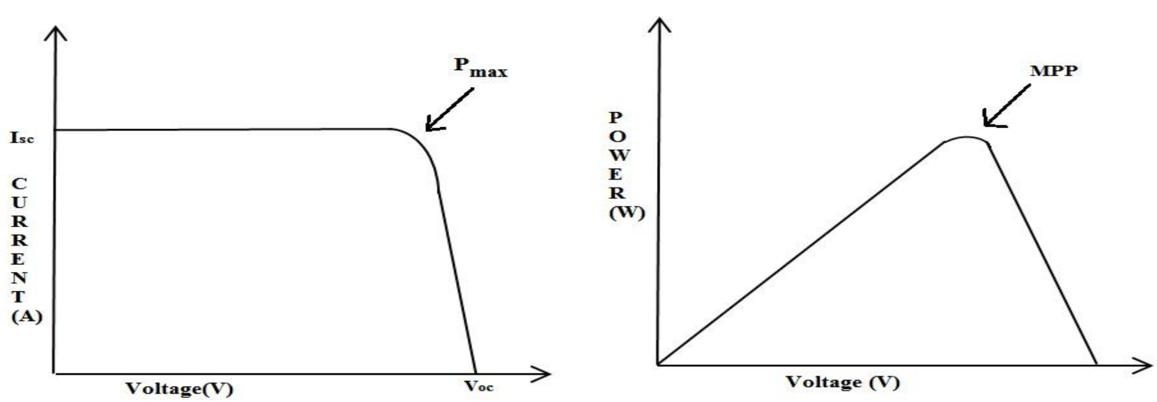

Figure 2.7 IV and PV characteristics

Through the open circuit voltage and short circuit voltage of the cell the electrical presentation is calculated chiefly. The maximum power is illustrated through the equation written below as:

$$P_{max}=V_{max}I_{max}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

2.2.1 Maximum Power Point Tracking

From the PV mechanism in order to derive the maximum power the Maximum power point tracking mechanism is utilized. Through fluctuating the operating point of the modules electrically the MPPT mechanism operates in order to provide large accessible power and no mechanical or shifting component is involved that alters the location of the mechanism in order that the sun is faced straight forwardly by the mechanism [3].

2.2.2 Necessity of Maximum Power Point Tracking

The individual maxima presents that the Maximum power point connected among particular voltage and current. From the power Vs voltage characteristics of the PV module this maxima can be experiential. In order to attain the maximum power the total effectiveness of the PV module is relatively less therefore it becomes significant in order to perform it at the optimum power point. The usage of the PV module becomes much efficient through the enhancement in the power. Through the DC-DC converter the impedance matching within PV module and the circuit is accomplished and hence, to the load the power is transmitted. For the impedance matching the Switching elements varying duty cycle is utilized [4].

2.3 MPPT Methods for PV System

Through considering the and solar irradiance the maximum power point tracking mechanism is utilized by the Maximum power point controller in order to take maximum power of PV modules on that time. In order to generate the maximum power several mechanisms are utilized. In the MPPT paradigm the effectiveness is decreased through the slow tracking of the power that is the very general issue in this. There are several MPPT control mechanisms that are Generic paradigms, Hill Climbing Perturbation and Observation (P&O), Ant colony Optimization (ACO), Incremental conductance (INC), single input fuzzy controller for tracking MPP, Artificial Neural Network (ANN) with back propagation, feedback of power fluctuation among voltage mechanism and also among voltage mechanism, fuzzy logic controller Intelligent Control (FLCIC) with DC-DC converter, Short Circuit Current Control (SCCC), Particle Swarm Optimization and Open Circuit Voltage Control (OCVC) to improve the solar energy effectiveness. The occurrence of multi-crest yield bends of partial shading in PV demonstrated is regular; here the enhancement of a computation for accurately pursuing the authentic MPPs of the confounding and nonlinear yield bends is critical [5].

2.3.1 Curve Fitting

As an offline process the curve fitting mechanism is allotted. In this mechanism a couple of parameters utilized that are the Power gain G, and the environmental parameter X. The gain becomes larger as there is an enhancement in X [6]. This mechanism is identified by the several models of PV Panel and the other section of this is the mathematical modeling. To the MPP the voltage flexibility is calculated and the operating point on the characteristics of the board is shifting [7] in an individual model. The equation (8) and (9) illustrates the PV panel characteristics. Through the sampling k values of PV panel output voltage VPV, PVV– current IPV and output voltage PVV the coefficients such as α, β, γ and δ are concluded. The MPPT measures the voltage that is expressed as below:

$$P_{pv} = aV_{PV}{}^{3} + \beta V_{PV}{}^{3} + \gamma V_{PV} + \delta \text{……………………. (8)}$$

$$V_{MPP} = \frac{-\beta \pm \sqrt{\beta^2 - 3\alpha\gamma}}{3\alpha} \text{……………………. (9)}$$

2.3.2 P&O METHOD

The MPPT paradigm utilized the perturbation and the observation strategies to achieve the MPP. It can be utilized throughout the world due to its easiness and effortlessness of execution. The panel working voltage is investigated in order to track the MPP and afterward measures and compares the PV yield control and the past power [10].

2.3.3 IC METHOD

The IC mechanism is the one of the strategies of MPPT mechanism. At MPP in order to achieve the power curve of PV array slope is zero this mechanism operates in that way. The slope is increased at MPP’s right side and the slope is decreased at MPP’s left side.

$$\frac{db}{dv}\text{=0 at MRP……….(10)}$$

$$\frac{db}{dv}<0, \text{ Right of MPP}………(11)$$

$$\frac{db}{dv}>0, \text{ left of MPP}………….(12)$$

This mechanism contained in using the incline of the subordinate of the current concerning the voltage so as to attain greatest power point [11].

CHAPTER 3

WIND POWER SYSTEM

3.1 Introduction

In the previous years in order to navigate the ships the wind was main power source. The Europeans utilized the grain grinding and water pumping mechanism through air. In the 1980 from the windmill the electricity was attained by the US. In 1988 a 3MW turbine was specially made and in 1979 in the Berger Hill, Scotland the wind turbine generator associated among the grid generating power of 2MM was made especially. In the remote regions the usage of the electric power produced through the wind energy is in lightning the building. The size of the wind power generators are short that is appropriate for independent framework these days. The capacity throughout the world of the wind power is 39294 MW and the capability of Indian wind power was about 1550 MW. The wind energy mechanism is illustrated below as:

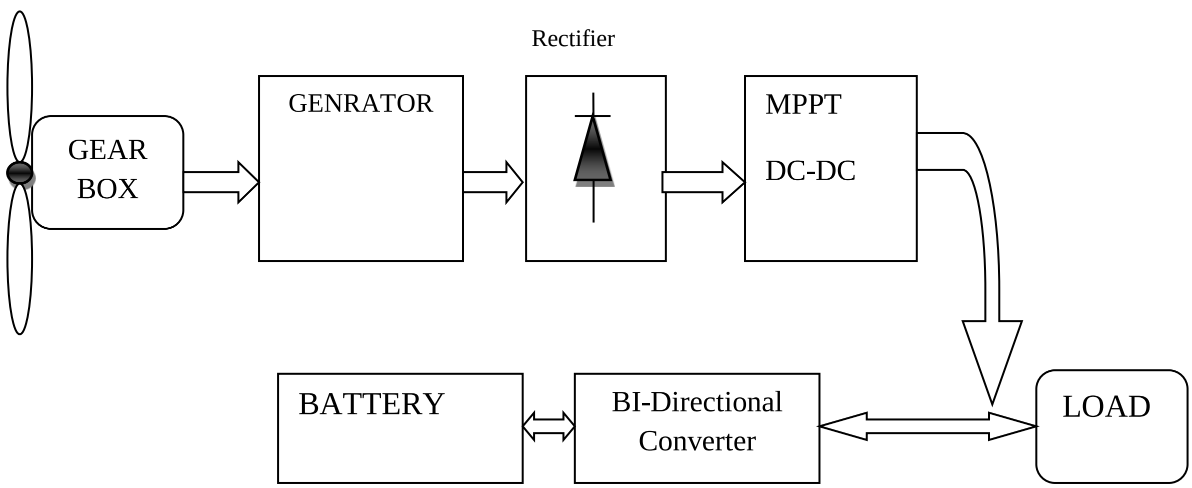

Figure 3.1 Wind energy system block diagram

In the wind turbine mechanism in order to alter the kinetic energy into mechanical energy the wind constructs rotors to rotate. A gear box is implanted in order to alter the mechanical energy into electrical energy in order to match the turbine speed among the generator speed. By utilizing a rectifier the AC output is altered into DC. The maximum power point is observed by the DC-DC converter and the battery charge and discharge is constructed by the bi-directional converter.

Wind Turbine: In order to generate a wind turbine there are several components collected. A set of rotor blades, a hub, a gearbox-generator set are the main components of the wind turbine. The architectural design of the wind turbine is demonstrated below in the figure:

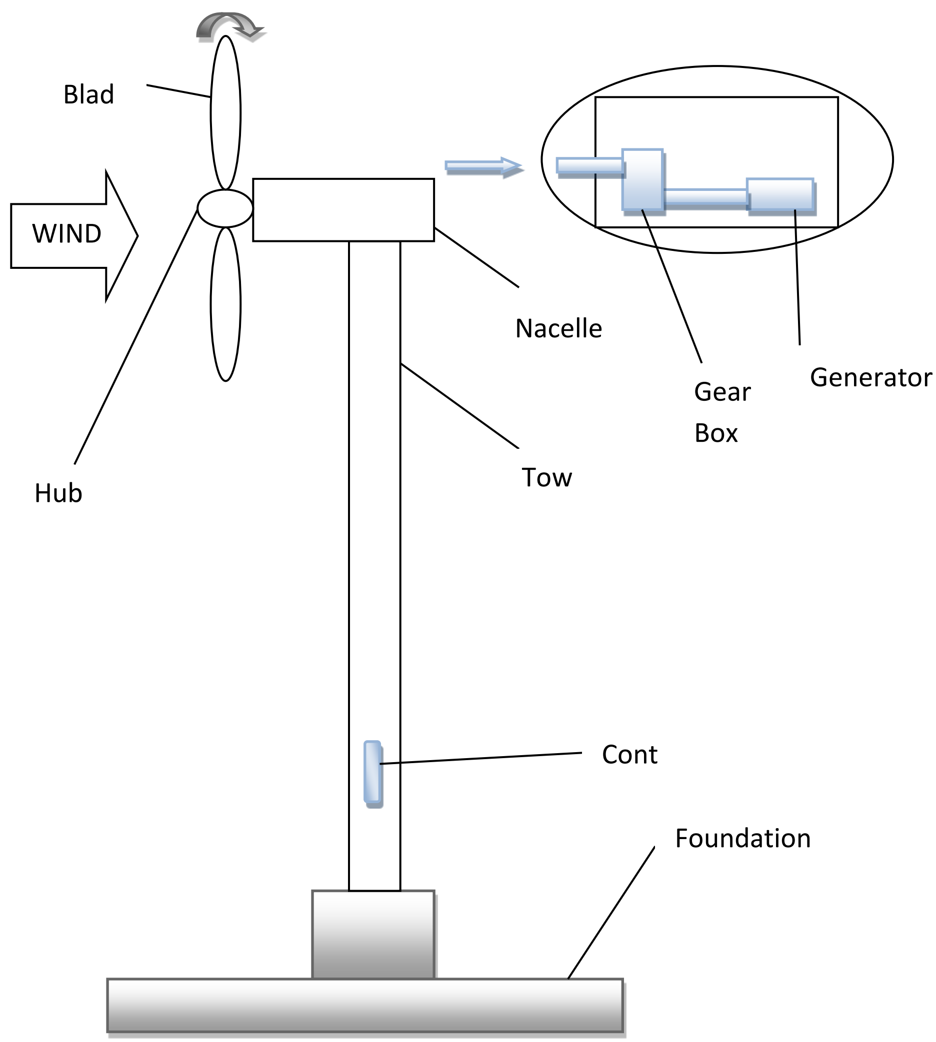

Figure 3.2 Major Turbine Components

3.2 Modeling of Wind Turbines

Initially the kinetic energy is altered into the mechanical energy of the wind by the operation of the wind turbine through the rotational motion off the rotors and afterward into the electrical energy the mechanical energy is altered. The power of the wind turbine blade is affected by the shape of the blade, pitch angle, speed of rotation and radius of motor [13]. The generation of power is illustrated as below:

$$P_M = \frac{1}{2}\pi\rho C_p(\lambda,\beta)R^2V^3 \text{..........................(13)}$$

Here,

P_M= Power captured through wind turbine,

ρ = air density,

β = pitch angle (in degrees),

R = blade radius (in inches),

V = wind speed

The following equation illustrates the tip speed ratio (λ) that is:

$$\lambda=\Omega R/V$$

Here,

Ω = speed of rotation of rotor in rad/sec

The CP can be illustrated as the function of tip speed ratio (λ) as follows:

$$C_p = \frac{1}{2}\left(\frac{116}{\lambda_1} - 0.4\beta - 5\right) exp^{\frac{-16.5}{\lambda_1}} \ldots\ldots\ldots\ldots\ldots\ldots(14)$$

$$\lambda_1 = \left(\frac{1}{\frac{1}{\lambda+0.089} - \frac{0.035}{\beta^3+1}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

Here C_P = wind turbine power,

λ = tip speed ratio and λ_1

3.3 MPPT Methods for Wind Power

The power V/S. wind speed characteristics are illustrated below in the Figure 3.3:

At peak power

$$dp/d\Omega=0 \ldots\ldots\ldots\ldots\ldots(16)$$

From the chain rule

$$\frac{dP}{d\Omega} = \frac{dp}{dD} \times \frac{dD}{dV_W} \times \frac{dV_W}{d\Omega e} \times \frac{d\Omega e}{d\Omega} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(17)}$$

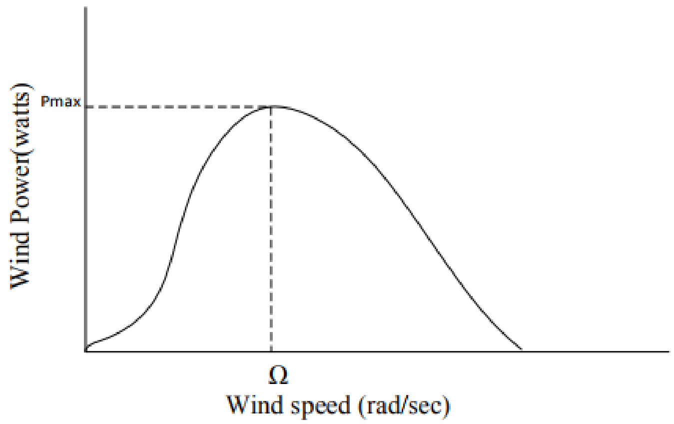

Figure 3.3 Power vs. Speed characteristics of wind turbine

Here,

P, Ω and Ωe are the wind power, rotor speed and the phase voltage angular speed of the generator.

