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MODELING AND INTELLIGENT CONTROL OF A STANDALONE PV-WIND-DIESEL HYBRID SYSTEM

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ABSTRACT

MODELING AND INTELLIGENT CONTROL OF A STANDALONE PV-WIND-DIESEL HYBRID SYSTEM

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The aim of this thesis is to study the modelling and intelligent control of a stand-alone hybrid energy system based on solar-wind-diesel with battery. The renewable sources are major components of a standalone hybrid system as a combining photovoltaic with the wind turbine. Each component of these systems has been modeled and implemented in MATLAB/Simulink software. The proposed system is able to operate in standalone mode, without the need for connection to the main grid. The fluctuations in voltage and frequency of the system can be encountered depending on wind speed, solar irradiation and the temperature. Thus it can be observed the decrease in power quality in such systems which operate in standalone. This condition can even go worse when varying loads are considered. In order to improve power quality and reduce unwanted fluctuations of system quantities under different operating conditions an intelligent control is designed in this work. The capabilities of this designed intelligent control system on the control of voltage and frequency of the system are tested under different operating conditions and compared to PID controllers. The superiority of the designed intelligent control system over PID controllers is shown by the simulation studies.

Keywords: Hybrid standalone micro-grid, voltage control, frequency control, intelligent controller, fuzzy logic control.

ÖZET

TEK BAŞINA ÇALIŞAN HİBRİT BİR PV-RÜZGAR-DİZEL SİSTEMININ MODELLEMESİ VE AKILLI DENETİMİ

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Bu tezin amacı tek başına çalışabilen güneş-rüzgar-dizel ve bataryadan oluşan hibrit bir enerji sistemini modellemek ve akıllı denetimini çalışmaktır. Yenilenebilir enerji kaynakları tekbaşına çalışabilen, rüzgar ve fotovoltaiğin kombinasyonları olan hibrit bir sistemin başlıca bileşenleridir. Bu sistemlerin her bir bileşeni Matlab/Simulink yazılımında modellenmiş ve gerçekleştirilmiştir. Önerilen sistem ana şebekeye bağlantı ihtiyacı olmadan tek başına çalışabilmektedir. Rüzgar hızı, güneş ışınımı ve ısıya bağlı olarak sistemin gerilim ve frekansında oynamalar yaşanabilmektedir. Dolayısıyla bu tür tek başına çalışan hibrit sistemlerde güç kalitesinde bozulmalar yaşanabilmektedir. Bu durum anlık değişen yükler sözkonusu olduğunda daha kötüye daha gidebilmektedir. Güç kalitesini iyileştirmek ve sistem büyüklüklerindeki istenmeyen oynamaları farklı çalışma koşullarında azaltmak için bu çalışmada akıllı bir denetim tasarlanmıştır. Tasarlanan bu akıllı denetim sisteminin gerilim ve frekansı kontrol etmedeki yeteneği farklı çalışma koşulları altında denenmiş ve PID denetleyicileriyle karşılaştırılmıştır. Tasarlanan akıllı denetim sisteminimi PID'ye göre üstün olduğu yapılan benzetim çalışmalarıyla gösterilmiştir.

Anahtar kelimeler: Hibrit tek başına çalışan mikro-şebeke, gerilim denetimi, frekans denetimi, akıllı denetleyici, bulanık mantık denetimi.

Dedicated to

My dear mother, father, my wife and children

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LIST OF SYMBOLS/ABBREVIATIONS

PV	Photovoltaic
WT	Wind Turbine
DG	Diesel Generator
BESS	Battery Energy Storage System
VSC	Voltage–source Converter
DE	Distributed energy
MPPT	Maximum power point tracking
PWM	Pulse width modulation
PI	Proportional Integral
FLC	Fuzzy logic control
ID	Forward-bias diode current
e	Electric charge
m	Ideal factor of diode
K	Boltzmann’s constant
Tc	Cellar's temperature
D	Duty ratio (duty cycle)
f	Frequency
L	Inductor
Vc	Carrier voltage
Vtri	Triangular voltage
M	Modulation index
Fr	Reference signal of frequency
Fs	Switching frequency
Ma	Amplitude modulation ratio
K_P	Proportional coefficient
K_i	Integral coefficient
q	Electron charge = 1.6 x 10^{-19} Coulombs
A	Curve fitting constant

K	Boltzmann's constant = 1.38×10^{-23}
I_{PH}	Photocurrent
I_{PV}	Photovoltaic current
I_{SC}	Current at Short circuit
Irs	Reversing saturated current.
Voc	Voltage at open circuit
Rs	Series resistance
K_1	Coefficient of cell at short circuit current
λ	Coefficient of irradiation
Np	Number of parallel cells
Ns	Number of series cells
$V\infty$	Velocity of the wind
CP	Power coefficient
CT	Torque coefficient
ω_m	Angular velocity of the shaft
ρ	Air density
R_b	Radius blades of the swept area
P_m	Mechanical power production from wind turbine
T_m	Torque production from wind turbine

CHAPTER 1

INTRODUCTION

1.1 General Information

Nowadays, the necessity for the electrical power is high because of increasing the demand of many places as villages and any public service stations as a water station in the rural areas which did not reach the electricity to them, and located far from the existing national grid. By these reasons, the losses of energy were been high in recent years.

By trying to supply power electricity in remote areas without having the main source of grid electricity has been mostly provided by stand-alone diesel generators. This solution is relatively inefficient and expensive and pollutes environment due to the greenhouse emission. Some level of penetration of hybrid systems containing panel solar photovoltaic-wind turbine-diesel generator can be considered for more efficient and clean electrical power generation. Otherwise, in some country like Iraq this diesel generator used in the cities and towns instead of the main grid system during the time that the main grid was interrupted, which is due to emission of pollutant gases, of the environment, then it must be solved this dangerous problem by using other alternatives as suggested by other authors from the works of literature by papers, conferences, and thesis as it was suggested in this work.

Therefore, electrification of those places by using standalone renewable resources is one of the interesting and attractive alternatives nowadays. Analyzing the hybrid system implies the development of simulation models of hybrid system operating standalone in a rural/remote area or any area that need to electric power because of cost cannot be ability to transfer electric power for their region. The demand for energy grows by the day, by the increasing of the necessity for life with increasing population of the earth. Then because of it, some of the countries tried to reduce of in energy and using other alternatives for product electrical power energy from the renewable sources, like the USA, Denmark, India, china, and etc.

Recently it has been reported by the International Energy Agency that 46% global electricity would be from RES by 2050. The share of global electricity from wind, according to Global Wind Energy Council, would be 21-30%. As with regard to solar, it was projected by Greenpeace International that electricity from solar would increase from 16 GW in 2008 to 180 GW of solar PV worldwide by 2030.A large percentage of electricity generated from the renewable energy sources (RES) would be non-grid connected. For example, according to Greenpeace International about 40% of the 180 GW forecasted power, solar system’s electricity by 2030 would be non-grid connected [1].

Locally, there are a great interest and plans for Iraqi-Kurdistan regional government to redevelop the evacuated and transferred villages by the previous regime in the past decade years. Then its need to transport electrical power for these villages, for the past reason the using renewable sources is benefited for solving this matter as a stand-alone hybrid system that used in this project.

Therefore, providing energy is one of the most important factors in the redevelopment and rehabilitation of the rural areas [1].

1.2 Renewable Energy Sources (RES)

The global environmental conditions get worse day by day. The rapidly increasing energy, increasing uptake, along with limited resources of fossil fuel and the continued increase price of fuels provides a more reasonable sense for an alternative energy source in the form of renewable energy [2].

The classical power systems such as large power generation plants are situated at a convenient geographical location to receive a maximum of the electrical power, which is then transformed into large consumption centers over the long distance transmission line. The system control centers detect and determine the power system continuously to guarantee the quality of the power, rated voltage, and frequency. Though, at this stage the complete power system is under challenge.

For providing this matters can be using of large number renewable sources like a PV panel or wind turbine and connection to gather as a micro-grid, which can be operated as alternative energy sources in this area that have a suitable environment to use these type of renewable sources. A public use of renewable energy sources in distribution networks and a high inventive level will replace the aged ones in the near future. Renewable resources are a natural resource, which basically gain from the natural environment the surrounding atmosphere.

Over the last few decades or so, natural resources have become something popular to use. This is particularly the case with developed countries. It’s worth mentioning that the new energy source has both cost effective and more environmentally friendly use. As well as being less reliant on importing energy from other countries. Moreover, it also provides a good source of employment for the local population. A common application of renewable energies is electricity generation. The renewable energy sources have a minimal effect on the environment, and a minimum of maintenance compares with other older traditional power generators.

Because of the renewable energy sources need for maintenance less than the diesel generator or other generators, so it is environment-friendly Among all the renewable energy resources, the solar and wind energies have the greatest potential as a power generating energy source, because of their many advantages like low or zero emission of pollutant gasses, low cost, inexhaustible sources and easy availability of these energy sources. But these systems have some disadvantages also like dependency on weather conditions. The difficulty to generate the quantities of electricity is one of the major disadvantages of the renewable energy when compared to traditional generators which work by fossil- fuel machines. So it's necessary to decrease using the quantities of energy or by find an alternate source of energy. Using different power sources, is the best solution to balance our energy problems [2].

1.3 Hybrid Micro Grid System

A small system power supply which is produced power for the local area, by small sources is defined as a Micro-grid system. And then by connecting some of this sources as a hybrid system to make it more flexible and efficient [1]. It is better if use renewable sources only but in some area cannot use without diesel generator because of the weather.

The hybrid system consists of different sources; which includes diesel with renewable sources as the Photovoltaic solar system, the wind energy turbine generator, battery systems and etc. Each of them depends on various natural energy sources. Varity of their dependence will be difficult to control overall system. So in one hand they need robust control in order to solve the entire changes in those natural sources that always occur due to the fluctuation of the environment nature, in another hand these difference of sources are useful that lead to be more strong system for achieving electricity efficiency for consumers because if those sources be inactivated due to any reason, there are another compensators. There are more than one source and those sources rely on the different natural sources that most of them are available in most places though we can be benefited in these systems in whole places.

In this work, the proposed micro-grid hybrid power system modeling and studied in MATLAB/Simulink. Since the voltage and frequency control of this system is one of the most important cases; therefore, control schemes are designed in order to it, within changes of loads and weather.

1.3.1 Photovoltaic (PV)

French physicist Edmund Becquerel in 1839 was the first scientist that noted the photoelectric effect and found some materials for generate few amounts of electric current when exposed to sunlight was proposed several materials which have this property.

The first photovoltaic module was built by Bell Laboratories in 1954, as its idea from Albert Einstein which found the photoelectric effect in 1905, too. The operation of a PV cell is based on a photoelectric effect by increasing the number of a free electron in the conduction band in the semiconductor material, when sunlight hits its surface, some portion of the solar energy is absorbed.

The first practical applications of PV solar panels were on spacecraft in the 1960s. As time went on, the technology progress and the panels became smaller and cheaper.

Today solar panels are affordable and capable enough for generation electrical power for serving demand. [3]

Can be determined the efficiency of the solar cell by changing sunlight to obtain enough electrical energy, and whenever to increases the surface area of solar cells, the electrical energy will be increased.

Solar cells are small devices which can transform light into electrical power. Can provide a large amount of power energy product by several cells connected together by a frame to make a module or solar panel, thus by connecting this solar panel by electrical cable in parallel and serial together can make a solar array, that are the number of panels and type of the connecting depends on the power demand and terminal voltage system in DC side.

The PV system mostly is used in the local region and this places that more exposed by radiation of sunlight. Always used with its battery to storage its energy and used in during cloud time or at night. This sources can be used directly as a DC source or indirectly as an AC source by using inverter at the output.

This type of sources has less than others for maintenance, because of independent on mechanical dynamic rotating in its operating.