V, W and D are the rectifier output voltage and the duty cycle of the converter.

For the buck boost converter the equation is as follows,

$$V_o = \frac{D}{1-D} Vw \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(18)}$$

Here V_o and Vw are the output of buck boost converter and the input of buck boost converter

From equation (17) we have

$$\frac{dD}{dVw} = -\frac{D^2}{Vo} \neq 0$$

From the equation (18) it is illustrated that $\frac{dD}{dVw}$ has negative and non-zero significance.

The rotor speed of wind turbine is correlated by the generator phase angular speed as expressed below:

$$\Omega e = p.\Omega$$

$$\frac{d\Omega e}{d\Omega} = p > 0 \ldots\ldots (19)$$

Here p = number of pole pairs in generator

From equation (19) it is illustrated that $\frac{d\Omega e}{d\Omega}$ is positive and has non zero significance

The output voltage of the rectifier can be illustrated as follows:

$$V_{ph} = 4.44 * f * \varphi * t$$

And f is directly proportional to Ωe

so $\frac{dV_{ph}}{d\Omega e} > 0$ as V_{ph} is directly proportional to V_w

$$\frac{dV_{ph}}{d\Omega e} \approx \frac{dV_w}{d\Omega e} > 0 \ldots\ldots\ldots\ldots (20)$$

Here, V_{ph}, f, φ and t are generators output, frequency of rotor, flux and number of turns.

From equation (18), (19), (20) it is illustrated that $\frac{dD}{dVw}, \frac{d\Omega e}{d\Omega}$ and $\frac{dV_W}{d\Omega e}$ are non zero significances, therefore $\frac{dP}{d\Omega} = o$ can be probable so if Dp/dD turns into zero. From above equations it is demonstrated that the operating point of the crest power is coerced due to the fluctuation in the duty cycle of the converter [14].

3.4 MPPT Algorithm for Wind Energy System

There are various mechanisms of MPPT in wind energy conservation mechanism is illustrated as follows:

3.4.1 Hill Climb Search (HCS) Method

In the wind power mechanism at variable wind speeds this paradigm is utilized. Presuming that the wind power's preceding cycle is P (□-1) in order to create a speed alteration Δ and compare the present wind power P (□-1) among P (□-1). As the power enhances gradually then the Δ will shift continually to the optimal revolving speed, besides the power reduces as illustrated in the Figure 12.

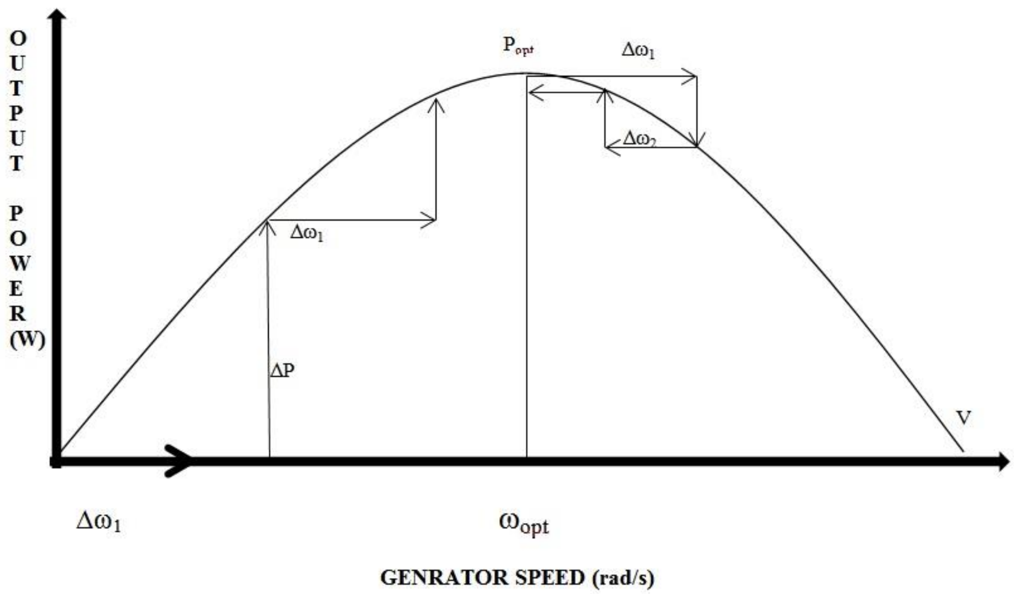

Figure 3.4 Output power Vs. Generator speed characteristics

The earlier produced power is measured in this mechanism and on the particular time the power is produced. The power development increases with the increase in the duty cycle and to the peak point the operating point is generated and if the duty cycle reduces the power generation is also reduces. This mechanism is not capable to monitor the maximum power growth as the fluctuation in the speed is quick and impulsive.

3.4.2 TIP Speed Ratio Control

For a specified wind turbine on the TSR the wind speed has no effect. On the optimum significance if the TSR residues continuous the energy comes to the maximum point, hence this mechanism energy alteration is bound to preserve this point through doing the evaluation among exact significance and feeding back the difference. The tip speed ratio control is illustrated in the block diagram as follows:

In order to decrease the error the speed of the generator alters. In order to attain the specific quantity of the wind speed it is not probable the continuous observation of the speed of the wind constructs the mechanism easy.

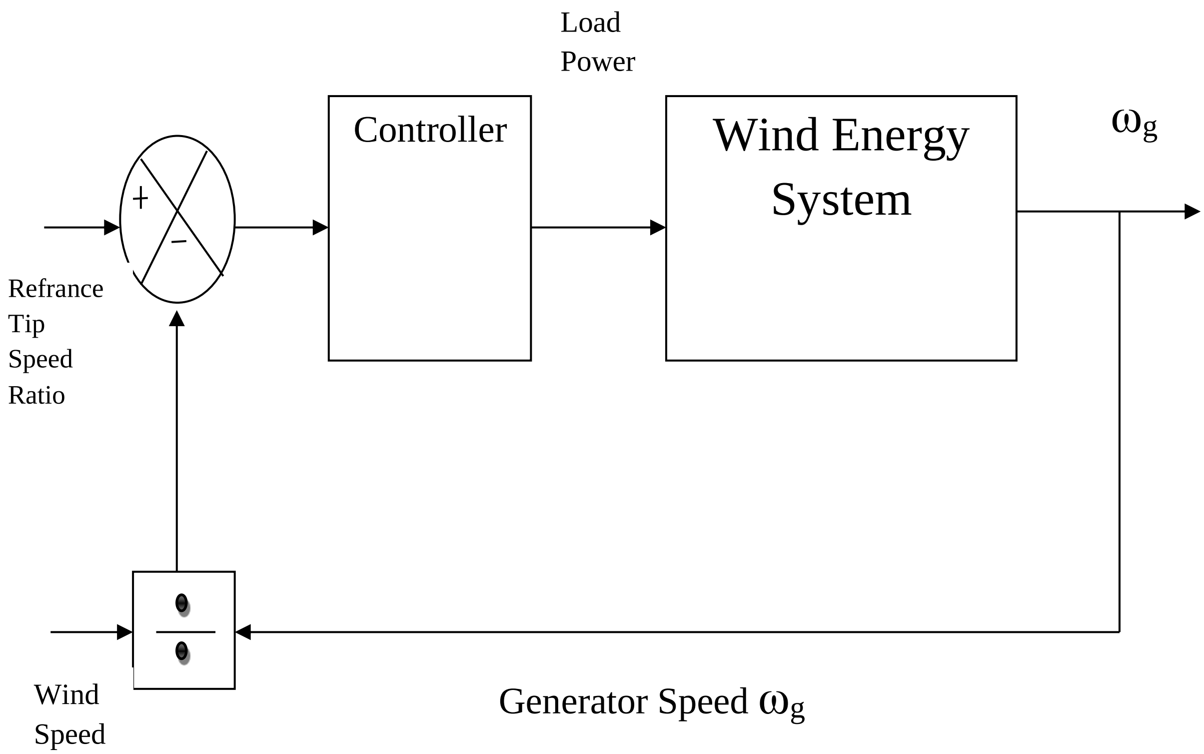

Figure 3.5 Control block diagram for Tip Speed Ratio Control

3.4.3 Optimal Torque Control.

For the optimum energy the rated wind speed offers the MPPT –based control paradigm. On the specific wind speed this mechanism utilized the PMSG torque for the maximum power torque. The turbine power illustrates the λ and ω_m functions:

$$V_m = \frac{\omega_m R}{\lambda} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

And also $P_m = \frac{1}{2} \rho \pi R^5 \frac{{\omega_m}^3}{\lambda^3} C_p \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$

If the motor is operating at λ_{opt}, it will operate at C_{pmax} then

$$P_{m\_opt} = \frac{1}{2} \rho \pi R^5 \frac{C}{\lambda^3{}_{opt}} {\omega_m}^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

$$P_m = \omega_m . T_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

$$T = \frac{1}{2} \rho \pi R^5 \frac{C_{pmax}}{\lambda^3{}_{opt}} {\omega_m}^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (25)$$

The torque control mechanism and the term for the optimum torque curve is illustrated by the equation (23), (24) and (25). For the controller that is associated to the wind turbine the reference torque is illustrated in the Figure (14). If the TSR control mechanism offers improved effectiveness as the wind speed is not computed straight forwardly so this mechanism is very quick and sufficient.

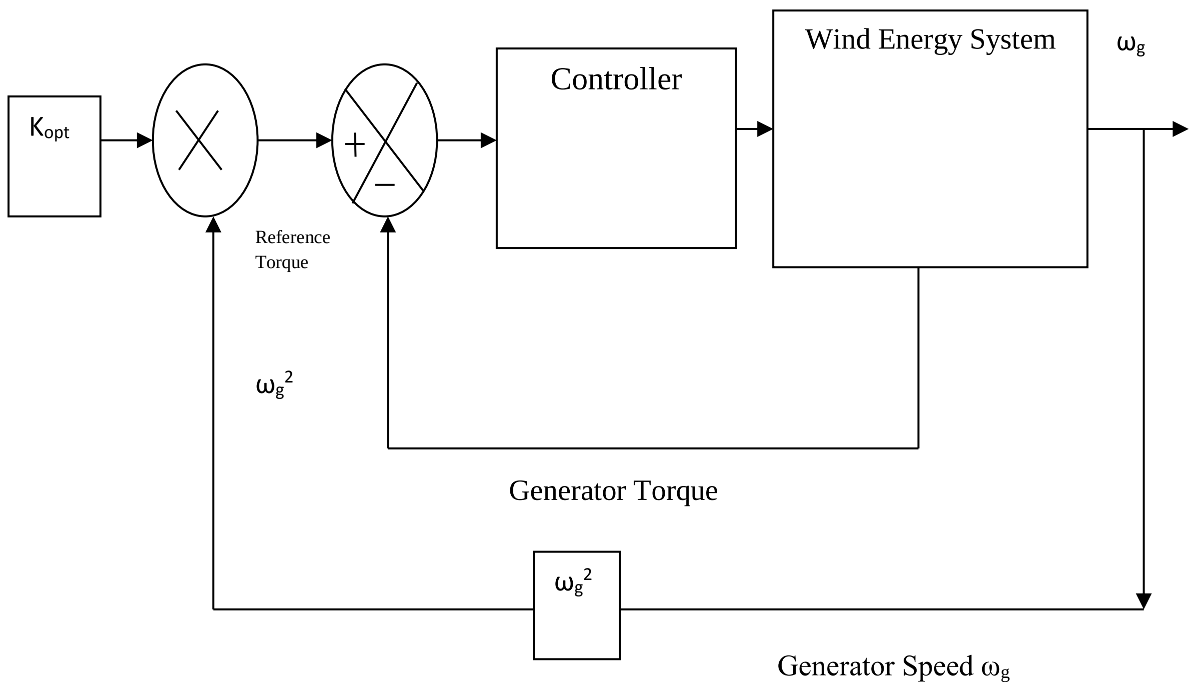

Figure 3.6 Optimal Torque Control MPPT Method

3.4.4 Method of Power Signal Feedback

In order to distinguish the former information of wind speed and wind turbine features, at specific wind speed the maximum power is utilized as a reference power through the PSF mechanism. On the particular wind speed as the reference control is obtained from the power bend among the current power an examination of yield is completed.

Through the error generation the control paradigm is generated. Here P defines the Proportional (P), also I defines the Integral (I) control that is PI. In order to compute the error the P and I section influences the identified set points and considered instantaneous significances. The wind energy alteration mechanism presents the Figure 15. Equivalent to the wind turbine speed the lookup table saves the maximum output power data points [15]. The large power output and DC-link voltage are illustrated in the input and output of the lookup table.