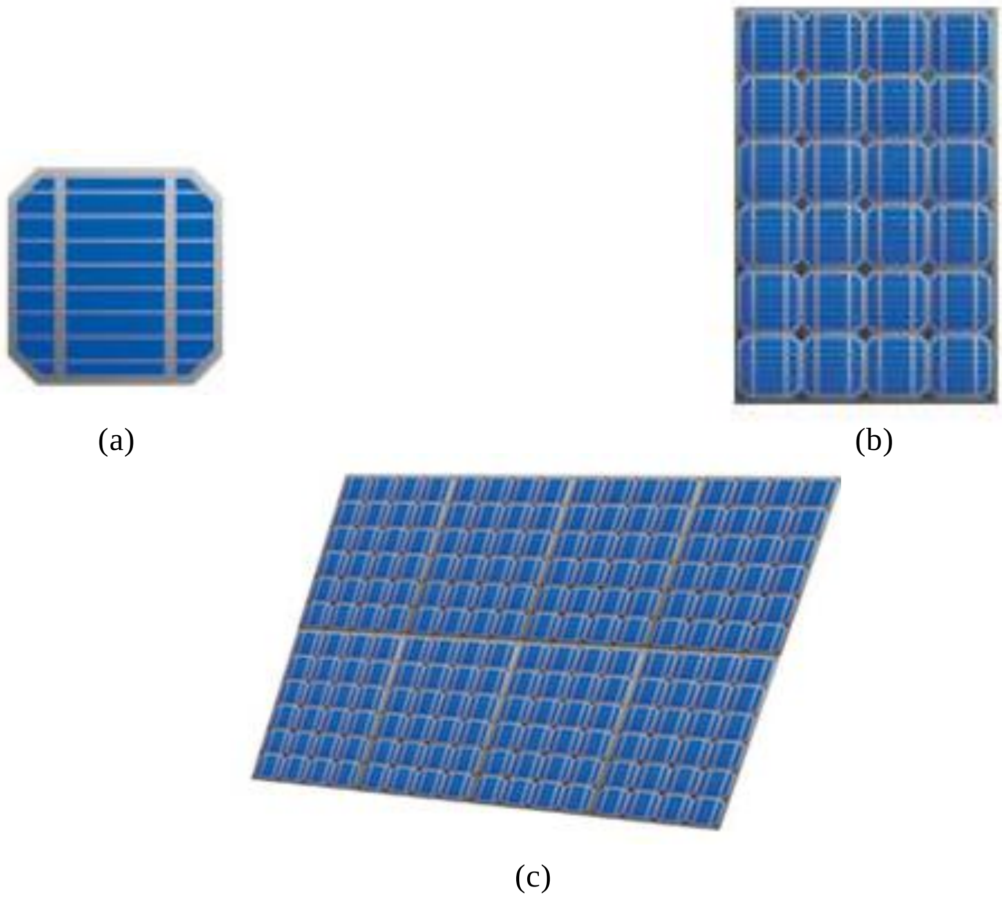


Figure 1.1 (a) Solar Cell, (b) Module, and (c) Solar Array [4]

1.3.2 Wind Power

The wind turbine can be defined as a machine which is produce the electrical power by converting wind's kinetic energy. Therefore, the wind turbine would be benefited from the regions that have average annual wind. The wind turbine has been ruled as another renewable energy source used for generating electrical power energy.

Recently it has been reported by the International Energy Agency that 46% global electricity would be from renewable energy source by 2050, and 21-30% of them from the wind turbine, according to Global Wind Energy Council. Nowadays, the world is going the way of getting green energy because of the great problem of increasing greenhouse with increasing demand of electrical power plant which were most of them used burn of fossil fuels to produce the electrical power energy.

The wind turbine is one of the important sources which is used in hybrid system as micro-grid renewable energy specialty in this region that have more wind annually. Because of the wind turbine depend of dynamic mechanical energy, it has more maintenance if compared with the PV panels. So, when it used with PV solar panel it must be making the PV system as a significant to avoid the maintenance.

The wind also depends on the sun but indirectly, and its energy comes from the sun by the differences in temperature on the different area in the earth. Especially in the beaches and in the mountains, in some countries used on the sea. Nowadays, the wind turbine is used widely that developed in many countries, in the some of them it is a majority to produce of power plants.

Figure 1.2 Wind Turbine in Power Plants [5]

1.3.3 Diesel Generator

The diesel engine is working as energy conversion devices which are used to produce electrical power from the energy contained in the fuel supplied to the engine. This process requires by the process of combustion to converting the chemical energy into the fuel oil to thermal energy, after expansion the gas which produced from it by heating and cooling, converted this energy into mechanical energy by forcing the gas on the pistons and transport this energy from the pistons to the crankshaft that is connected to it, that is due to rotational output shaft horsepower, finally, converts the mechanical energy supplied by the engine into the required electrical energy through electromagnetic induction by the generator.

Figure 1.3 Diesel Generator (Diesel Engine, Electrical Generator, and Control Panel) [6]

The diesel generator is a set of a diesel engine and electrical generator that are combined them to produce electrical power energy from the fuel energy that explained above, with an exciter and governor to control each of the mechanical and electrical power by control each of speed and voltage, respectively. The diesel generator will be taken in action in cases where renewable sources are incomplete to produce sufficient electrical power to the consumer.

The Diesel Engines are be developed more than 100 years ago, as a distributed generator to fed the load demand at a case of absent the electrification in this place. Because of high reliability and efficiency, it is used on many scales, a compression ignition and Otto spark ignition in the diesel engines cycle have gained popular agreement in the economics sector.

Because of the fast dynamic response of the diesel prime movers has a good capabilities of disturbance rejection, due to flash changes by the consumers in load demands, that is significant to distribution power in stand-alone systems. Normally, intake, compression, combustion, and exhaust are four stroke cycles diesel engines, which is used for power generation and operate. The process begins with fuel and air being mixed. In turbocharged applications, the air is compressed before mixing with the fuel. The fuel/air mixture is introduced separately with fuel being injected after the air is compressed.

1.3.4 Battery Energy Storage System

The battery is a nonlinear device that used as an energy storage that consists on current and case of a charge, which it can be discharged by a form of electrical power DC source, so it can be used more than time by repeating the charging and discharging this device can be used as an active energy source. In this work, the battery energy storage system acts as a control of voltage and frequency of the standalone system after converting to AC by an inverter and it was connected to the hybrid system.

The batteries made up of different chemical combinations in many shapes and sizes, it's used in for energy storage applications, such as renewable energy systems. A most common battery type used in off-grid and hybrid energy storage are Lead-acid batteries, however, more recently lithium-ion (Li-ion) based battery systems have become available for this purpose. And it's used in a home because its specialty of chemical, which has not produced a smell.

Figure 1.4 Cabinet of Battery Energy Storage System [7]

1.3.5 Converters

In the last years, the one of the big progress in the electrical power sector is by power electronic devices, which is due to high ability to controlling power system. The one of the power electronic devices is the converters, which are several types it depends on the type of the source that needed to one of them to convert its form to another form.

In this study, in the DC site of the PV used DC to DC booster converter to stabilize the DC output voltage, and to investigate Maximum Power Point Tracking (MPPT) of the PV panel system and (VSC) the voltage source converter, used as a DC to AC and AC to DC converter, as works as a bi-directional switch, and can be control its direction and changing output current by trigger fed signals.

The Proportional-Integral (PI) control and fuzzy logic control (FLC) are used as a modern and intelligent control to the control these action.

Figure 1.5 Inverters [8]

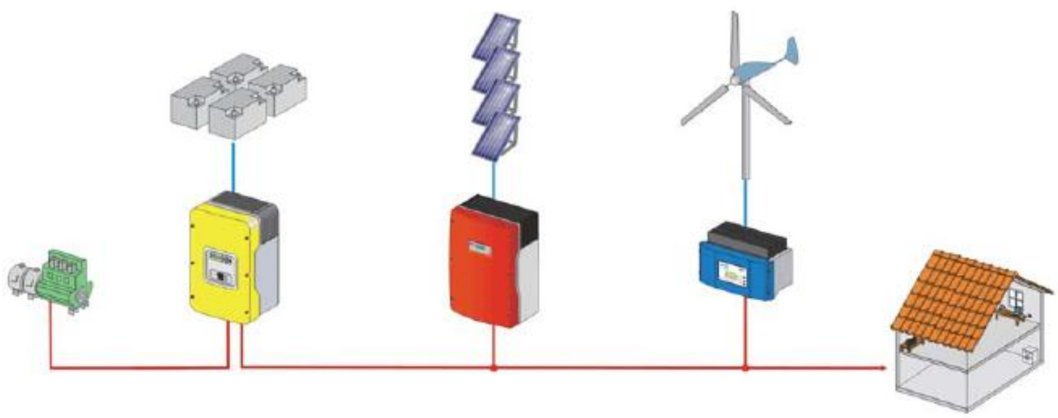


Figure 1.6 Using Inverters with Different Type of Sources [9]

1-4 Objectives of Thesis

In this thesis, the modeling and intelligent control of a standalone hybrid system depending on a photovoltaic (PV) system, a wind turbine (WT), and a diesel generator (DG) was been studied in MATLAB simulation environment.

The PV system was considered with a maximum power tracking method to benefit sun energy at the possible maximum rate. Wind turbine system will consist of a variable speed AC generator that is preferred due to its flexibility to capture wind power at varying speeds. The diesel generator will be taken in action in cases where renewable sources are inadequate to produce sufficient electrical power to the consumer. The suitable inverter type for PV and wind turbine systems will be investigated in the literature and later modelled with their intelligent control for the required operating conditions.

The complete system will be modelled and controlled in MATLAB software. The dynamic response of the hybrid system obtained from the simulation results will be studied and evaluated to draw conclusions at the end of the study.

1-5 Outline of Thesis

This thesis is organized fife chapter as follows:

Chapter 1: This chapter gives a simple detail of the work, and an introduction of the study that is including objective and the contribution of the thesis and the organization of the project.

Chapter 2: This chapter explains the place of this study in the literature and the kinds of literature related to it.

Chapter3: This chapter deals with modeling of the hybrid standalone micro-grid system .

Chapter4: This chapter explains the principle of the intelligent control and how it is effective to improve power quality (regulating voltage and frequency). It also explains the structure of the FLC.

Chapter 5: This chapter represents the simulation studies and the discussion of the results.

Chapter 6: This chapter contains the conclusion and something new which can be done in the future work.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

The pertinent research reports in the literature with regard to the field of modeling with controlling on off-grid hybrid model for renewable energy, and their conclusions are briefly cited below:

2.2 Related This Work with the Other Literature

Jong-Yul Kim, Hak-Man Kim, Seul-Ki Kim, Jin-Hong Jeon, and Heung-Kwan Choi (2011) they were improved frequency control performance in microgrid by using energy storge system with PID fuzzy controller and compared with PI controller by swarm optimazation tuning [10].

Singh S., Singh A.K., and Chanana S. (2012) they were indicate a role of distribution generator sources in the controlling grid frequency. The fuel cell sources have been developed to response to the fluctuations on the grid frequency, which gave better response when combined with the diesel generator to control the frequency [11].

Sheeja V., Singh B., and Uma R. (2009) they proposed a new topology of a controlling for standalone wind energy conversion system, to regulate voltage and a frequency, by used a bi-directional convertor VSC with a battery energy storage system (BESS) [12].

Ertugrul Cam (2007) was presented and studied a comparison a fuzzy gain scheduler with a proportional and integral controller, and only a conventional proportional and integral controller. Each of these controllers was applied to a single area and a two area hydro electrical power plant. The simulation results suggested that the fuzzy controller has considerably better performances than the

PI controller for both two area hydro electrical power plant, whereas the latter controller has a relatively better overshoot value than that of the former for only the two area power plant. And recommended using the proposed fuzzy logic controller as an advanced controller for providing load frequency control in such single area and two area hydro electrical power plants [13].