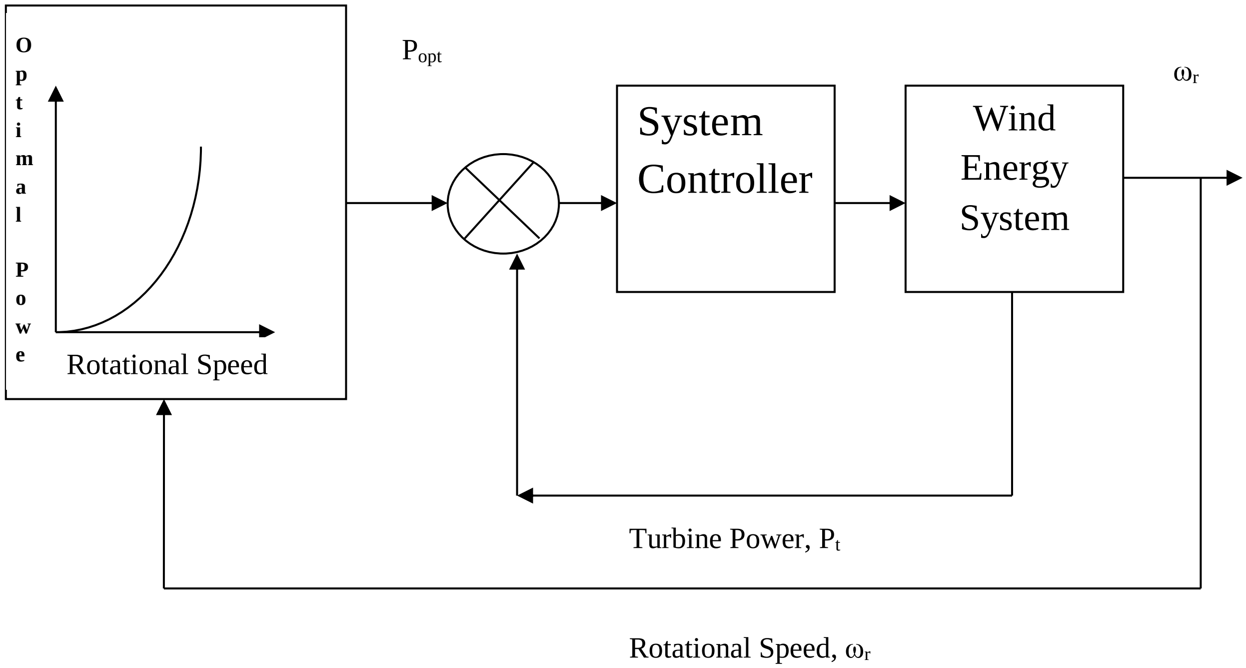

Figure 3.7 Power Signal Feedback Method

3.4.5 Battery Energy Storage System

In the worldwide overdue time the photovoltaic or wind power based energy creation has got widespread attention. Among the Transmission Joint showing job the State Grid Corporation of China (SGCC) is constructing the National Wind/PV/battery vitality stockpiling station. At Zhangbei, Hebei China it is located. From wind power the power creation capability of Zhangbei is up to 10 Million kW.

The power superiority of the renewable energy hybrid power generation mechanism is improved by the battery energy storage mechanism. For the hybrid storage energy mechanism the various control strategies such as a superconducting magnetic energy mechanism, battery energy storage mechanism, a flywheel energy mechanism and an energy capacitor mechanism among total cell/electrolyzer hybrid mechanism have been recommended arrangement.

The battery energy storage mechanism have been used in various applications that are frequency regulation, grid stabilization, transmission loss decrease, diminished congestion, enhanced flexibility, wind solar energy smoothening, spinning reserve, peak-shaving, load leveling, un- interrupted power source, grid services, electric vehicle charging resolution.

These days the normalization of power variation problems in PV and wind power production is increasing extensive concentration. In order to influence the variations in the wind power and the PV, the battery power or the degree of efficiency has to be sacrifice as utilizing the BESS.

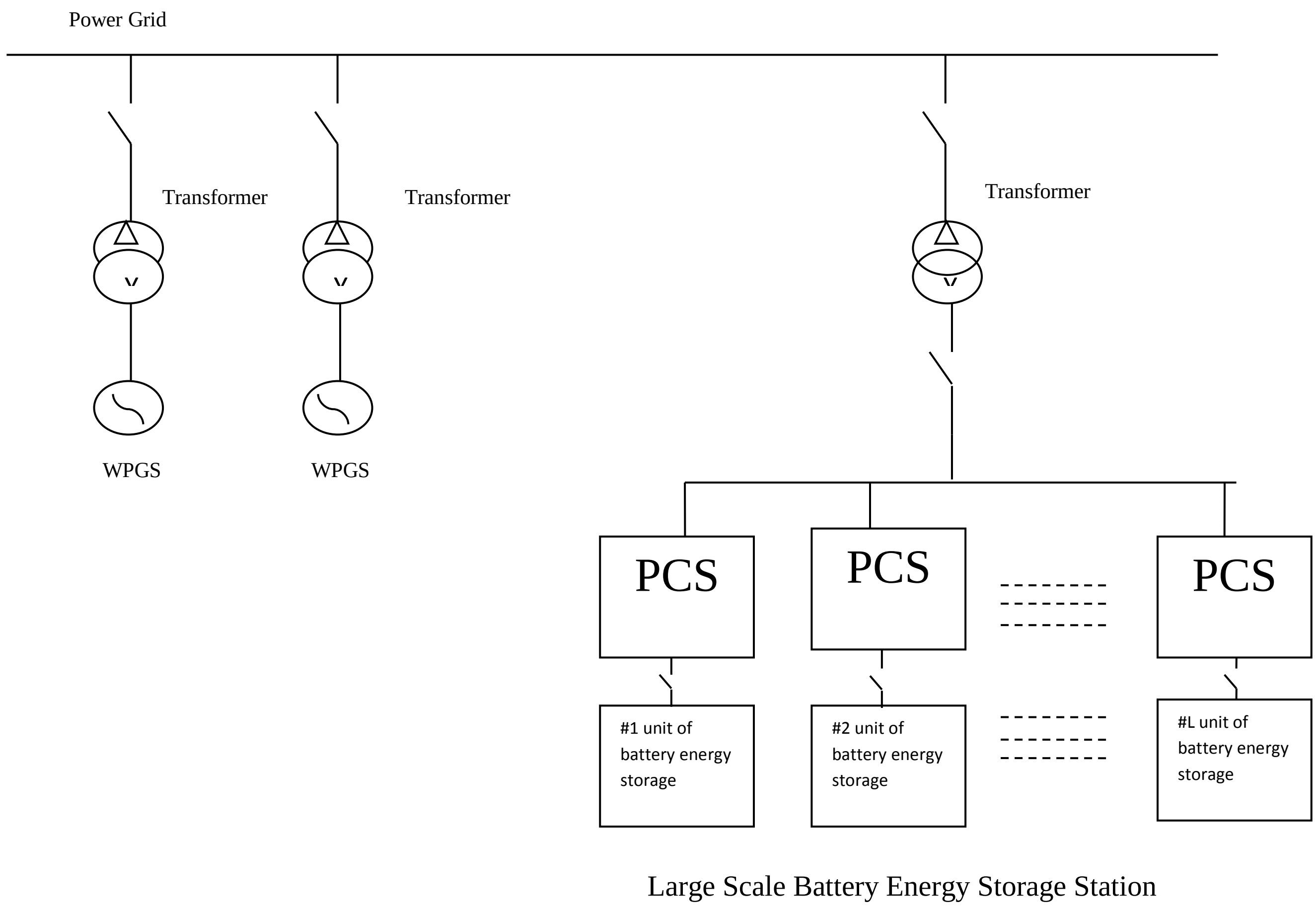

Figure 3.8Wind/PV/BESS hybrid power generations system

CHAPTER 4

NEURO-FUZZY BASED MPPT TECHNIQUE

4.1 Fuzzy

4.1.1 Introduction to Fuzzy

From previous few years the MPPT method base in fuzzy logic has increased recognition in the research study. In order to control and practice the nonlinear operations this mechanism didn't require some accurate model. On the estimated inputs, this makes fuzzy logic mechanism much accepted this mechanism works. The several terms in which the fuzz logic mechanism is alienated that are Fuzzification, Decision making and Defuzzification. The operating procedure of the fuzzy mechanism is illustrated in the Figure 17. In order to the crisp significances the procedure of the fuzzification is utilized. In the procedure of the fuzzification the Fuzzy Sets are achieved through the crisp significances [16].

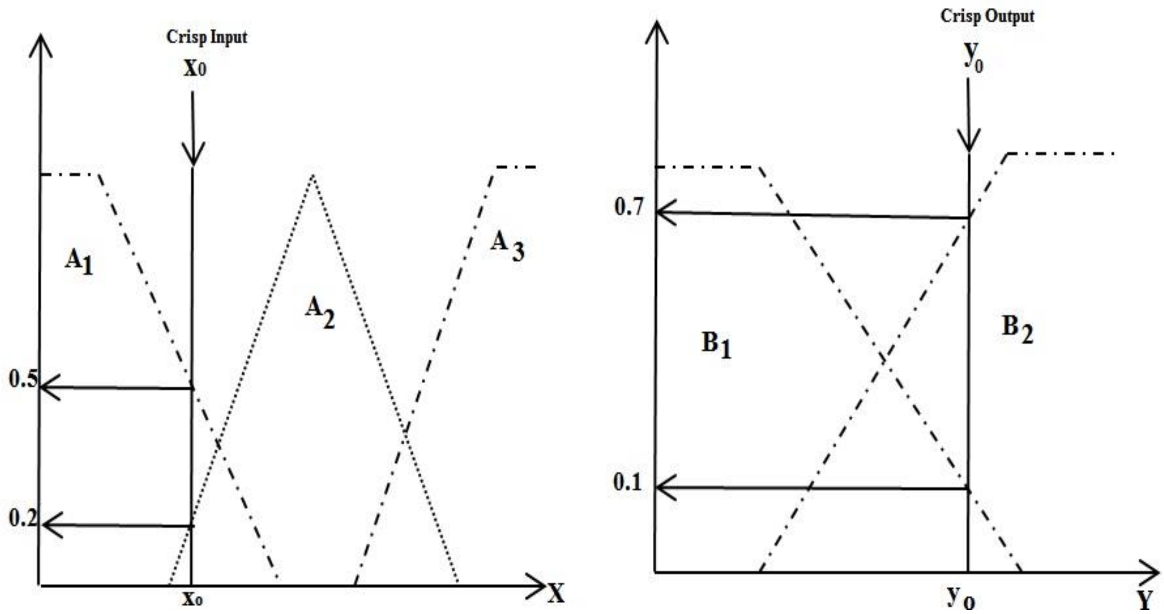

Figure 4.1The process of Fuzzification

While utilizing the Fizzification several regulations are utilized to the fuzzy input set. Based on the regulations and the fuzzy set the intelligence decision is made that 9is to alter the crisp significances back through utilizing the de-fuzzification.

4.1.2 Fuzzification

The fuzzification is the procedure of alteration of mathematical significances to the linguistic variables. The particular input function is some interval like [-1 1]. In the terms of the power mechanism in order to describe the control significances a couple of inputs are constructed to operate that are the PV array and MPPT voltage.

4.3 Decision Making Phase

Based on the If-Then rule set the input function is utilized in order to produce the outcome in this phase. In the formation of the If-Then the fuzzy logic contained the fuzzy rule set that describes the rule.

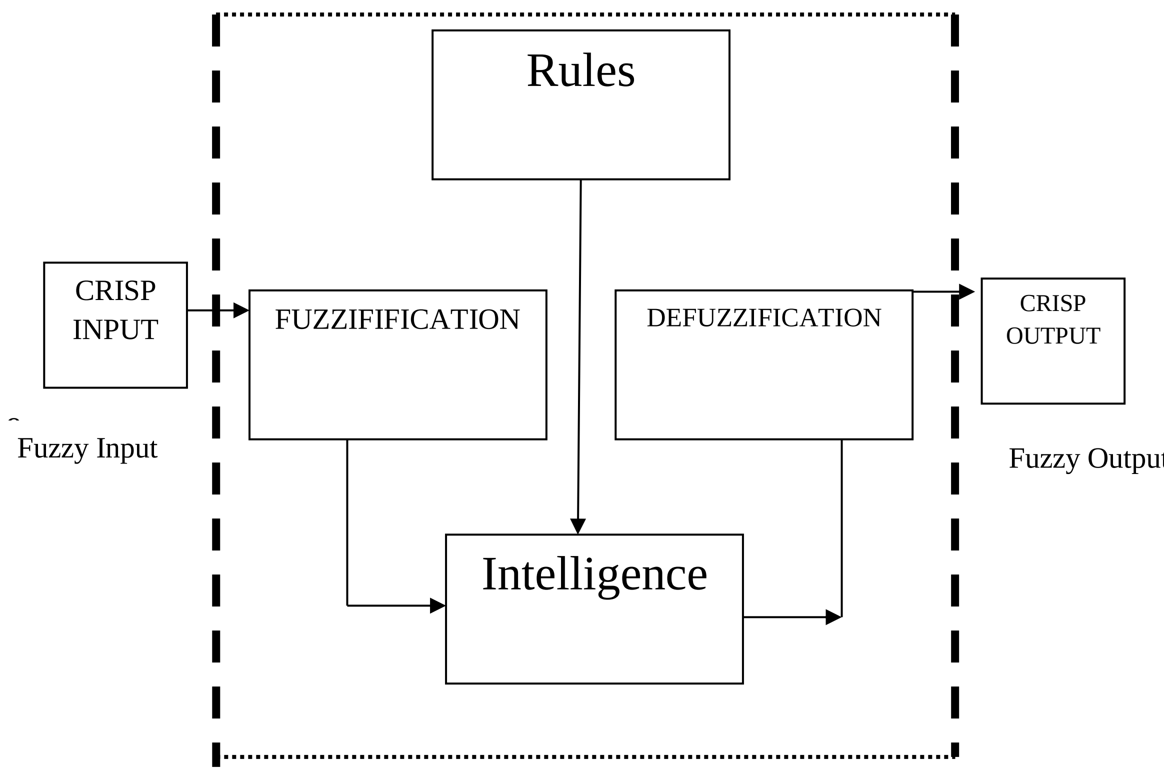

Figure 4.2 Working of Fuzzy Logic based system.

4.1.4 Defuzzification

The experimental results are generated in crisp logic in this mechanism. In this procedure the fuzzy sets are planned to crisp and the power arrangement is on the main concern.

4.2 ANFIS

ANFIS combines the characteristics of fuzzy system and neural network under an umbrella.

ANFIS stands for Adaptive Neuro Fuzzy Interference System. It is a technique which implements various learning method for training an Artificial Neural Network to Fuzzy model as name shows. FIS is implements non-linear mapping of the inputted data. The mapping is done by using various if-then rules of the fuzzy system. Each and every rule of system describes the nature of the mapping. The input space is referred by the parameters used in if-then rules of fuzzy network. The output space is defined as the output corresponding to input space.

Hence the working and the output generated by fuzzy is sensitive to the selected parameters. The selection of the parameters is not guided by any of the available procedures itself. Hence ANFIS is a solution to this problem. ANFIS facilitates the Fuzzy network for which the membership functions or parameters can be adjusted by using various algorithms such as least square method and back propagation etc. ANFIS enables a Fuzzy system to be trained from the data which is being modeled. Fuzzy network or rules should be chosen efficiently when they are going to incorporate in the form of ANFIS.

Sugeno: Sugeno is a fuzzy model. It works as follows:

1. Let's consider that fuzzy inference two inputs x and y respectively and generate corresponding single output z.
2. A first-order Sugeno model will have following rules:
3. Rule 1: If x is A_1 and y is B_1 then $f_1 = p_1 x + q_1 y + r_1$
4. Rule 2:

If x is A_2 and y is B_2 then $f_2 = p_2 x + q_2 y + r_2$

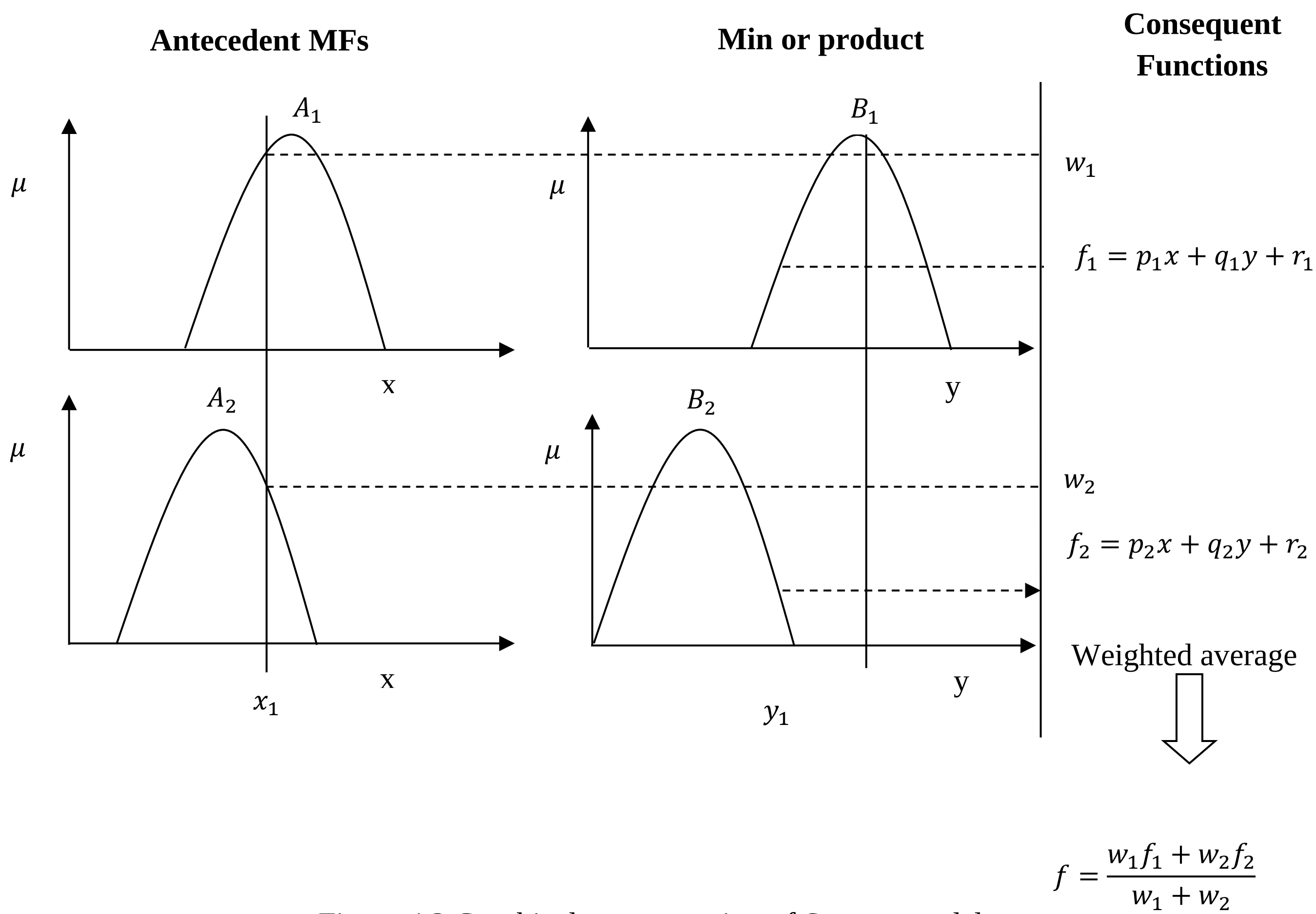

Figure 4.3 Graphical representation of Sugeno model

ARCHITECTURE OF ANFIS

The rules defined in above section can have the following defined architecture[28] (figure4.4).In figure the circle defines the fixed nodes whereas the adaptive nodes are represented by square. The architecture of NAFIS is divided into five layers as below:

1. Layer 1
2. Layer 2.
3. Layer 3.
4. Layer 4.
5. Layer 5.

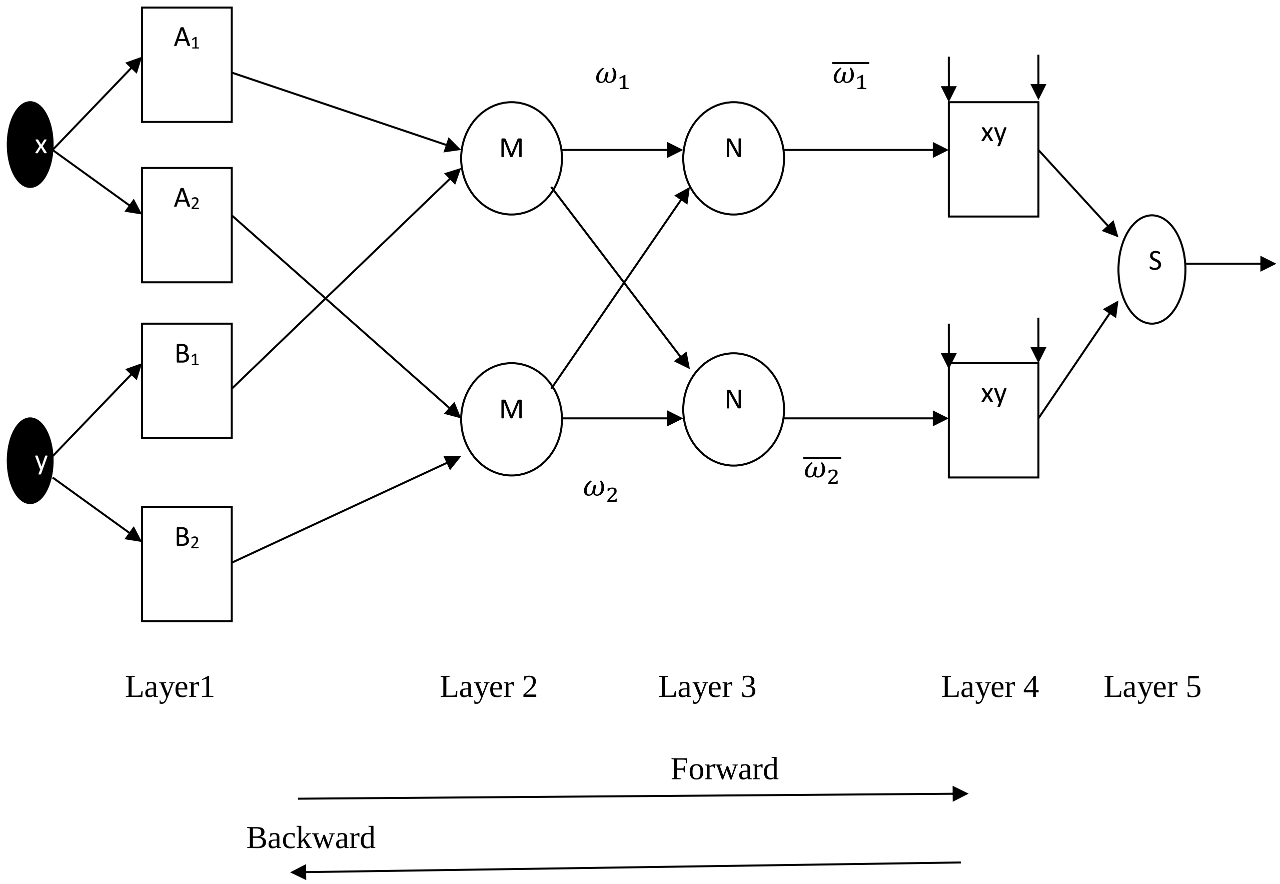

Figure 4.4 Architecture of ANFIS

LAYER 1: This layer contains all of the adaptive nodes of the network.

LAYER 2: This layer contains all of the fixed nodes which works as a multiplier as denoted or labeled by M.

LAYER 3: This layer also includes the fixed nodes but ;labeled as N as indicate that these nodes perform normalization.

LAYER 4: As shown in the figure the nodes of this layer are adaptive in nature. The output of this layer is the product of th normalized fixed nodes.

LAYER 5: This layer contains only one node and that is of fixed nature and labeled as S.

CHAPTER 5

RESULTS AND EXPERIMENTS

5.1 Simulation Model of Solar Energy MPPT

The figure 5.1 shows the simulation model for solar energy MPPT in which the ANFIS system is used for Maximum Power Point Tracking (MPPT). In this model the output of Photovoltaic arrays is fed as input to the ANFIS system and after processing the output generated is fed to the load which is connected on the output section. To measure the output characteristics like voltage, current and power a panel is connected. The Table 5.1 shows the PV array input parameters. Table 5.1 shows PV array Input parameters.

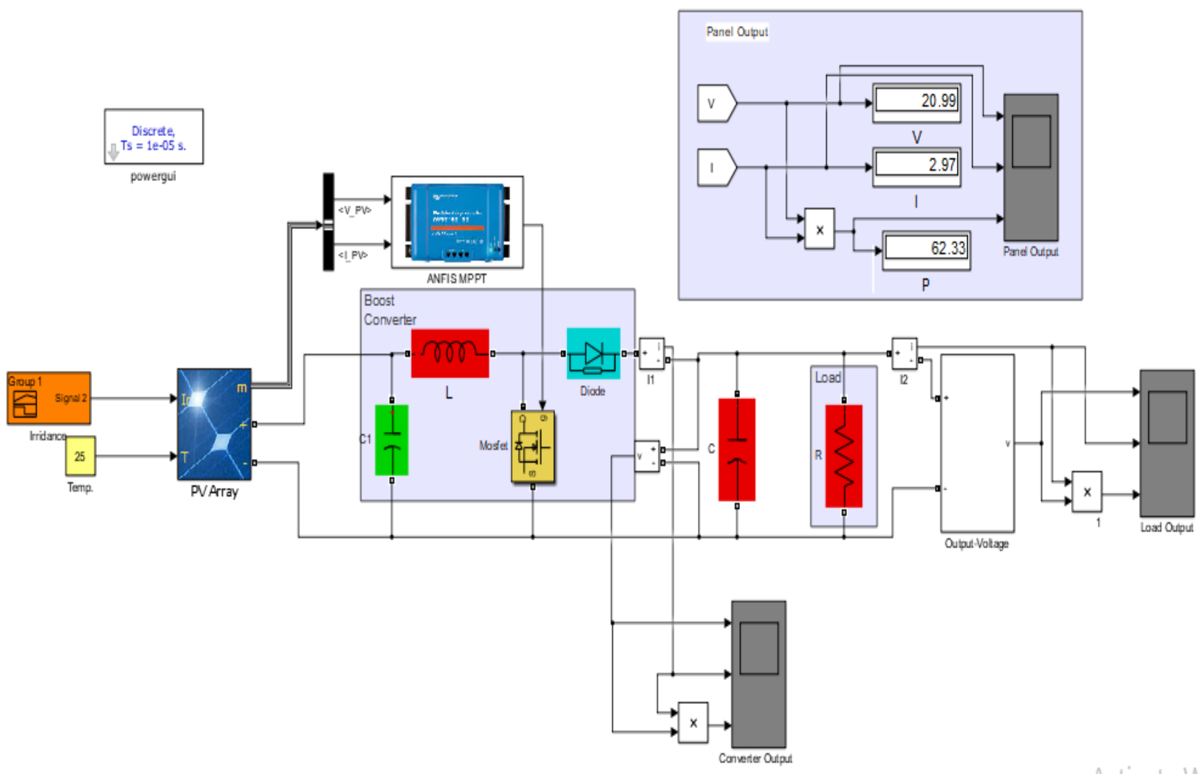

Figure 5.1 Simulation model of solar energy MPPT

1. PV array: In this model the irradiance input that is varied and the temperature input is given to the PV array. In the PV array m is used to define the voltage, current and power. After that the output of the PV array is offered to the ANFIS MPPT controller.