P. Raju and S. Vijayan (2013) were discussed the results from two type of intelligent controller, fuzzy Neural Network and fuzzy logic for management of battery energy system, and made compared between them. Which the results showed Neural network an improved version. From a particular of periodic time in the PV and Wind hybrid system by charging and discharging of battery improved its characteristic to meet large load demand of local or industry area. [14].

Juang C.-F. and Lu. C.-F. (2006) they were compare reveals the superiority of the proposed fuzzy-proportional-Integral (FPI) controller by hybridizing a genetic algorithm and particle-swarm optimization (FPI–HGAPSO) over both genetic algorithm (GA) and particle-swarm optimization (PSO). Also, based on the proposed design approach, the total number of fuzzy rules is reduced, and the design effort is eased. From the proposed control approach achieves better control results than the conventional PI controller [15].

Singaravelan.A. and Kowsalya M. (2013) presented the demonstrated dynamic model of an islanded microgrid which was formulated in a reference frame instantaneously synchronized to the collector bus voltage. And shows that the real power balance between the converter and the load. The developed model shows the regulating of voltage and frequency by dq-frame [16].

Mousa Marzband, Andreas Sumper, and Mircea Chindris (2011) they were used fuzzy logic control to controlling of frequency for an isolated network with a High Penetration, no-storage wind-diesel (HPNSWD) system, that

demonstrated a small-scale wind turbine generator in a standalone distribution network can be maintained at a certain level without violation in the output power balance and voltage profile of the network. And compared the effectiveness of fuzzy logic with the PID controller [17].

Parikhan Muhsin Ali, Asso Raouf Majeed, and Hermann R. Fehrenbach (2012) they studied a proposed to providing power energy for several villages, therefore, make up to the analysis of the wind and solar of data from 17 meteorological stations during different years from 2001-2010. According to this data were designed a hybrid system for these villages. And were calculated energy consumption for them by a list of information applied by using MATLAB neural network toolbox [18].

Rashid Al Badwawi, Mohammad Abusara, and Tapas Mallick (2015) provided a review of challenges and opportunities combination the two resource, and try to solve the varied effect of the solar and the wind from nature resources and made more reliable and economical system. This clearly has a high influence on the stand-alone generation in power systems. The mixture of renewable energy generation with the diesel generator and battery storage as a backup systems is growing a cost-effective solution for the stand-alone mode. The strategies of energy management should warrant to the system for high efficiency and reliability with minimum cost, by grouping the wind-battery-diesel as a hybrid system to meet peak times of load. [19].

M.Sivaram Krishnan, M.Siva RamKumar, and M.Sownthara (2014) were proposed to study of a strategy of frequency control in the standalone system based on coordination control of fuel cells and ultra-capacitor bank in an islanding mode of hybrid renewable energy power generation system was achieved. The suggested system includes the renewable energy power generation subsystems as the photovoltaic and the wind turbine generator, with fuel cell system and the ultra-capacitor as energy storage system. By using real data from the weather, the performance of the system has been verified under different condition. Simulation results proved the validity of proposed studied hybrid power generation system feeding isolated loads in power frequency balance condition [20].

Abd El-Shafy A. Nafeh (2009) was proposed an operational control technique, based on using the fuzzy logic controller (FLC), is developed and applied to a proposed Photovoltaic-Diesel-Battery (PV) hybrid system.

The proposed scheme is modeled and simulated using MATLAB-SIMULINK and FUZZY toolbox. The FLC is designed, to work simultaneously with the commonly used ON-OFF controller, for optimizing the operation of the PVDB system under different insulations. Where, the proposed system becomes able to reliably satisfy the system's load and, also, to optimize the battery and diesel operation at all working conditions. The results indicated the high capability of the FLC in controlling the system [21].

Jitendra Kasera, Ankit Chaplot, and Jai Kumar Maherchandani (2012) they were modeled a hybrid system that consisted on PV-Wind model, and connected to the mian grid system to conversion energy, also simulate in MATLAB software [22].

M.V. Santhi Lakshmi, Dr. Ch. Sai babu, and GRKD Satya Prasad (2012) they were shows used Homer software get results from hybrid islanded mode micro-grid renewable system, and benefit of long term programmatic planning for off-grid power system [23].

Ming Ding, Bo Wang, and Zhong Chen. (2012) They were presented and studied using of battery storage system with a super capacitor for storage energy to achieve using of different storage to solve the power deviation in the system and renewable energy sources by smoothing of control system response. The complementary system takes fully improved battery operating performance and increase its lifetime as it works under more stable [24].

Zhongqiu Wang, Fengying Li, Gang Liu, and Hao Yue. (2011) they were shows that the operation of renewable sources like solar or wind system when connected with a micro-gird power system it was unstable power sources need to an equipment or technique to made it stable that there were tested several way to improve this case. They were designed the control system by PSCAD/EMTDC simulation software platform. And, they could reduce the power fluctuations from PV system, used the battery with a supercapacitor as an energy storage system to solve this case, and balanced the power for the load as the multi-type composite energy storage device [25].

Arulampalam A., Mithulananthan N., Bansal R.C., and Saha T.K. (2010) they had proposed a hybrid Micro-Grid system which it was consist of PV-Wind-Diesel systems. Regulated DC side voltage and controlled drop voltage with using MPPT technique to control PV system inverter. Also designed a governor and AVR control for a diesel generator. The performance of the proposed system was studied as a standalone system with seasonal nature of wind and PV power plants. The conclusion the smooth operation of Micro-Grid [26].

Juan P. Torreglosa, Pablo García, Luis M. Fernandez, and Francisco Jurado (2014) they were presented and evaluated an energy dispatching on Model Predictive Control for a stand-alone Micro-Grid hybrid PV-Wind-Hydrogen-Battery power system. However the energy dispatching is responsible for controlling the operation of battery and hydrogen system when generated the renewable energy sources the maximum available power [27].

Sanjukta Patel (2014) he studied two of the methods that used for finding Maximum power point, which are disturbance and checking way and incremental conductance, which is used MATLAB/Simulink for his simulation. For achieve maximum efficiency from power generation in photovoltaic system chased perturbation and observation as an efficient control technique. And shows the dynamic behavior and control performance of the hybrid Wind turbine and Photovoltaic system, by hold constant DC voltage [28].

Garcia-Hernandez R., and Garduno-Ramirez R. (2011) presented the model synchronous generator that used as a wind generator with its complete control system, they have investigated the suggested model with its controller system which used as more established system [29].

Eltamaly A. M. (2007) he was shows the simulation and analysis of 15kw wind turbine which it was rotate a permanent magnet synchronous generator, investigated to increasing efficiency and reducing the cost, and run the turbine at maximum performance with constant voltage by controlling modulation index of PWM and boost converter in DC side [30].

2.3 Place Of Work In The Literature

This work presents a method which can be used to control of voltage and frequency by coordinating theory Id and Iq axis to enhance the stability of stand-alone hybrid micro-grid power systems using an intelligent controller technique, as a Proportional - Integral and Fuzzy logic control, to control each of the voltage and frequency from the fluctuations, which as occur with varying loads and weather.

CHAPTER 3

MODELING AND INTELLIGENT CONTRO OF STANDALONE HYBRID PV-WIND-DIESEL SYSTEM

3.1 Introduction

Modeling is getting information about how something will behave without actually testing it in real life. The photovoltaic solar system, and wind turbine generator are the renewable sources that are dependent in the natural the weather otherwise the diesel generator depend on the weather of prime mover, and the battery energy storage system depend on state of charge. Then these different systems can be modeled separately after than connecting to each other to produce a hybrid system.

It is not easy to design this system and apply some cases on it in actual operation testing, therefore, must be used modeling in a simulation environment by a software computing program, that are explained and design these systems with illustrated each of them from this chapter.

3.1.1 Modeling Of Photovoltaic Panels

The direct current electricity can be generate in photovoltaic system when is exposed to sunlight without environmental impact. The solar cell is the basic building block of Photovoltaic arrays. For inducing electrical energy from sun lighting energy, the PV system depends on semiconductor PN junction.

Photovoltaic solar cell characteristic depends on the sunlight (temperature and radiation), also its output voltages [28]. Figure 3.1 illustrate the similar circuit of a solar photovoltaic system array.

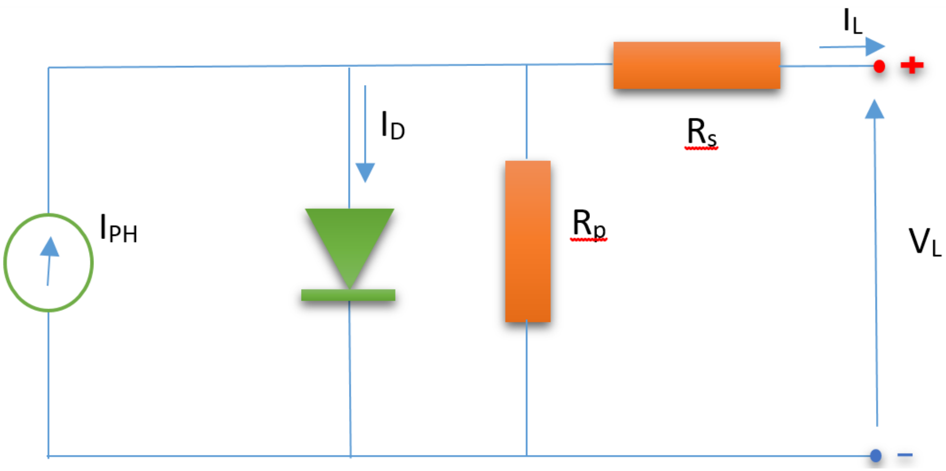


Figure 3.1 Equivalent Electrical Circuit of PV Array [28]

When the load current is zero, the open circuit voltage (Voc) of the cell is obtained [28].

$$V_{OC} = V + IR_{sh} \tag{1.1}$$

Normally, a photocurrent expressed as a diode with two resistors which are connected in parallel and serial with it.

The leakage current represents by a parallel resistor, otherwise, the internal resistance to current flow represents by series resistor, and then totally represented as a circuit of a general photovoltaic model.

The current-voltage characteristic equation of a solar cell is given in equation (1.2) [28].

$$I_{PV} = I_{PH} - I_S \times [\ell^{\frac{(q(VPV+IPV)RS))}{K \times TC \times A}} - 1] - \frac{(V_{PV} + I_{PV})R_S}{R_P} \tag{1.2}$$

Basically, the effect of temperature and solar irradiation on the photocurrent of cells, which is defined in equation (1.3) [28].

$$I_{PH} = \frac{[I_{SC} + K_1(T_C - T_{ref})]\lambda}{1000} \tag{1.3}$$

The cell temperature due to varying of the saturation current that is expressed in equation (1.4) [28].

$$I_S = I_{rs} \times \left(\frac{T_C}{T_{ref}}\right)^3 \ell^{\left[\frac{\left(\frac{1}{T_{ref}} - \frac{1}{T_C}\right)}{K \times A}\right]} \tag{1.4}$$

The relationship of the parallel resistance (Rp) to the shunt leakage current to the ground is reversely.

Normally, the PV array efficiency is insensitive to variation in Rp and the shunt leakage resistance can be assumed to approach infinity without leakage current to ground.

Alternatively, significantly effect of the PV cell output power by a small variation in series resistance Rs.

Equation (1.2) can be modified to be [28].

$$I_{PV} = I_{PH} - I_S \times [\ell^{\frac{(q(V_{PV} + I_{PV})R_S))}{K \times T_C \times A}} - 1] \tag{1.5}$$

In an ideal PV cell, the series loss and leakage to ground are neglected.

Then, Rs=0 and Rp = ∞ [28].