Table 5.1 PV array parameters

Parameters	Values
Parallel strings	1
Series-connected modules per string	1
Maximum power (W)	80.15
Cell per module (N cell)	36

The graph 5.1 PV array parameters illustrated the parameters of the PV array that are Parallel strings, Series-connected modules per string, Maximum power (W) and Cell per module (N cell) and the values of these parameters are 1, 1, 80.15W, 36.

2. ANFIS-MPPT controller: The output of the PV array is provided to the ANFIS-MPPT controller. This controller is used to compare the previous voltage value and power value to the current voltage value and the current power value. While comparing the values some errors will be generated. The controller is used to analyze the difference values by using duty cycle. If the difference of the values is minimum or zero then the maximum values have been tracked and if the difference of the values is more then it increases the duty cycle.

In figure 5.2 shown below the power input membership function characteristics are drawn. In below characteristics the x-axis represents the range which is varying from -5 to 5, the y axis represents the degree of membership that varies from 0 to 1.

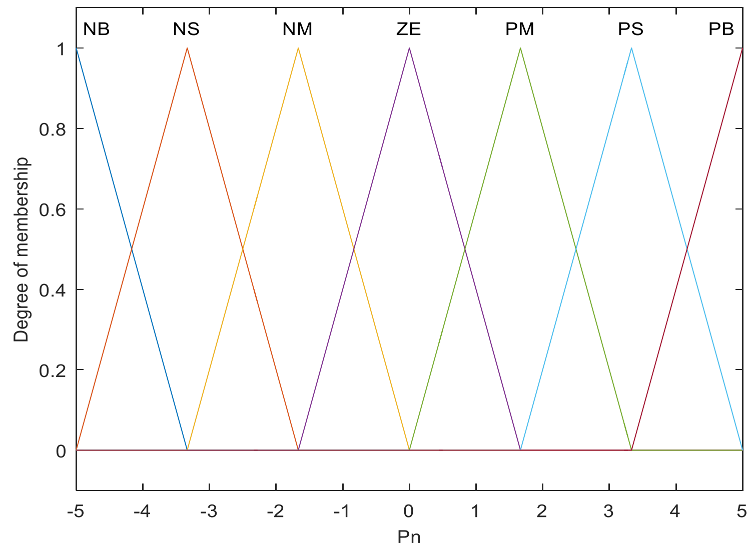

Figure 5.2: Power input membership function

In figure 5.3 shown below the voltage input membership function characteristics are drawn. In below characteristics the x-axis represents the range which is varying from -5 to 5, the y axis represents the degree of membership that varies from 0 to 1

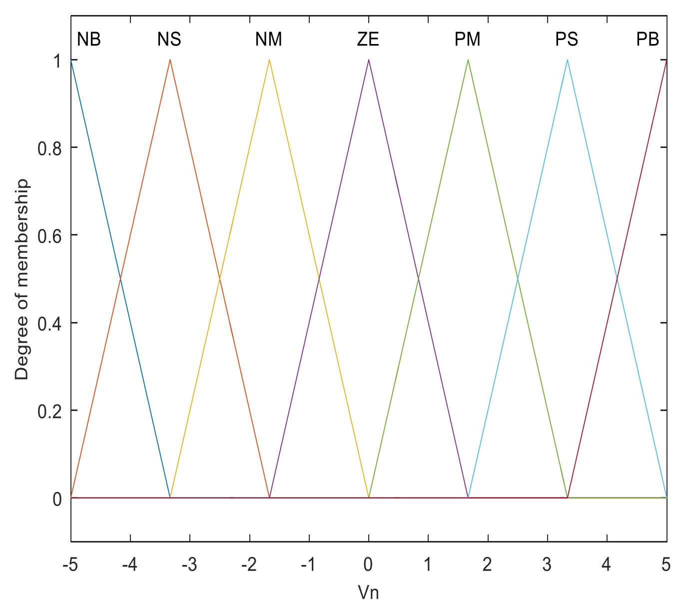

Figure 5.3: Voltage input membership function

.In figure 5.4 shown below represents the basic model of ANFIS system. In this model it is described that there is one ANFIS system where two inputs are fed and these inputs are processed to produce the output function. For the processing of signals there are 49 rules and these rules are derived on the basis of input signals.

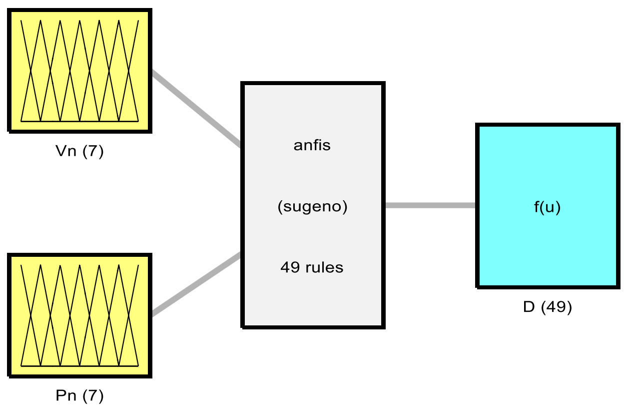

Figure 5.4 ANFIS system with 2 inputs and 1 output, 49 rules

Table 5.2 ANFIS Dataset

Input 1=Vn (7)	**Input 2=Pn (7)**	**Output=F(u)**
1	1	1
2	1	1
3	1	1
4	1	1
5	1	2
6	1	2
7	1	3
1	2	1
2	2	1
3	2	1
4	2	2
5	2	3
6	2	4
7	2	4
1	3	2
2	3	2
3	3	2
4	3	2
4	3	3
5	3	3

6	3	4
7	3	4
1	4	3
2	4	3
3	4	3
4	4	4
5	4	5
6	4	5
7	4	5
1	5	4
2	5	3
3	5	3
4	5	4
5	5	5
6	5	6
7	5	7
1	6	2
2	6	2
3	6	3
4	6	4
5	6	5
6	6	6
7	6	7
1	7	2
2	7	3
3	7	3
4	7	4
5	7	5
6	7	6
7	7	6

3. Boost Converter: Here boost converter is used to generate the output and also to fetch the maximum power the boost converter is applied after the ANFIS MPPT controller. Here Load of 100 ohm is applied in the circuit. Here the value of irradiance is varied that is from 800 to 1000 in order to analyze the system. After running the model it has to be checked that how much output is offered by the PV array or the PV array provides the exact output.

4. Load: Here Load of 100 ohm is applied in the circuit. The figure 5.5 illustrates the Load diagram which is a series RLC Branch consisting of a single resistor, inductor or capacitor or a series of combination these. The branch type parameter is used to select the elements that are needed to include in the branch. For resistance, inductance and capacitance the negative values are also permitted. The value of the load used in the projected simulink model is 100 ohm. Table 5.4, 5.5 and 5.6 show the parameters of Wind turbine, Panel (Wind + PV Array), Parameters of MOSFET respectively.

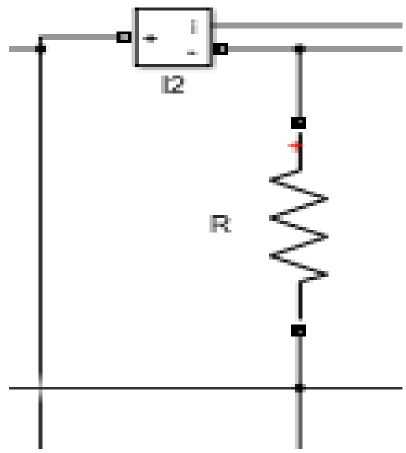

Figure 5.5 Load

Table 5.3 Parameter values of Load

Parameter	Value
Resistance	100 Ohm

5.2 Simulation Model of Hybrid System

In figure 5.6 shown below the simulation model for receiving the maximum power from the Hybrid system consists of ANFIS system is implemented for Maximum Power Point Tracking. The output received from the PV array and wind system is fed as input to the ANFIS system and then after processing the output is fed to the load. To measure the output characteristics the output panel is connected in which the voltage, current and power characteristics can be obtained.

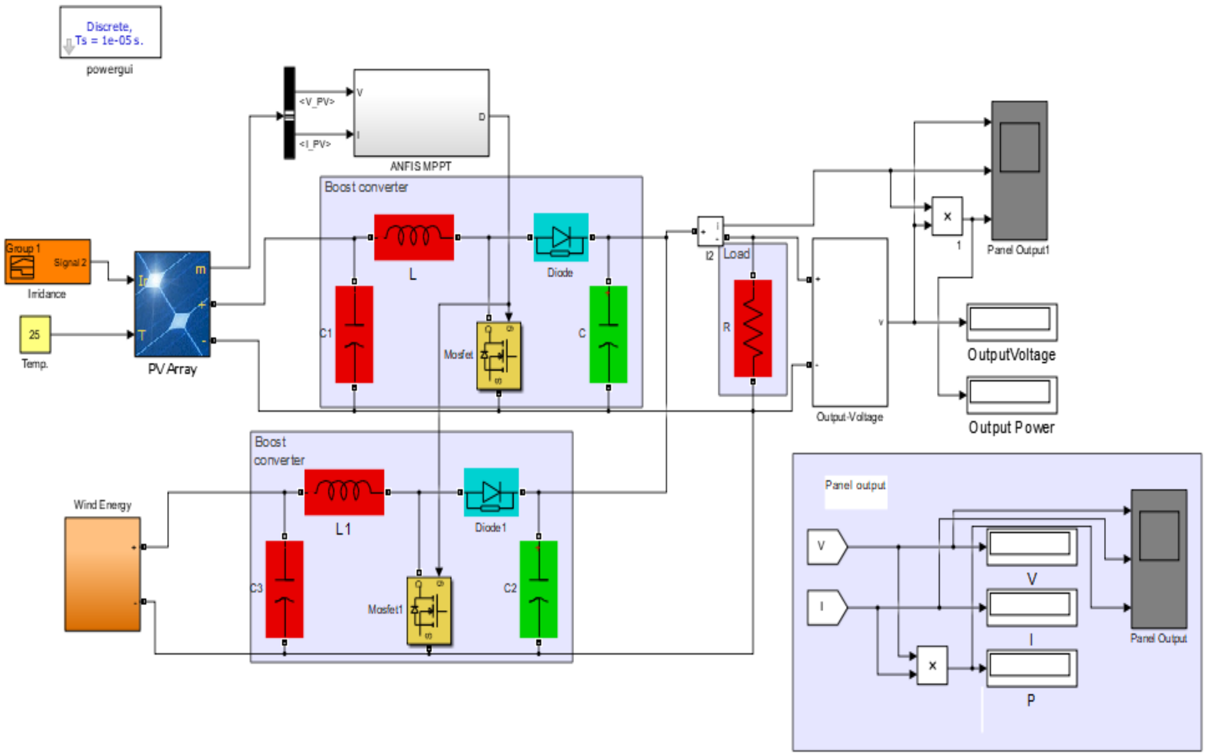

Figure 5.6: simulation model for Hybrid MPPT

In the projected model of the simulation, the hybridization of solar and wind energy mechanism is accomplished. The boost converter receives the DC voltages produced from solar panel. Accordingly, applying the boost converter the preferred magnitude of output voltage, input voltage magnitude is enhanced. Also through utilizing the boost converter the operation of conversion is presented among the no utilization of the transformer.

The three main elements that are diode, inductor and a switch with high frequency are contained in the boost converter. Among the huge voltage the power is accessible to the load by utilizing these elements. With the duty cycles of large frequency based switches, the voltage alteration and control arrangement happens. For the presentation of the boost converter the closing and opening of the switch is taken into an account. In terms of the closed switch, the charging mode is taken into an account and in the terms of the open switch the discharging mode is taken into an account. Through utilizing the MPPT based on ANFIS the maximum power is tracked which is useful in order to produce a pulse that is offered to boost converter. By using ANFIS, MPPT is implemented in the projected simulation model.

For the diodes in order to create a pulse a PWM generator is provided. The resultant outcome is computed as follows

Table 5.4 Parameters of Wind Turbine

Parameter	**Value**
Nominal mechanical output power (W)	8.5 * 10^3
Base power of electrical generator (VA)	8.5 * 10^3/0.9
Base wind speed (m/s)	10
Max power at base wind speed	0.8W
Base rotational speed	1rpm
Pitch angle beta(β) to display wind turbine power characteristics	0 deg
Torque	4250Nm

Table 5.5 Parameters of Panel (Wind + PV Array)

Parameter	**Value**
Voltage	545.5
Current	5.455
Power	2.976*10^5

Table 5.6 Parameters of Mosfet

Parameter	**Value**
FET resistance Ron (Ohms)	0.1
Internal diode inductance Lon (H)	0
Internal diode resustance Rd (Ohms)	0.01
Internal diode forward voltage Vf (V)	0
Snubber capacitance Cs (F)	1*10^5
Snubber Capacitance Cs (F)	Inf

Table 5.7 Parameters of Diode

Parameter	**Value**
Resistance Ron (Ohms)	0.001
inductance Lon (H)	0
Forward voltage Vf (V)	0.8
Initial current Ic (A)	0
Snubber resistance Rs (Ohms)	500
Snubber Capacitance Cs (F)	250*10^9

The Mosfet and diodes are utilized in the converter of the Simulation model of solar energy MPPT and Wind energy MPPT model.

5.3 Simulation Model of Wind Turbine

The graph of Figure 5.7 illustrates the simulink model for the Wind turbine model. The wind turbine model is based on turbine steady state power characteristics. The drive train stiffness of this model is very large. The turbine inertia and friction factor is combined with the generator coupled to turbine.

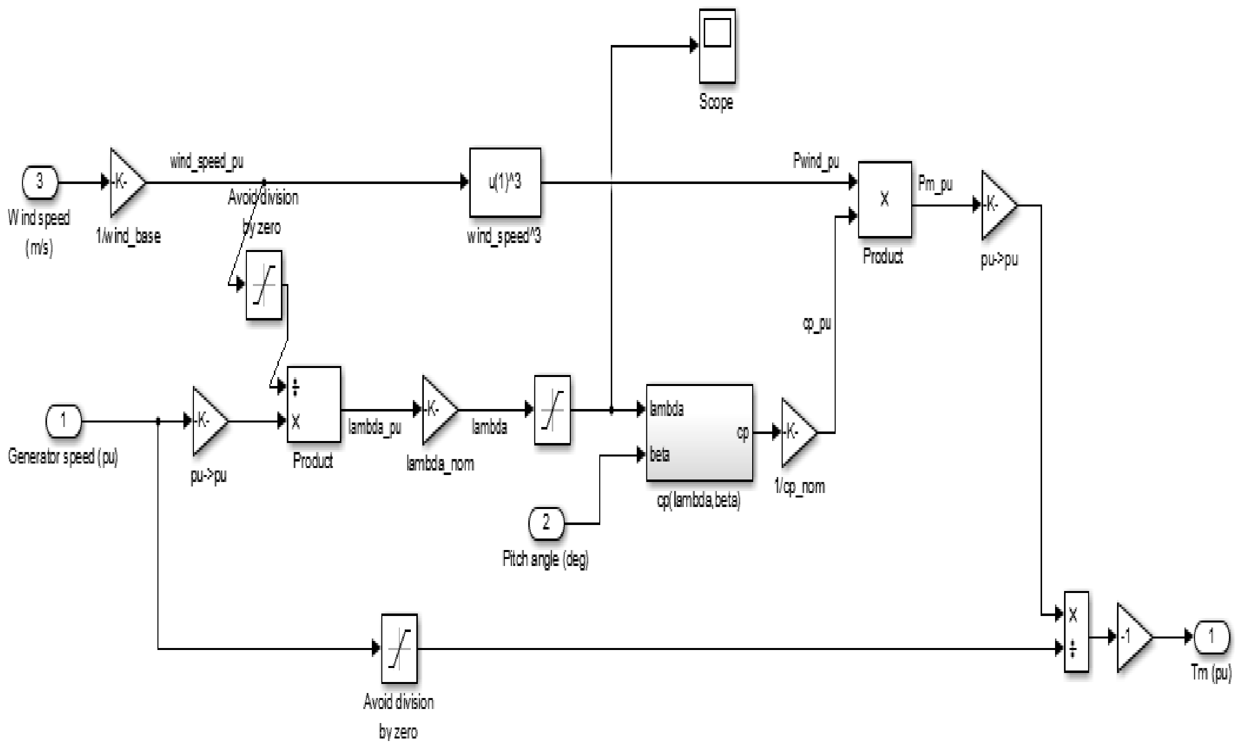

Figure 5.7: simulation model for Wind turbine model

The output parameter of Wind turbine is given by:

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2}v_{wind}^3 \qquad (26)$$

The equation (26) is the standard equation utilized in the function of the wind turbine model. The above equation (26) gives the output power of turbine.

Where P_m is mechanical output power of the turbine (W)

c_p = performance coefficient of the turbine,

ρ = Air density in kg/m^3,

A= Turbine swept area,

v_{wind} = speed of wind,

λ = Tip speed of the rotor blade and

β =blade pitch angle respectively.

The P_{m_pu} is given by equation 27 mentioned below:

$$P_{m\_pu} = k_p c_{p\_pu v^3_{wind\_pu}} \qquad (27)$$

Where power in pu of normal power for particular values is denoted by P_{m_pu} , c_{p_pu} is used to denote the performance coefficient in pu of the maximum value of c_p. The expression in equation (27) is utilized in the wind generation that is very much helpful to generate the wind. It is a standard expression. k_p is power gain whose value is 1.

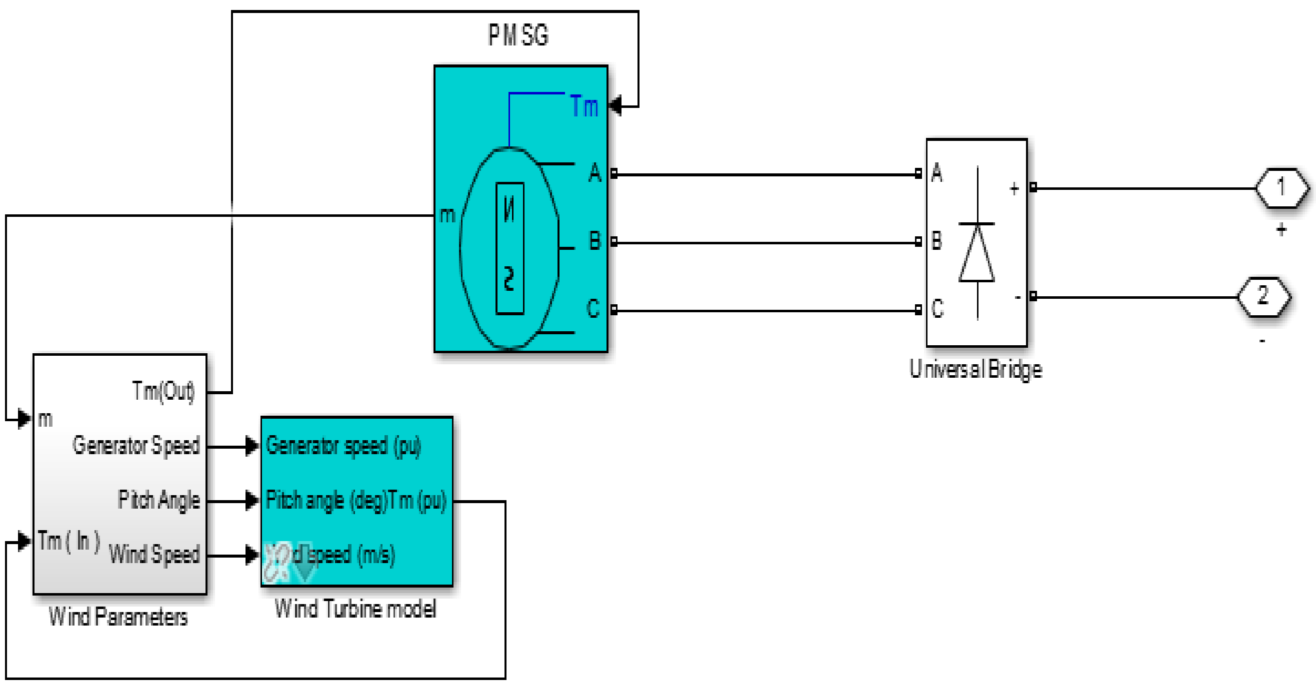

Figure 5.8: Block for Wind generation

The Figure 5.8 illustrates the block for the wind generation. In this model first of all the Permanent Magnet Synchronous Generators (PMSG) transmits the m signal to the wind parameters that are the Generator speed, Wind speed and the Pitch angle which in turn transfer the signal to the wind turbine model which offers the mechanical torque to the wind parameters that in turn transmits to the Permanent Magnet Synchronous Generators (PMSG) block. Next to the PMSG the universal bridge is utilized having diodes in it for the signals coming from PMSG that are Voltage current and the power. The universal bridge helps to convert the voltage from ac to dc and offered the dc output voltage that must be positive or negative.

The graph of figure 5.9 illustrates the Turbine speed characteristics that measures the Turbine speed and the Turbine power. This graph illustrates the speed of the turbine among the Turbine output power.

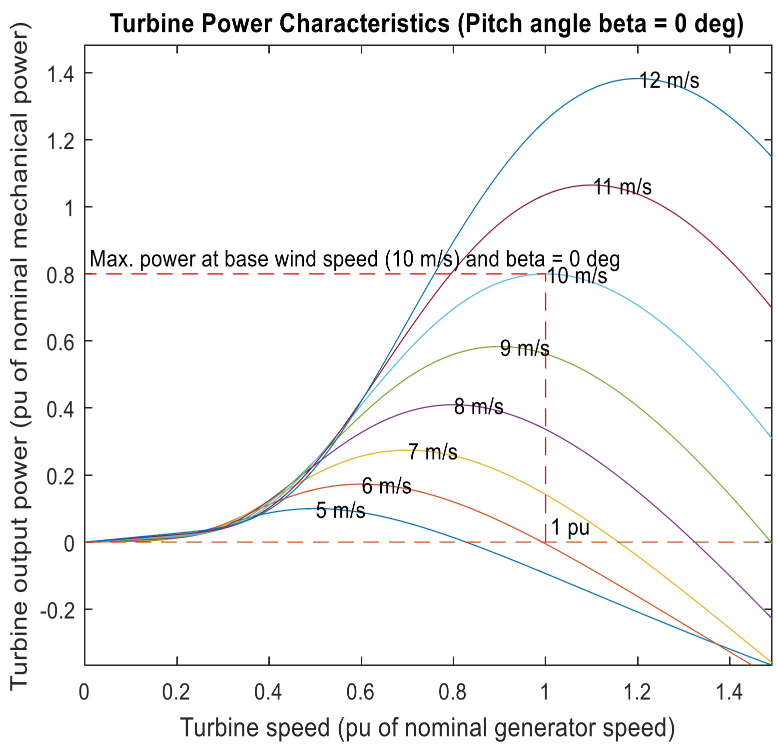

Figure 5.9: Turbine Speed characteristics

5.4 Computational Results

In the Figure 5.10 the P-V and I-V characteristic curves are illustrated. Here in this graph the we see, when the irradiance is 850 kW/m^2, the maximum power of the PV array should be 68.49 W and the voltage should be 17.52V.

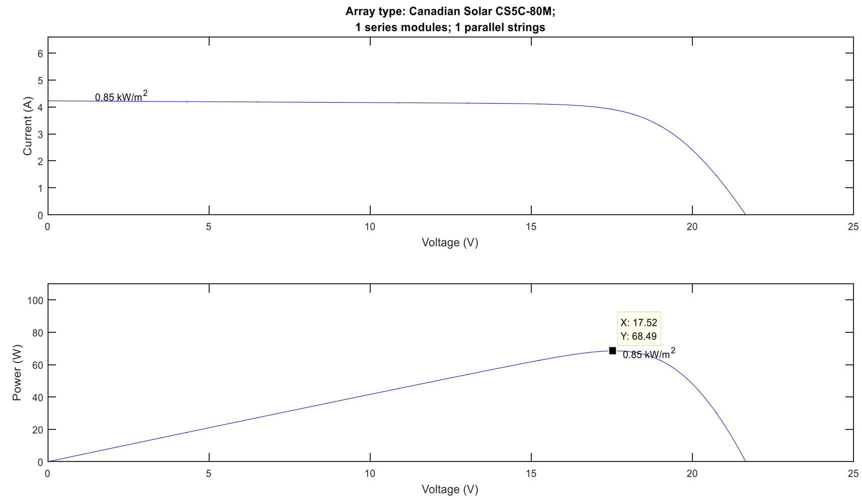

Figure 5.10: P-V and I-V characteristic curves.

The graph of figure 5.11 illustrates the panel output of the Voltage, Current and Power when the irradiance is 850 kW/m^2. Here the Voltage, Current and Power is 20.95V, 3.31A and 69.92W.

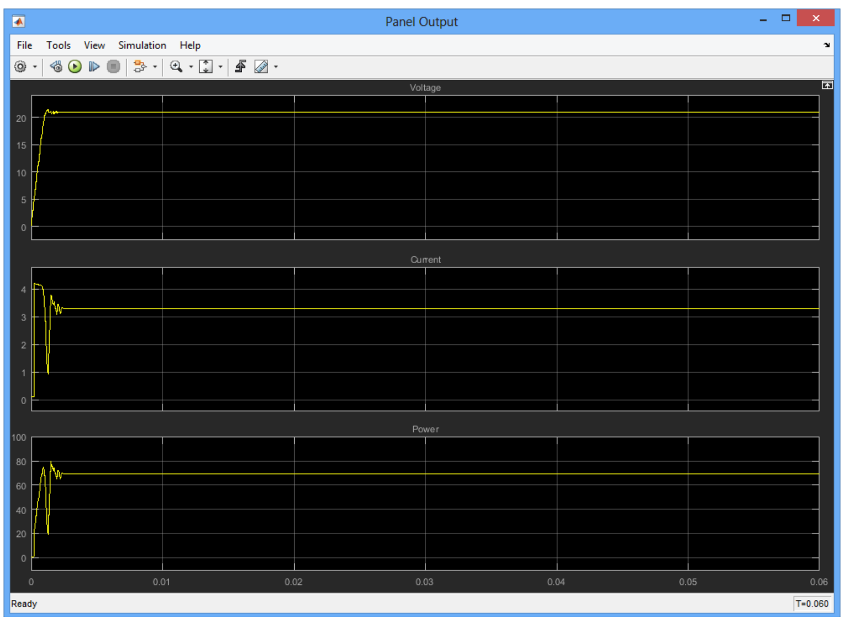

Figure 5.11: Panel output of Voltage, Current and Power when the irradiance is 850kW/m^2.

The graph of figure 5.12 illustrates the P-V and I-V characteristic curves. The output of the PV array of voltage and power must be 17.6V and 64.56W when the irradiance of the system is applied as 800kW/m^2.