So, the equation (1.5) can be written in another form as: [28]

$$I_{PV} = I_{PH} - I_S \times [\ell^{(\frac{q \times V_{VP}}{K \times T_C \times A})} - 1] \tag{1.6}$$

To generate a voltage and current can be connecting the array cells as a parallel and series circuits and can be represented Np parallel modules as: [28]

$$I_{PV} = N_P \times I_{PH} - N_P \times I_S \times [\ell^{(\frac{q \times VVP}{K \times TC \times A})} - 1] \tag{1.7}$$

The efficiency is insensitive when the parallel resistance is varied in photovoltaic cell system but is sensitive with changing series resistance.

The model can described mathematical by considering parallel and series resistance.

The equation (1.7) can be simplified as: [28]

$$I_{PV} = N_P \times I_{PH} - N_P \times I_S \times [\ell^{(\frac{q(\frac{V_{PV}}{N_S} + \frac{I_{PV}}{N_P} \times R_S)}{K \times T_C \times A})} - 1] \tag{1.8}$$

$$I_{PV} = N_P \times I_{PH} - N_P \times I_S \times [\ell^{(\frac{q \times V_{VP}}{N_S \times K \times T_C \times A})} - 1] \tag{1.9}$$

The two most important parameters open (Voc) and short (Isc) circuits which are use describe the cell electrical performance. Normally Iph >> Is, so the ground leakage and small diode currents are neglected under zero-terminal voltage, the short circuit current is nearly equal to the photocurrent [28].

Then,

$$I_{PH} = I_{SC} \tag{1.10}$$

By considering the output current to zero, the open circuit voltage parameter is obtained. So, the reverse saturation current can be achieved, by ignoring the shunt leakage current and given open circuit voltage at reference temperature, as: [28]

$$I_{rs} = \frac{I_{sc}}{[\ell^{(\frac{q \times V_{oc}}{N_S \times K \times T_C \times A})} - 1]} \tag{1.11}$$

Additionally, the maximum power can be stated as: [28]

$$P_{MAX} = V_{MAX} \times I_{MAX} = V_{oc} \times I_{sc} \tag{1.12}$$

3.1.1.1 Maximum Power Point Tracking

The variation of irradiation and temperature due to the varying of the maximum power point in a solar panel, so it needs to a technic as a booster DC to DC converter used with PV array solar system to adjusting the duty cycle of it. Can obtain the peak power from the solar panel by using the (MPPT) algorithms. Many methods of the logarithm are available to find MPPT, Perturbation Observation Method was used in this PV system model that used in this study. It is easy to use and simple in operation and required less hardware as compared to other [29].

By maximum power point tracker factions can produce maximum power on the PV cell as its capability.

This technic is a fully electronic system, which is not mechanical tracking system to move cells with sun light direction.

So, the modules able to give maximum power available from its position with sun irradiance

The MPPT cannot deliver the output voltage perfectly, because of the outputs of PV system are dependent on the irradiation, temperature, and the load characteristic.

For this reason MPPT is necessary to be realizing in the PV system to maximize the PV array output voltage.

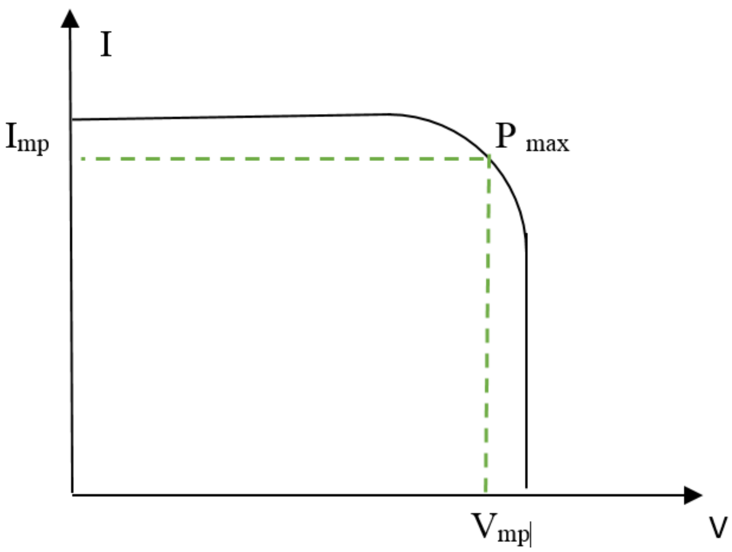


Figure 3.2 maximum power point characteristic [29]

In the power versus voltage in the PV module curve there exists a single maximum of power, then there exists a peak power according to a particular voltage and current.

Because of low efficiency of PV cells, it is desirable to operate the module at the MPP, so can be delivered the maximum power point to the load under varying irradiation and temperature.

By ability to maximize power can improve the use of the solar PV system to transfer the power to the loads.

Can be make a varying of the load impedance, by changing the duty cycle, to match at the point of the peak power with the source so as to transfer the maximum power. [29]

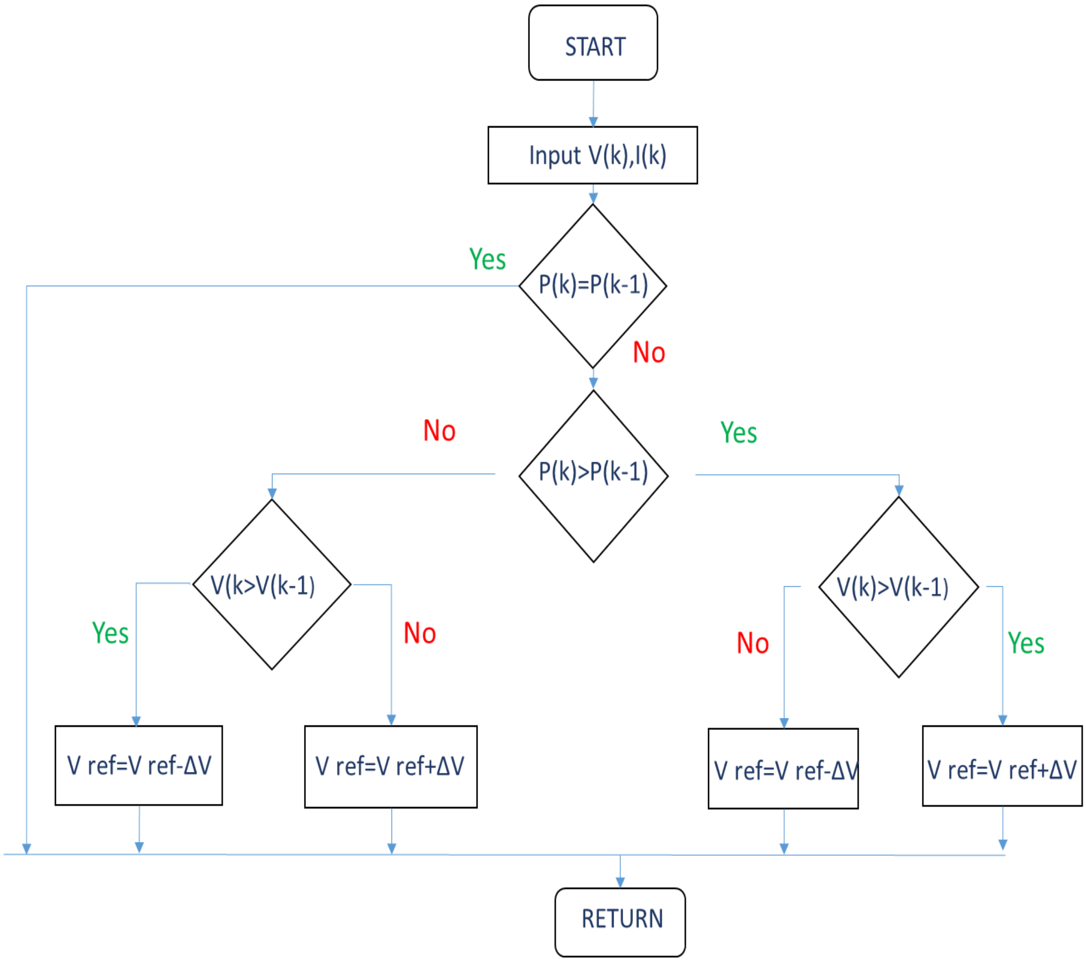


Figure 3.3 Flow Chart of MPPT by (Perturbation Observation) Algorithms [29]

3.1.2 Modeling Of Wind Turbine Generators

The wind generator set consists of a synchronous generator, wind turbine, rectifier, and inverter to get an ac supply. Basically the wind turbine sends the wind's kinetic energy in the rotor which is mechanically coupled to generators.

A complex mathematical modelling of wind energy conversion system includes, wind turbine dynamics and generator modelling.

The power contained in the wind is given by the kinetic energy of the flowing air mass per unit time. The equation for the power contained in the wind can then by written as : [29]

$$Pair = \frac{1}{2}(airmassperunittime) \times (V_\infty)^2 \quad (1.13)$$

Then

$$= \frac{1}{2}(\rho A V_\infty) \times (V_\infty)^2 = \frac{1}{2} \times \rho \times A \times V_\infty{}^3 \quad (1.14)$$

Although equation (1.14) describes the availability of power in the wind power transferred to the wind turbine rotor is reduced by the power coefficient Cp [29].

$$C_P = \frac{P_{windturbine}}{P_{air}} \quad (1.15)$$

A maximum value of Cp is defined by the Betz limit , which states that a turbine can never extract more than(59.3 %) of the power from an air stream.In reality, the wind turbine rotors have maximum Cp values in the range 25-45 % [29] .

$$P_{windturbine} = C_p \times P_{air} \quad (1.16)$$

It is also conventional to define a tip speed ratio (λ) as : [29]

$$\lambda = \frac{\omega \times R_b}{V_\infty} \quad (1.17)$$

The mechanical power and torque production from wind turbine is given: [29]

$$P_m = \frac{1}{2} \times C_p \times \rho \times \pi \times R_b{}^2 \times V_\infty{}^3 \quad (1.18)$$

$$T_m = \frac{1}{2} \times C_T \times \rho \times \pi \times R_b{}^3 \times V_\infty{}^2 \quad (1.19)$$

Where wind speed changes , the angular velocity of the shaft, ωm should be adjusted to achieve the best value of C_p .

This means that ωm and the wind speed must somehow be combined into a single variable so that the curve showing the relation between C_p and ωm can be drawn . Experiments show that this single variable is the ratio of the turbine tip speed $R\omega m$ to the wind speed V_∞ [29].

3.1.3 Modeling of Diesel Generators

To attenuate shortfalls in energy production during periods of poor sunshine, and poor wind speeds a backup diesel generator is used for increased system availability and minimum storage requirements. The choice of diesel generator depends on type and nature of the load.

The regulating of speed and voltage is the two main components, which was a proper operation of a diesel generator set. To precisely maintain the imposed the two main parameters (voltage and frequency) in electrical power should improvement of performances of that components.

Designing of a speed regulator to keep engine speed by changing the quantity of fuel consumed by the diesel generator, to stable frequency of voltage at the generator terminals. It is mean the frequency is proportional to the generator speed. The frequency is constant by a short response time from the speed regulator, at a variation of the loads.

In the other hands, the voltage regulator designed to control the excitation current, to a limiting of voltage amplitude at the generator terminals, due to load variations.

3.1.4 Modeling Of Battery Energy Storage Systems

Because of the battery output voltage depends on current and state of charge, which is a non-linear function of the current and time, is represented as a non-linear voltage source that changes with the amplitude of the current and the actual charge of the battery. Then the output of voltage is zero when a flow of current is zero. The controller consists a d-q frame based current controller. In island mode, that regulates the active and reactive power injected into the micro-grid system and outputs the d-and q-axis current commands, Id _ref. and Iq _ref. In upper system controller regulates the frequency and voltage of the micro-grid.