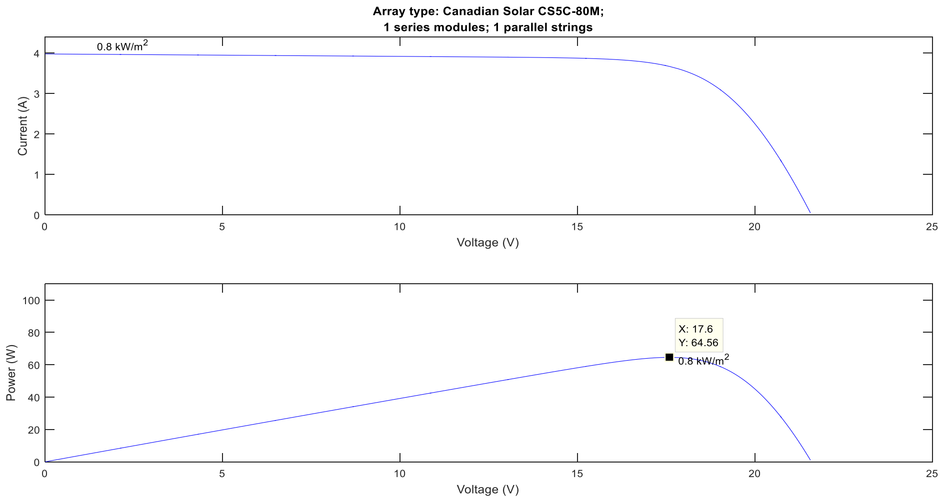

Figure 5.12: P-V and I-V characteristic curves.

The graph of figure 5.13 illustrates the panel output of the Voltage, Current and Power when the irradiance is 800kW/m^2. Here the Voltage, Current and Power is 20.99V, 2.94A and 61.9W.

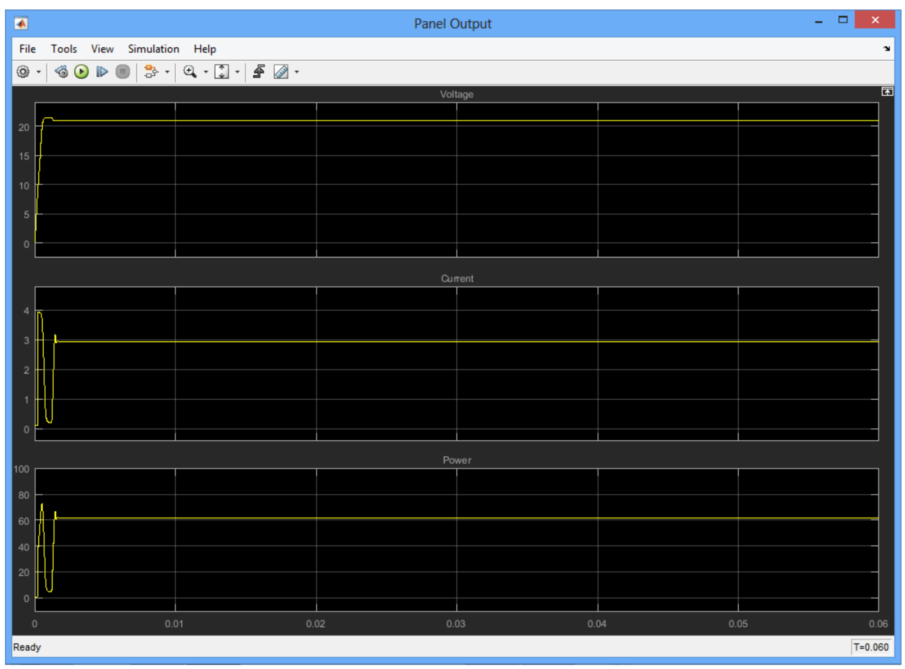

Figure 5.13: Panel output of Voltage, Current and Power when the irradiance is 800kW/m^2.

The graph of figure 5.14 illustrates the P-V and I-V characteristic curves. Here the applied irradiance of the mechanism is 950 kW/m^2 so the power and the voltage of the system should be 76.28W and 17.58V.

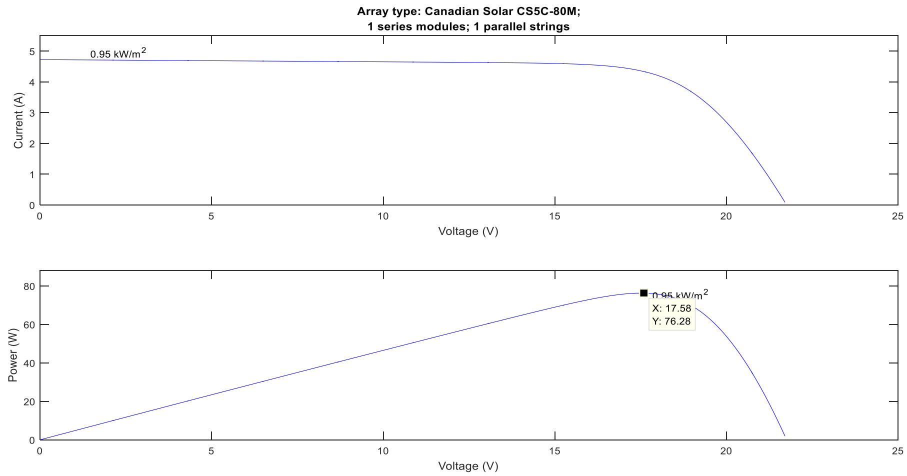

Figure 5.14: P-V and I-V characteristic curves.

The graph of figure 5.15 illustrates the panel output of the Voltage, Current and Power when the irradiance is 950 kW/m^2. Here the Voltage, Current and Power is 20.85V, 3.97A and 82.91W.

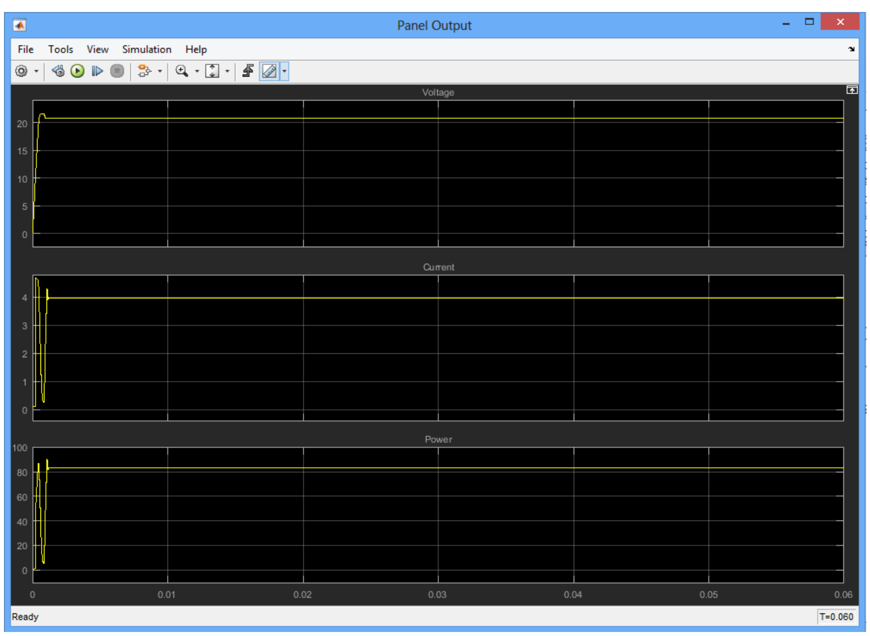

Figure 5.15: Panel output of Voltage, Current and Power when the irradiance is 950.

The Table 5.7 illustrates the values of voltage, current, power and temperature among the different values of the irradiance that are 800kW/m^2, 850 kW/m^2 and 950 kW/m^2.

Table 5.8 PV Array Input parameters.

Irradiance kW/m^2	Temp (°C)	Voltage (V)	Current (A)	Power (W)
950	25	20.85	3.97	82.91
850	25	20.95	3.31	69.92
800	25	20.99	2.94	61.9

The Table 5.8 illustrates the PV Array Input parameters of the base paper.

Table 5.9 PV Array Input parameters.

Parameter	**Value**
Irradiance (Watt/m^2)	800-1000
Temperature	25°C

The fig 5.16 characterizes the analysis of the Converter Voltage, Converter Current and Converter Power for PV System with ANFIS system. The numbers of variations in the current model are minimum that validates the mechanism as much steady.

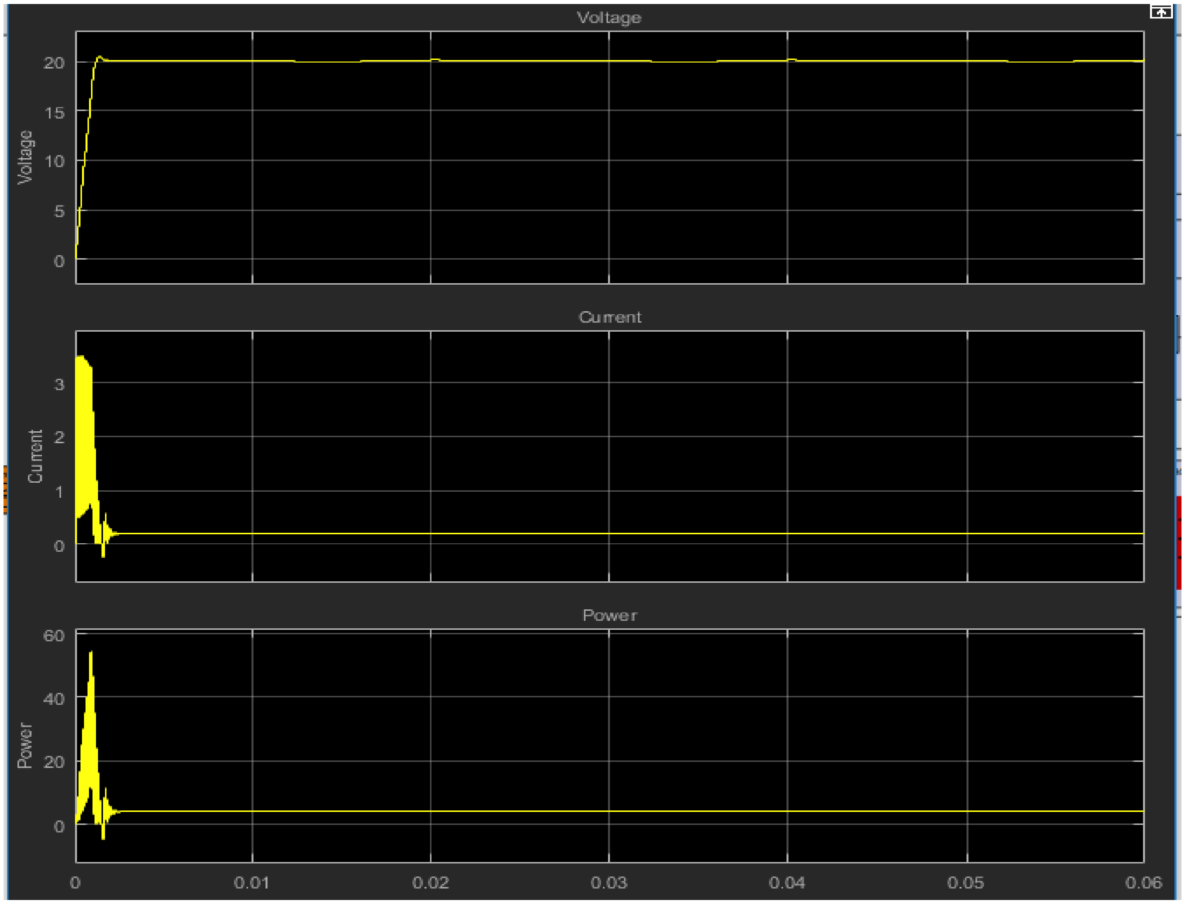

Figure 5.16: Converter Voltage, Converter Current and Converter Power for PV

The Figure 5.17 illustrates the Panel output Voltage, Current and Power for PV and wind system of the ANFIS–MPPT mechanism. It is illustrated in the figure that the power, voltage and current fluctuate a little in the ANFIS-MPPT based PV panel. The signal that is received residues constant from the start point to the stop point. The values of voltage current and power are 22V, 4.3A and 85 W.

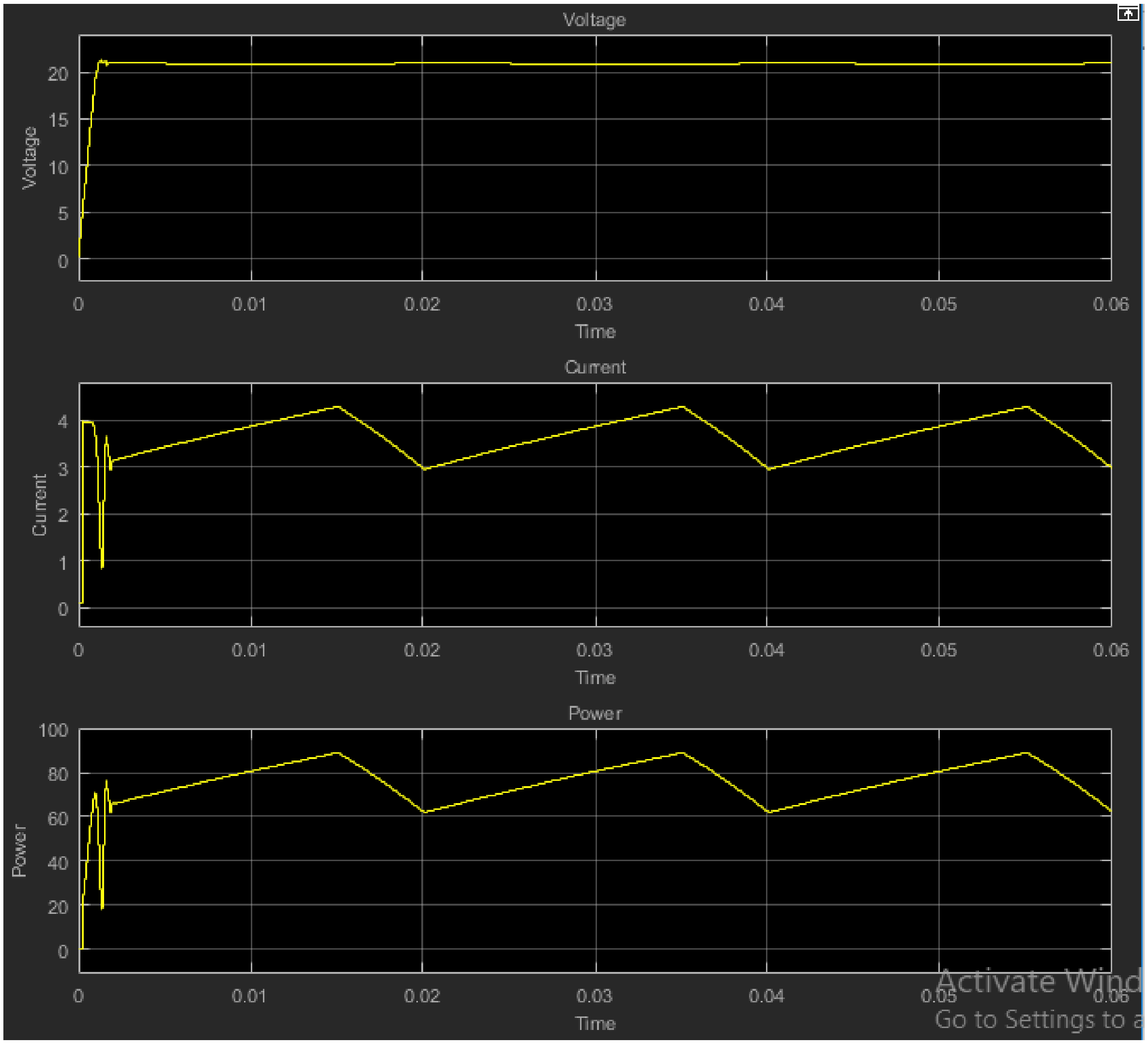

Figure 5.17: Panel output Voltage, Current and Power for PV

The graph in Figure 5.18 demonstrates the Voltage, Power and Current obtained from the hybrid of solar and wind mechanism panel that are very less comparative to the conventional mechanisms.

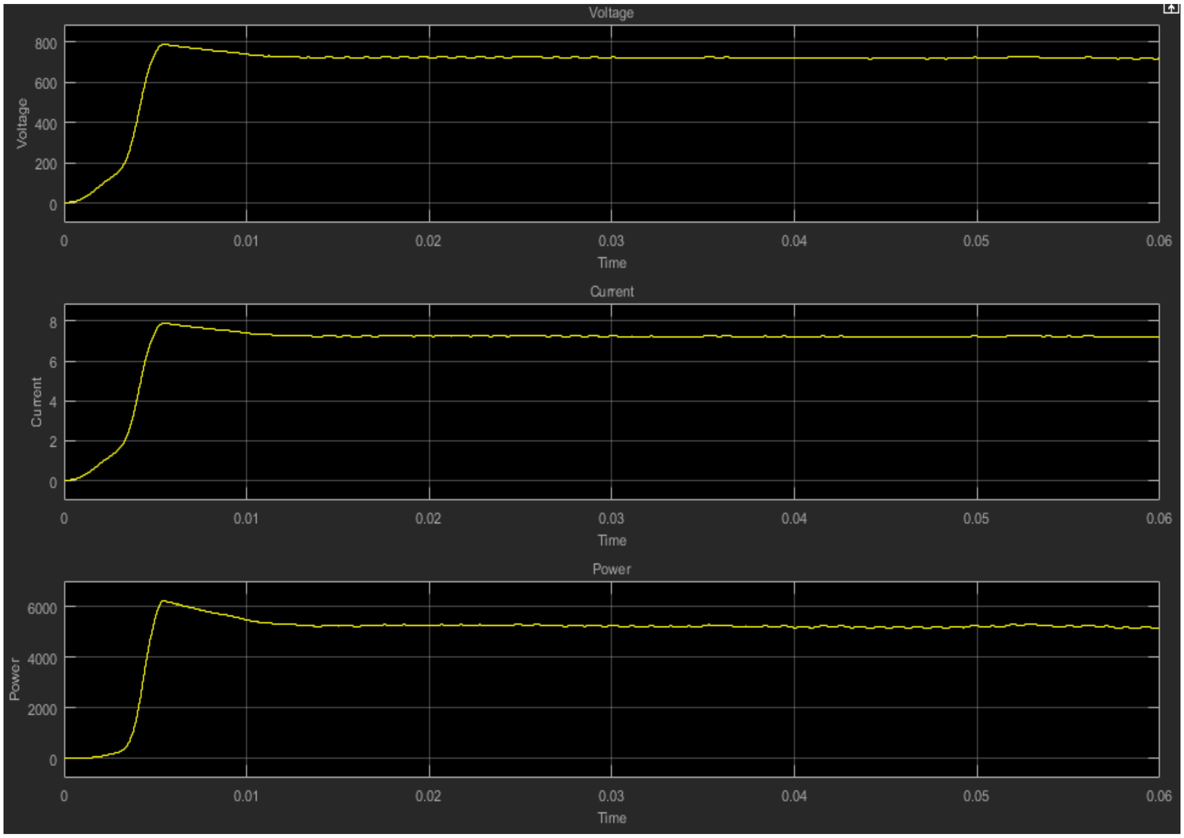

Figure 5.18: Hybrid Approach Panel Voltage, Current and Power.

Table 5.10 Comparison of Conventional and Projected mechanism parameters having irradiance 800kW/m^2.

Parameters	**Conventional mechanism**	**Proposed mechanism**
Current (A)	3.8	2.97
Voltage (V)	18	20.99
Power (W)	65	62.35

Table 5.11 Comparison of Conventional and Projected mechanism parameters having irradiance 1000 kW/m^2.

Parameters	**Conventional mechanism**	**Proposed mechanism**
Current (A)	3	4.28
Voltage (V)	18	20.82
Power (W)	50	80.02

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

This project has suggested a PV generation system to interface the solar power to a resistive load using ANFIS MPPT controller. The ANFIS controller has been implemented using MATLAB/SIMULINK software. The interface stage between the generation source and the load is accomplished by a boost converter. The boost converter boosts the output voltage from the PV array which is controlled by the ANFIS based MPPT controller. The maximum power point tracking and voltage boost are achieved using the proposed system. The simulation has been carried out in MATLAB/SIMULINK environment and the results have been produced. The maximum power and voltages are obtained at various irradiance values and compared with the result obtained. Further the solar energy system is hybridized with the wind energy system as is trend now a days to achieve power with greater reliability and efficiency. The simulation results demonstrates that by utilizing the present research, maximum power can be achieved.

6.2 Future Scope

As the trend of renewable energy in present day scenario is increasing in a very good pace, the presented research work has a very wide scope in future. In this work further, the MPPT can also be further applied on the wind energy system. The research work can be further applied on a three phase load using an inverter in combination with the boost converter. Also other methods like GENFIS can be applied and the results can be compared.

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APPENDIX

The modules used for proposed MPPT system are listed below:

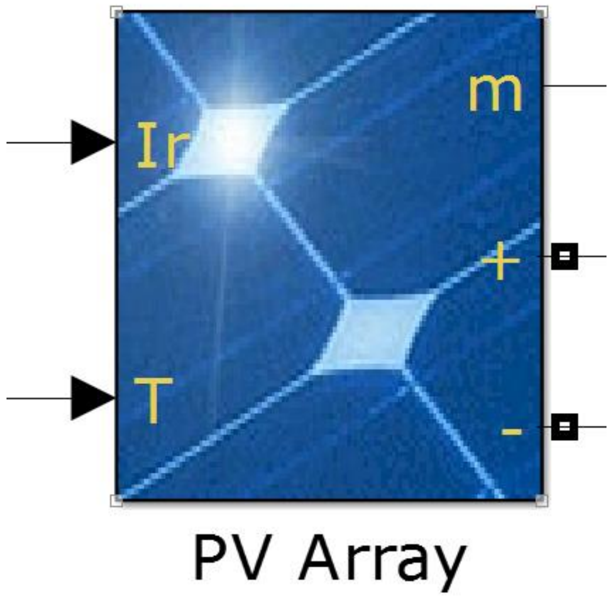

Figure 1 PV Array

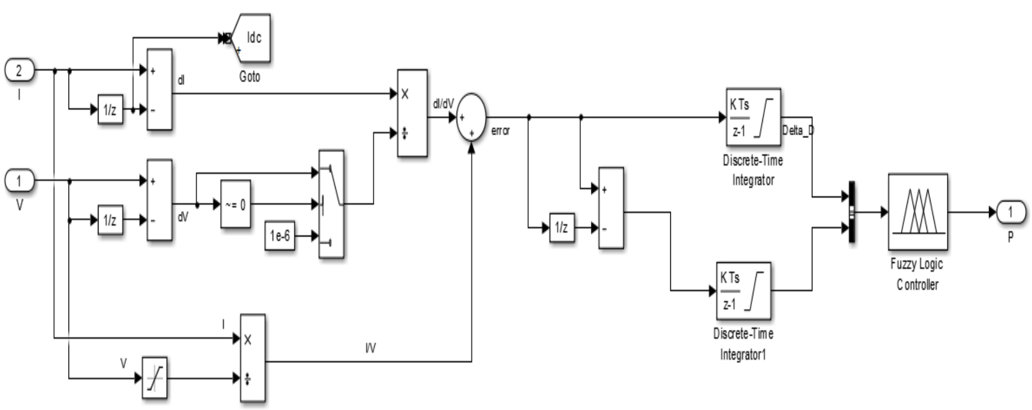

Figure 2 Proposed MPPT

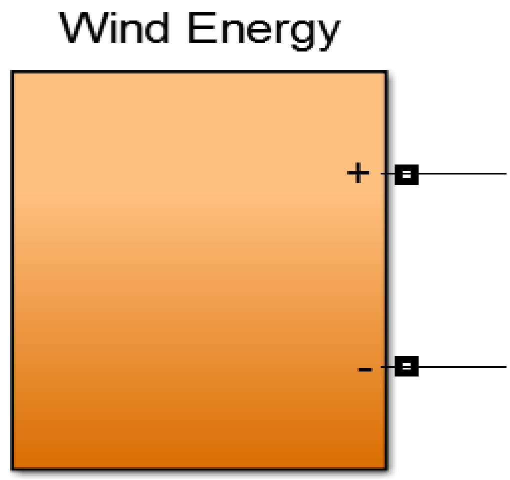

Figure 3 Wind Energy

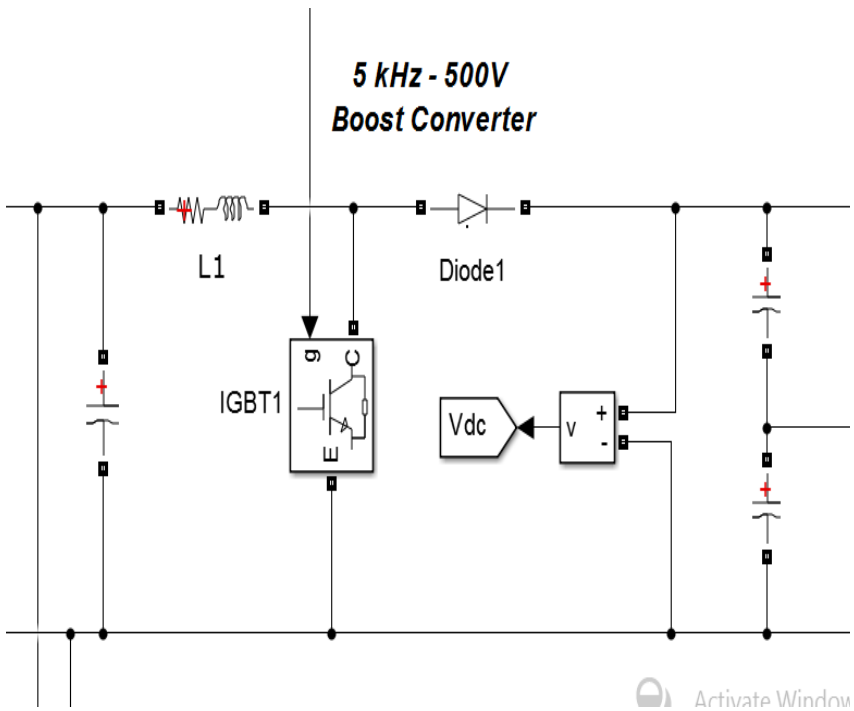

Figure 4 Boost Converter

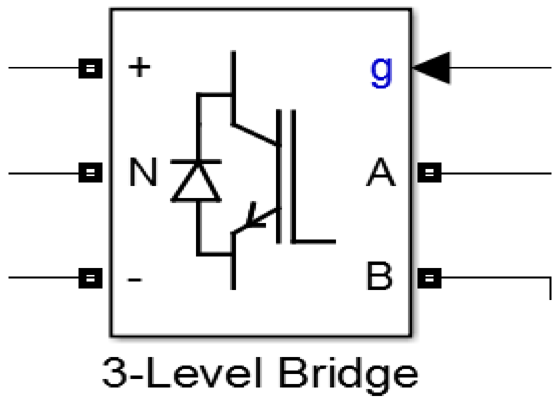

Figure 5 Three-Level Bridge

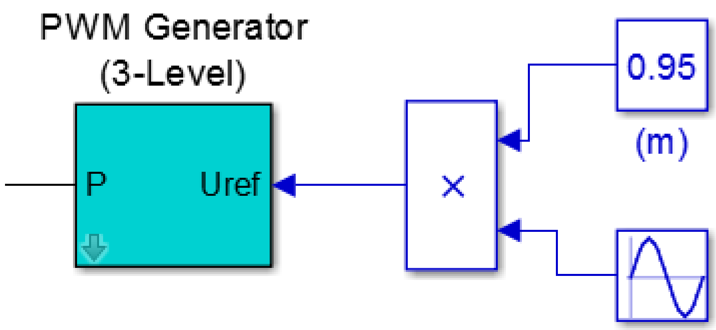

Figure 6 PWM Generator