3.1.5 Pulse Width Modulation

The first proposed of the PWM scheme in 1964, which the modulation index (m_a) defined as a ratio of the switching frequency to the reference signal frequency f_1. And the frequency modulation ratio m_f is defined as the ratio of switching frequency of the PWM inverter to the fundamental frequency [29].

$$m_a = \frac{V_{control}}{V_{tri}}$$

$$= \frac{V_{PLL}}{V_d} \tag{1.18}$$

$$m_f = \frac{f_s}{f_1} \tag{1.19}$$

By minimizing the distortion factor of output voltage the PWM inverter to be better, therefore, when the ma is greater than one the distortion is more in the linear region. For better result on the control and to reduce harmonic in the output, the modulation index ma does not exceed one [29].

3.2 Design the Proposed Models by MATLAB Simulink

Integration of renewable energy generation with battery storage and diesel generator backup systems is becoming a cost-effective solution for resolving less usable renewable energy during the year. However, if storage runs out, there is no way of importing energy. Therefore, a combination of PV and wind energy sources with the battery energy storage system (BESS) is a suitable alternative supporting energy source for this type of generation systems, where are fed the several of three phase resistive with inductive (RL) circuits which represents as a variable loads by opening and closing of the circuit breakers, thus it due to fluctuations in power energy. And distributed generators can help of these fluctuations in power supply since generation units will be close to the loads. However, introducing diesel generators will require an upgradation in the existing protection schemes, but it is not enough to the regulation of power because of the renewable sources depend on the weather [30].So the hybrid system needs to a controller to make a balance at each of any fluctuations that caused by each of the loads varying and the weather to keep of power quality by regulating of voltage and frequency.

In this model, we have benefited by the charge and discharge of batteries, can be controlling both of active and reactive power for solve this problem. After designing a simulation of the hybrid power system by using sim power system toolbox and Fuzzy logic Toolbox in MATLAB/Simulink software, which was obtained the results of simulation as shown in Fig.3.11. The performance of the proposed system which contains solar PV/wind turbine/diesel generator/battery was then tested under different operating conditions, as illustrated in characteristics of each of the solar panels and the wind turbine as shown in Fig.3.5 (a), (b) and Fig.3.8, respectively. The results were gained completely where the proposed system run at [0 to 6] second that is the simulation time.

3.2.1 PV System Model

Photovoltaic is a combination of more than one solar panel array of several solar cells, connected in series and parallel with large voltage and current output of one solar cell, which it can be simplified to a diode in parallel with a current source. The current generation is directly proportional to the sun radiation falling on the cell [35], as shown in Figure 3.4.

Description: From Figure 3.4, the 100KW of photovoltaic solar panel system array connected with the Micro-grid hybrid power system to feeding the loads demand with other sources in the same net.

This system is consist of:

1-The PV array, which depends on 66 panels that are connected to gather in parallel to generate DC voltage in 5 string that connected in series to supply power, which used sun power 305 WHT model type (305*66*5= 100650 watt per hour) approximately it is equal to 100kwh. 2- Boost converter average model, which is used to regulate DC output voltage from the PV array by MPPT controller, this converter it is necessary to connect with any solar system energy conversion because of the non-arrangement of sunlight used to vary of induced voltage during days.

3- Voltage source converter (VSC) average model, is one of the important converters that is used in this system to convert DC voltage to AC voltage.

Which is depends on modulation index as a trigger signal to make on or off of six internal switch like as IGBT, which is implemented in 3 bridge arms two level.

4- VSC controller, it is used to control of the VSC by trigger its gate, and regulate the DC voltage according to AC side. For more detail see Appendix-A

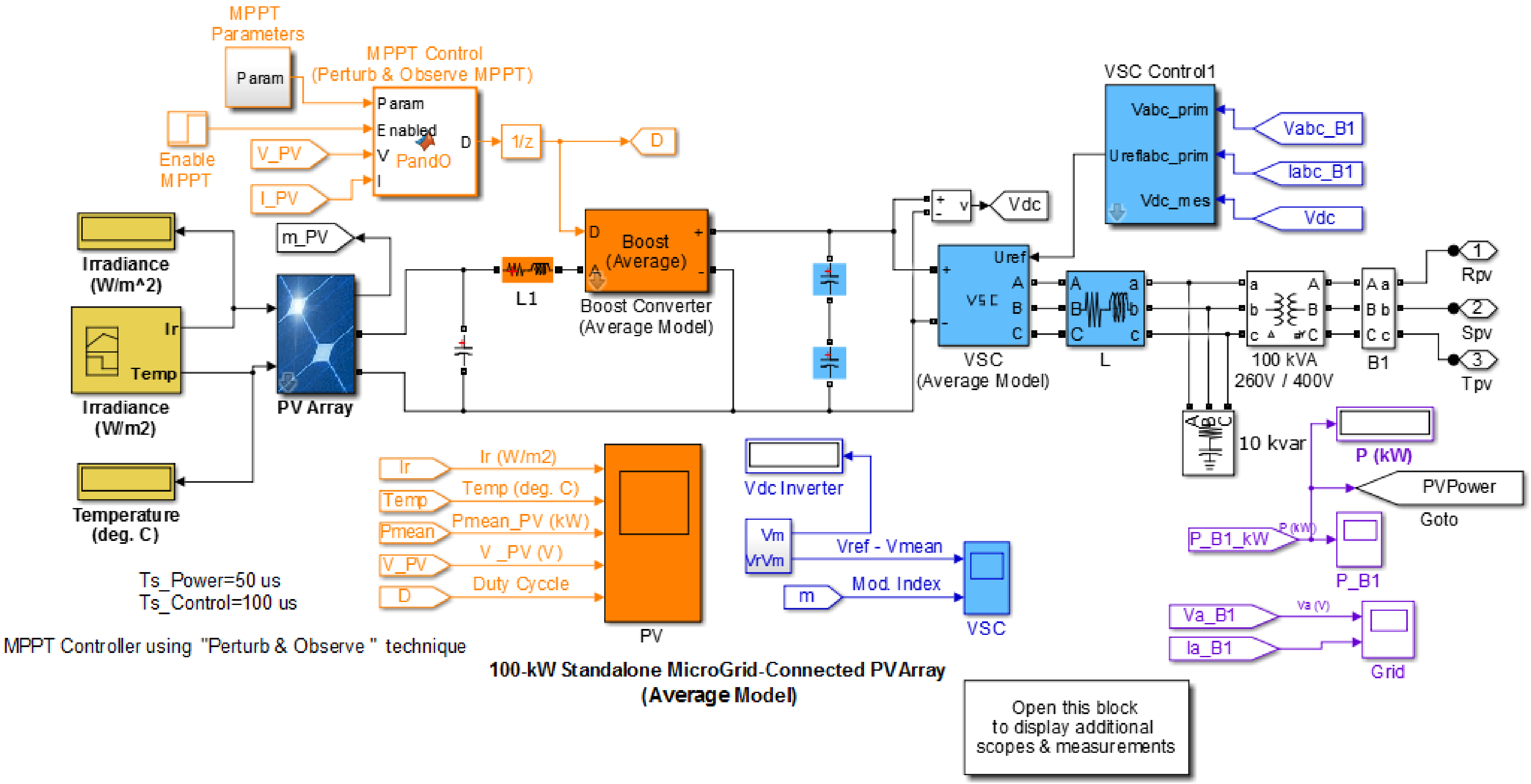


Figure 3.4 Photovoltaic System Model [31]

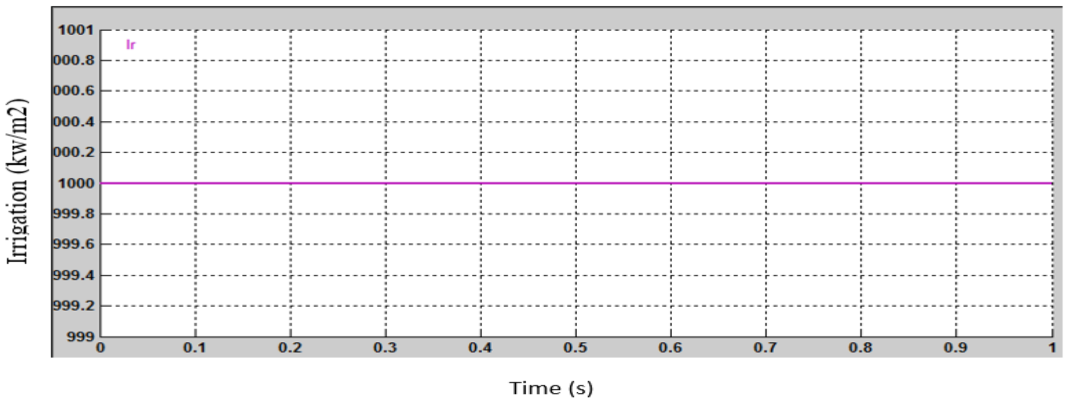


Figure 3.5 Profile of Irrigation (kw/m2) at Temperature (0C^o) in the PV Panel System [31]

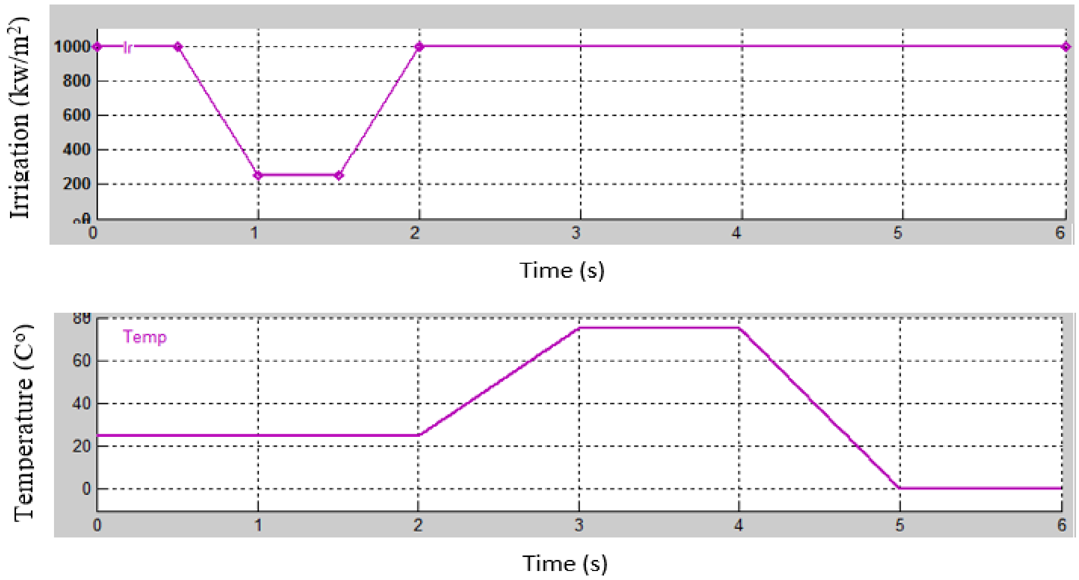


Figure 3.6 Profile of Irrigation (kw/m2), and Temperature (C^o) in the PV Panel System [31]

3.2.2 Wind Turbine System Model

Wind turbine generator is the other renewable source used widely in the places that have the wind at all reason, which is flexible to capture kinetic wind energy and convert to mechanical energy into electrical energy in a variables wind speeds as illustrated in Fig.3., for this reason, it be used Synchronous Generator [32] as shown in Fig.2, and for more detail see appendix-B.

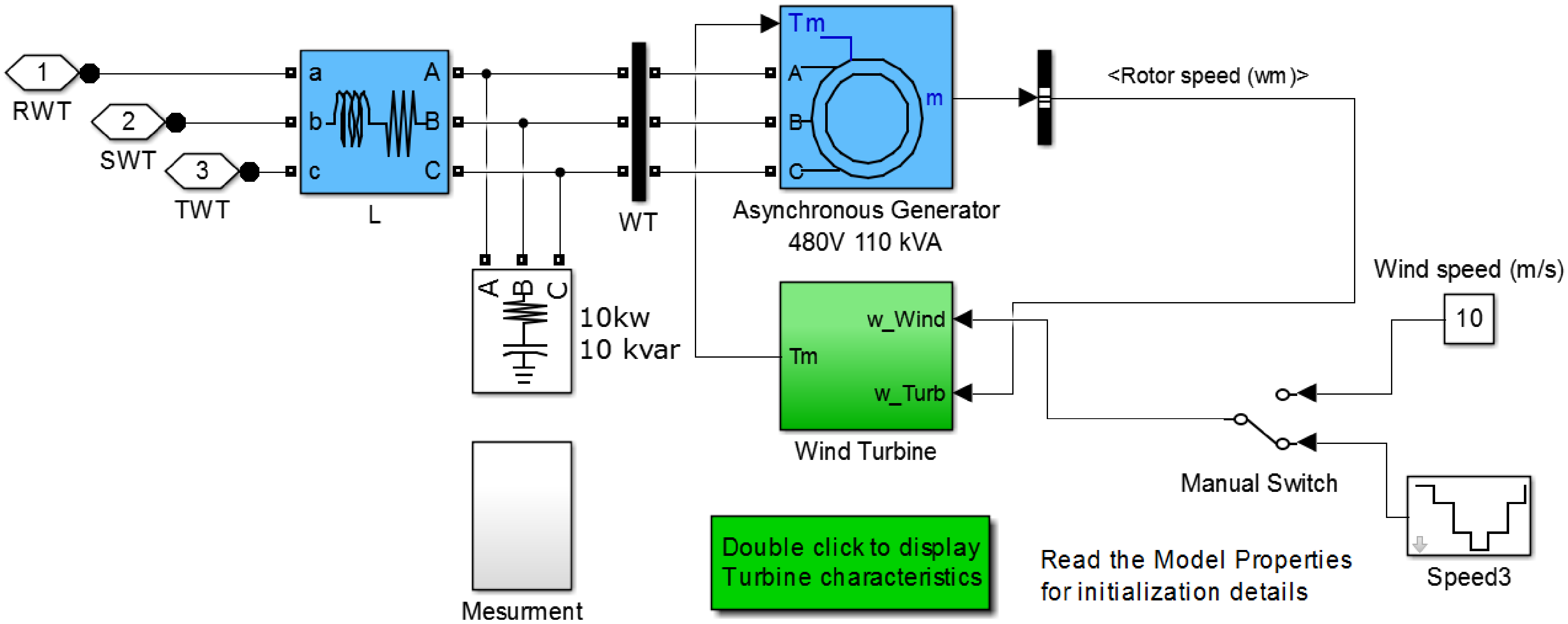


Figure 3.7 Wind Turbine Synchronous Generator System Model [31]

Description: For Figure 3.7, the model of wind generator is depend on the two main blocks which are the wind turbine and synchronous generator.

The wind turbine acts as a converting power energy form wind to dynamic mechanical rotating power by blades to capture maximum power energy from the wind in the ionospheric layer surrounding to the earth.

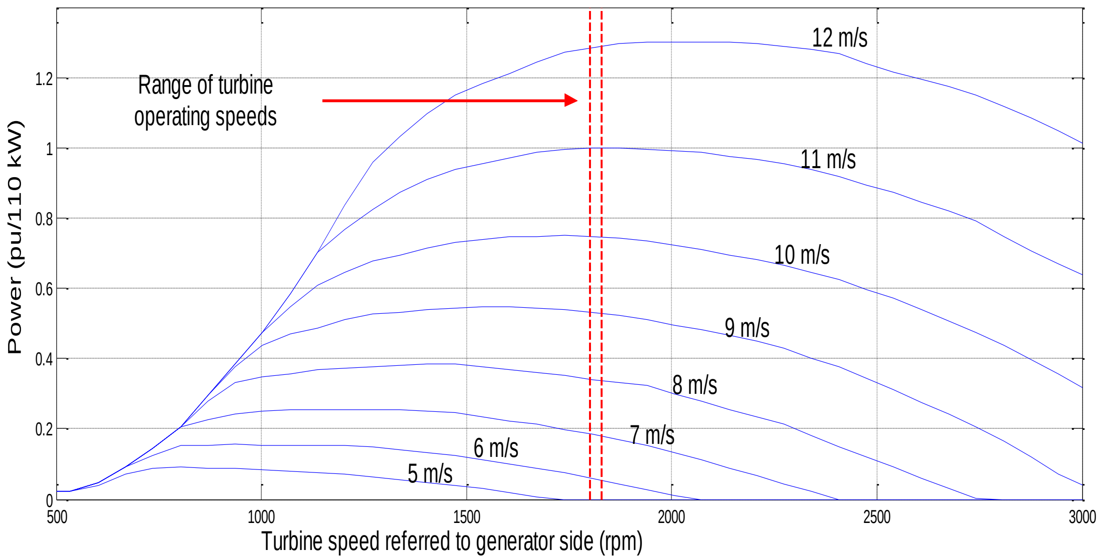


Figure 3.8 Characteristic of Wind Turbine Power with Respect to the Wind Speed [31]

3.2.3 Diesel Generator System Model

Diesel generator is the set of an electric generator with a diesel engine to generate electrical power by controlling the field current of the excite in the electric generator and speed governor in diesel engine can be regulation voltage and frequency of the generator [32], respectively as shown in Fig.6.

Description: From figure 3.9, the diesel generator that illustrated 250KVA synchronous generator connected with diesel engine fuel system to generate electricity for micro grid system.

The generator controlled by two signals close loop feedback system, which are:

1- Exciter system, which is able to control excitation current, thus for regulating terminal voltage in generator.

2- Speed governor system, which is able to control speed of engine by controlling the fuel system, thus for governor the speed in the generator and then to controlling the frequency.

The output of Exciter connected with the rectifier to invert the AC to DC, because of the rotor part of the generator is the need to DC current to induce magnetic flux. And for more detail see appendix-C.

3.2.4 Battery System Model

A 50 kWh Lithium-ion battery is simulated with an inverter VSC to convert battery DC voltage to AC system voltages, and vice versa. To a supporting system especially in the abnormal situations, by injection and absorbing each of the active and reactive power to the system respectively. Fig.7 illustrate a model of battery. Clearly, the BESS should play an important role in maintaining the voltage and frequency of the micro-grid during standalone operation.

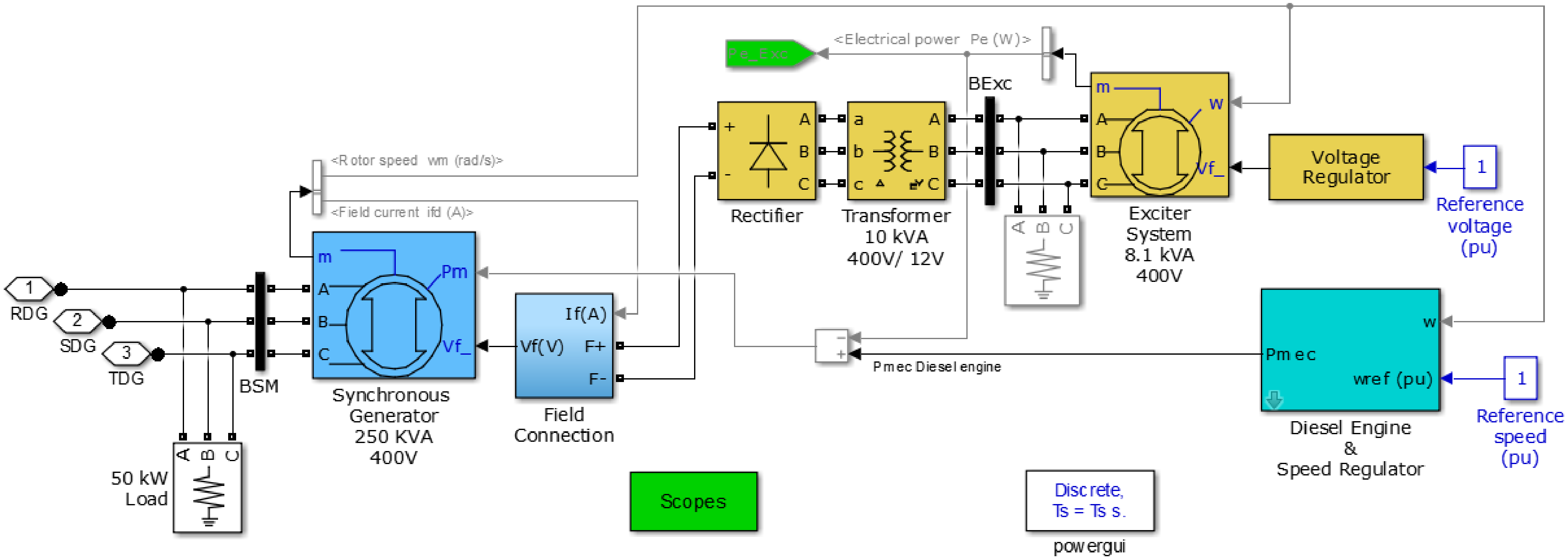


Figure 3.9 Diesel Generator System Model [31]

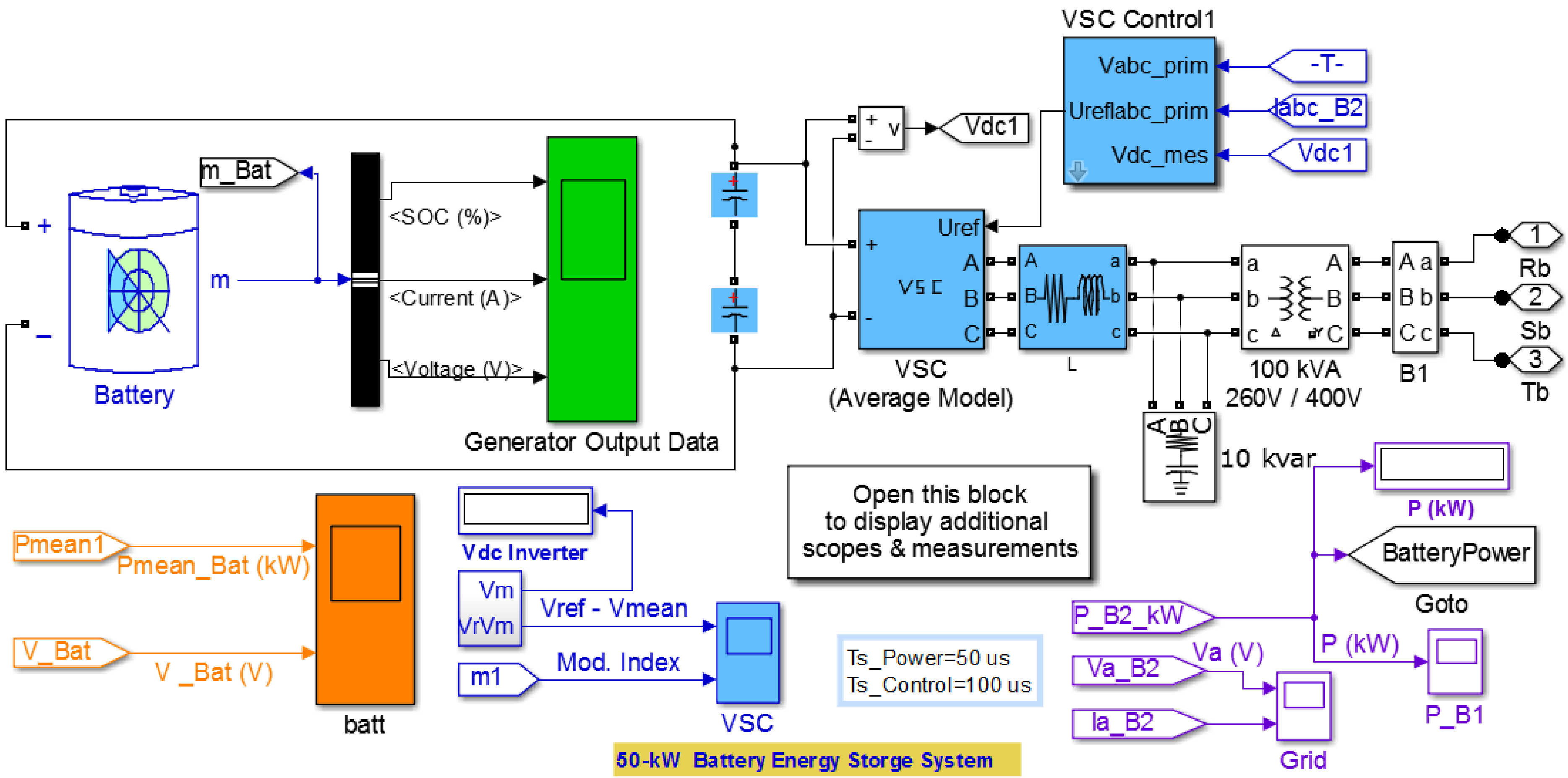


Figure 3.10 Battery Energy Storage System Model

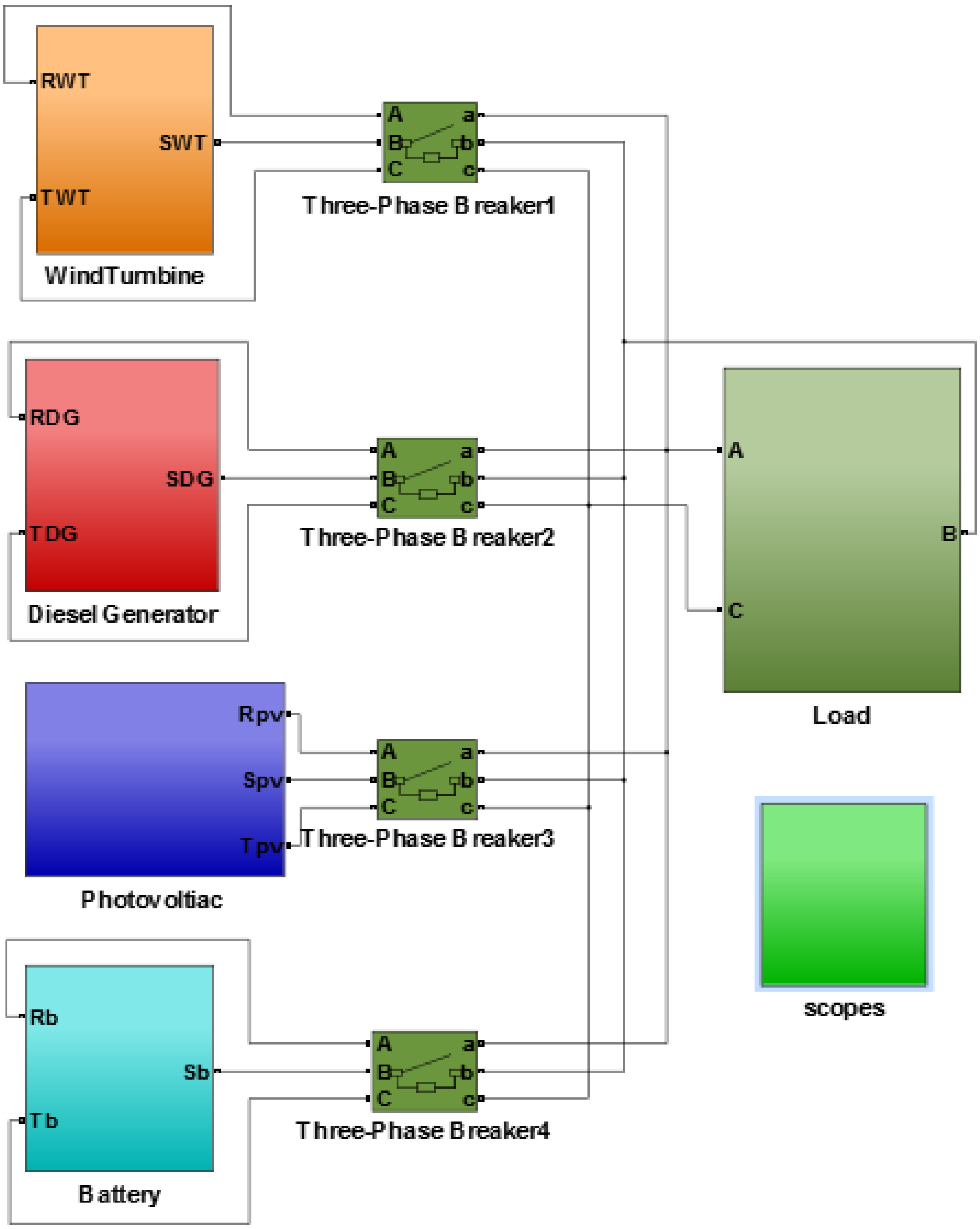


Figure 3.11 Standalone Micro Grid Hybrid System Modeled

CHAPTER 4

INTELLIGENT CONTROL

4.1 Introduction

In this chapter, an intelligent control is given for the simulation model of the control system to controlling a standalone hybrid power system. Fortunately, the robustness and the minimum overshoot of responses generally are the most important factors, which determine a specific design. The complete designed and implementation model of the intelligent control system is presented with a block diagrams and details are presented in this chapter.

4.2 Control System

In this study, the battery system used as a voltage and frequency regulator that is due to active and reactive power load compensated according to a variation of the load demand and fluctuations from the nature weather. By using two loop control systems, and modulation index the control of the terminal voltage and control of systems frequency was investigated. In the existing work, a trail has been made to control the terminal voltage and frequency (VF) of a standalone hybrid system that is driven by several renewable and nonrenewable energy sources by using the (BESS) with (VSC) is working for the autonomous system. Average-model based (VSC) worked as a voltage and frequency controller is injected and absorbed both active and reactive powers, because of proportionality between power with frequency and reactive power with the voltage. The hypothesis were if any change occurred on active and reactive power will be changed each of voltage and frequency in the system and so controls could be investigated on system's frequency and terminal voltage [33].

This project deals with the application of a bi-directional power electronic device with a small stand-alone hybrid micro-grid system, which was used a coordinate system for control of the systems stability.

Power managing method is proposed to conversion system which has its capability to support the load demand and remained the voltage and frequency near to steady state. (VSC) is used to lead active and reactive power flow between (BESS) with the capacitor that connected in parallel with a battery in DC side, and loads by the current regulator, as shown in Figure 3.10 In another hand by each of the Id and Iq frames, as shown in Figure 4.1.

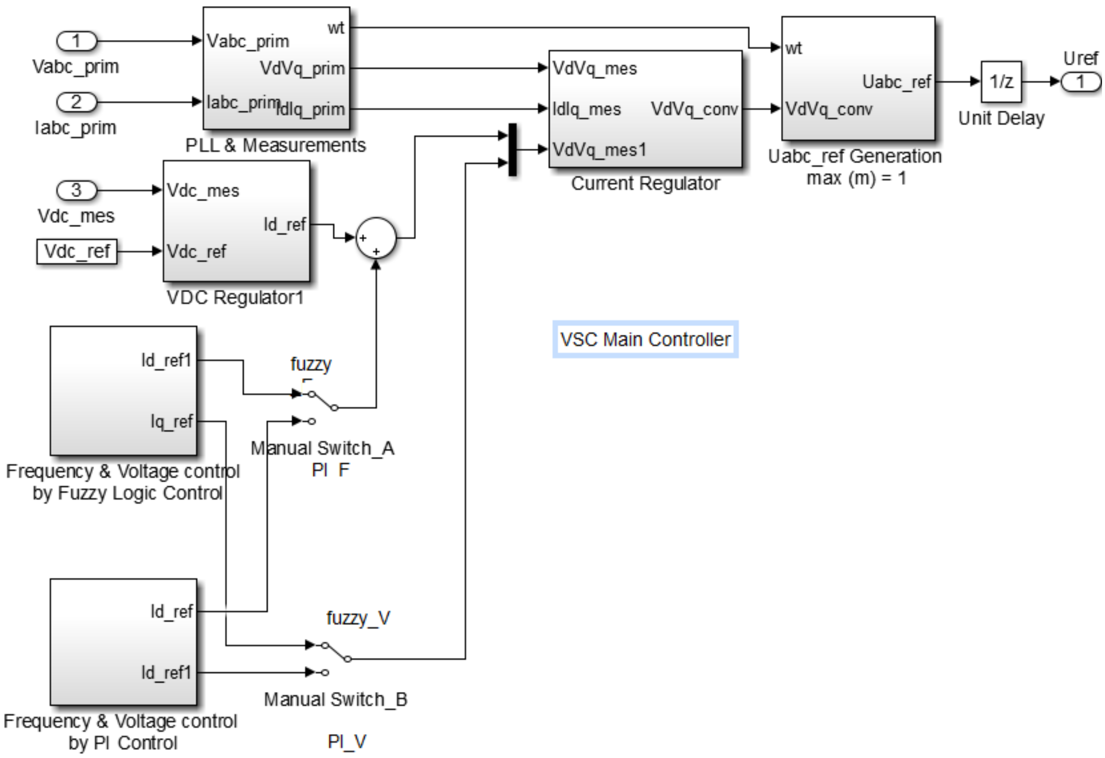


Figure 4.1 VSC (PI and Fuzzy Logic) Controller of BESS System Model

Sudden changes in active power drawn by a load could cause system frequency fluctuation in AC grids. These changes represent unbalanced situations between load and generation. In view of the above, it is important to design control loops for power and frequency control to mitigate quality issues, in this project, a new modified id and iq frame as a control signal, which are proposed for effective control and system stabilization, thus a pulse width modulation (PWM) which is fed a VSC, which is working as adjusting voltage and frequency in three-phase local load bus system.

Harmonics are normally caused by power electronics devices and non-linear appliances. Appropriate filters and PWM switching converter can be used to mitigate harmonics distortion [33].

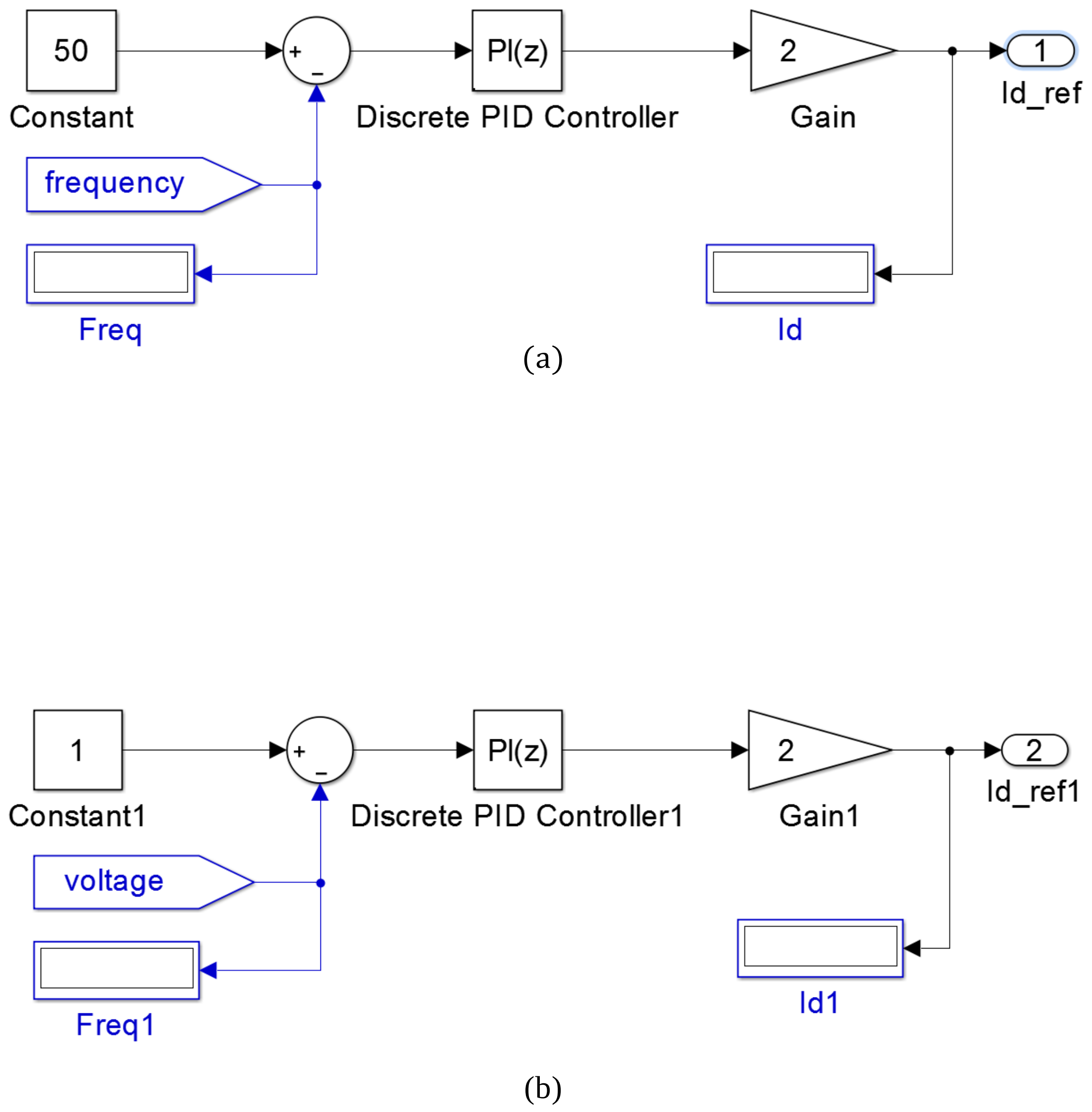
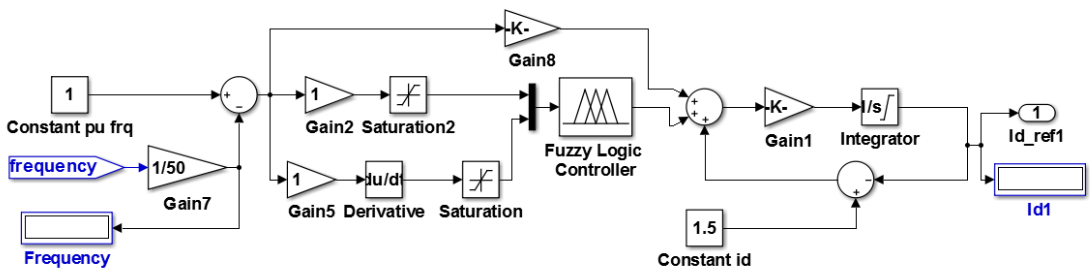
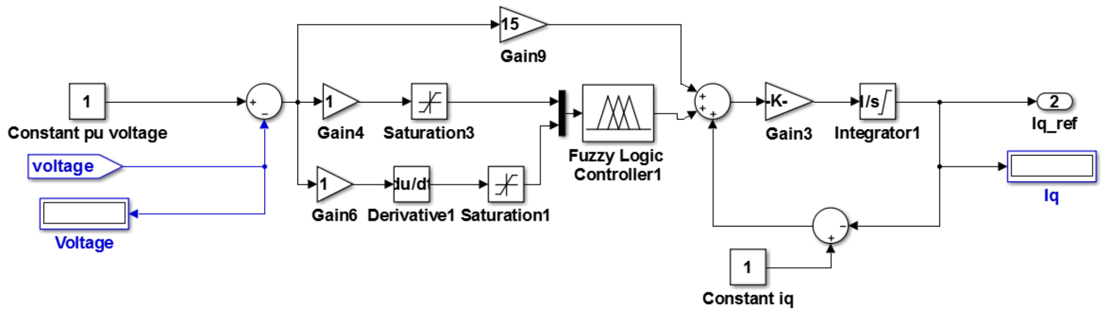


Figure 4.2 PI Controller of VSC in Battery System Model (a) Id-Frame and (b) Iq-Frame.



(a)



(b)

Figure.4.3 Fuzzy Logic Controller of VSC in Battery System Model

(a) Id-Frame (b) IQ-Frame

4.2.1. Intelligent Control

To regulate a quality of generation of electricity in any power system must control the system output, so that the voltage and frequency is maintained. Consequently, the control system is necessary for power systems, particularly at standalone hybrid system.

The intelligent control is one of the development techniques in recent years, which is useful for controlling and adaptive of the types of equipment of any systems when they need robust control because of sensitive of its work.

The word of "intelligent" used for its robust response with any Vicissitudes or swing on ever parameters from sensor surrounding it's of any control system.

Moreover, they need to take or think for everything that acts on them when implemented its design of intelligent control to do all active processes during its work to regulating and responding of its sensitivity in any environment.

In this study, it was used one of the types of intelligent control to control frequency and voltage of the micro-grid power system. One of the intelligent control method is fuzzy logic control which is used widely as a controller in the recent years. Lately, fuzzy logic is also used in science and manufacturing sectors, one of them is power system control [34].

The fuzzy logic toolbox in MATLAB Simulink software is one of the tool boxes that can be used for implementation of any control system by this software, and it can be designed easily by choosing number of inputs and outputs of your system that you want to control it, secondly choosing number of the Memberships and roles of them. Finally choosing rules to do the relation between them.

4.2.2 Fuzzy Logic Controller

Fuzzy logic set up of rules used in a non-linear systems to provides a basis for a systematic way for the application of suspiciously and unbounded models.

Fuzzy control is based on a logical system called fuzzy logic, and it is extremely closer to human thinking than classical logical systems [38]. In disparity to traditional control techniques, fuzzy logic control (FLC) is best to use in complex ill-defined processes that can be controlled by a skilled human operator without much knowledge of their underlying dynamics.

The basic idea behind FLC is to combine the "expert experience" of a human operator in the design of the controller in controlling a process whose input – output relationship is described by the collection of fuzzy control rules (e.g., IF-THEN rules) involving linguistic variables rather than a complicated dynamic model. The utilization of linguistic variables, fuzzy control rules, and approximate reasoning provides a means to incorporate human expert experience in designing the controller.

Fuzzy control algorithm is used to appreciate the fuzzification and defuzzification operation in MATLAB/Fuzzy toolbox.

The variable and membership functions (MFs) of the fuzzy toolbox is created, Fig. 4.2 show PI controller system and Fig. 4.3 shows fuzzy control system. By implementing this technology can control the two important parameters in this work, which were voltage and frequency, the error from voltage and from frequency is given to the fuzzy controller and the output of fuzzy is given to the controller of the plant. Variables of the fuzzy logic controller includes the input variable error (e), d/dt of error Δe and the output m. (e) is taken as the deviation of reference and signals frequency, and voltage of the load. Δe is taken as the change rate of change of e.

The "m" is taken as change each of id for frequency control and iq for voltage control. The design of fuzzy controller involves formation of Membership function and rule base Input to the fuzzy controller are voltage error and frequency error.

And the output from the fuzzy controller are Id and Iq which are caused by chancing of the real and reactive power respectively, from battery system to micro-grid networks system In MATLAB /Fuzzy Toolbox the controller is simulated which having two inputs [35]. The input and output variable are shown in Fig.4.4. For the each of input variable voltage and frequency which consist of 'error(e)' and 'rate of error change (Δe)' signals and each of output of voltage and frequency 'm' signals, with choosing a suitable range of them.

All membership functions are in 'trimf' types, which each of them created in seven (MFs), namely positive large (+L), positive medium (+M), positive small (+S), negative large (-L), negative medium (-M), negative small (-S), zero (0), as presented in Table 4.1 [36], as illustrated in Fig.4.5, Fig.4.6, and Fig.4.7. These (MFs) are regulated by relationship (If e is ----- Δe is ----- Then m is ----) as a rule by Rule Editor in (FIS Editor) as shown in Fig.4.5, the rule base proposed by "Mamdani" method for the simulation of the Fuzzy controller, as shown in Fig.4.4, whosesoever, Forty-nine fuzzy rules are used, in the fuzzy Logic control. The chosen of this code number is somewhat heuristic. We find that good control performance is done with only a few rules for all [37].

Table 4.1 Fuzzy Rules

e \ Δe	-L	-M	-S	0	+S	+M	+L
-L	+L	+L	+M	+M	+S	+S	0
-M	+L	+M	+M	+M	+S	+S	0
-S	+M	+M	+S	+S	0	-S	-S
0	+M	+S	+S	0	-S	-S	-M
+S	+S	+S	0	-S	-S	-M	-M
+M	+S	0	-S	-S	-M	-M	-L
+L	0	-S	-S	-M	-M	-L	-L

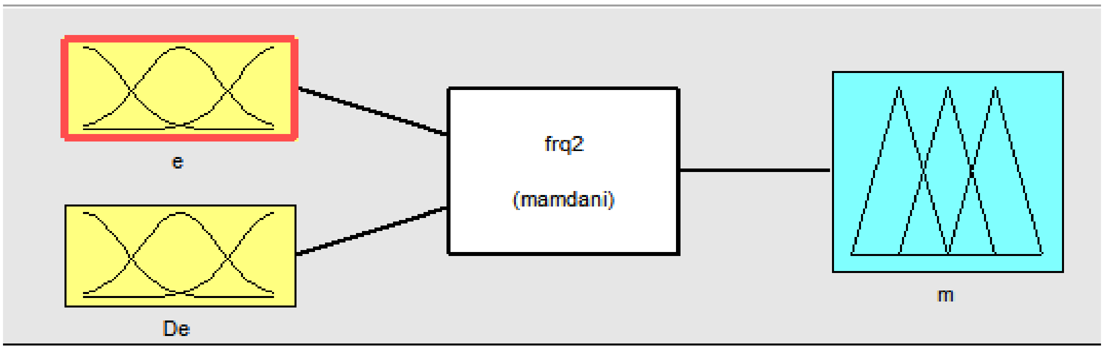
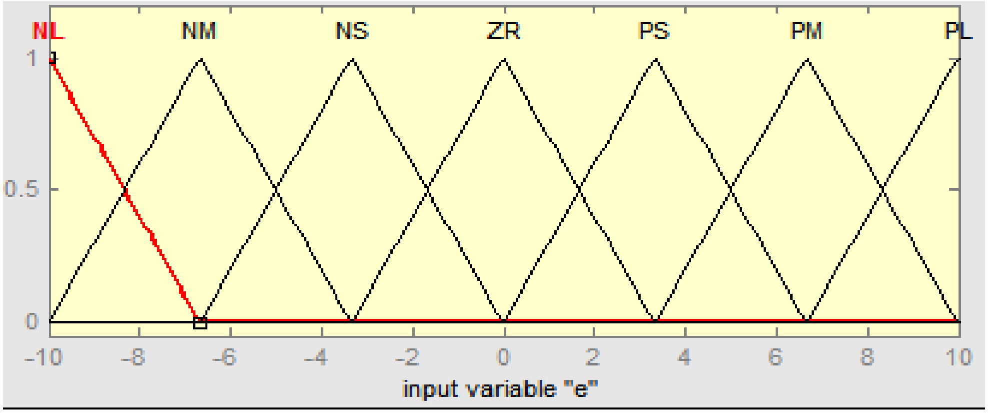
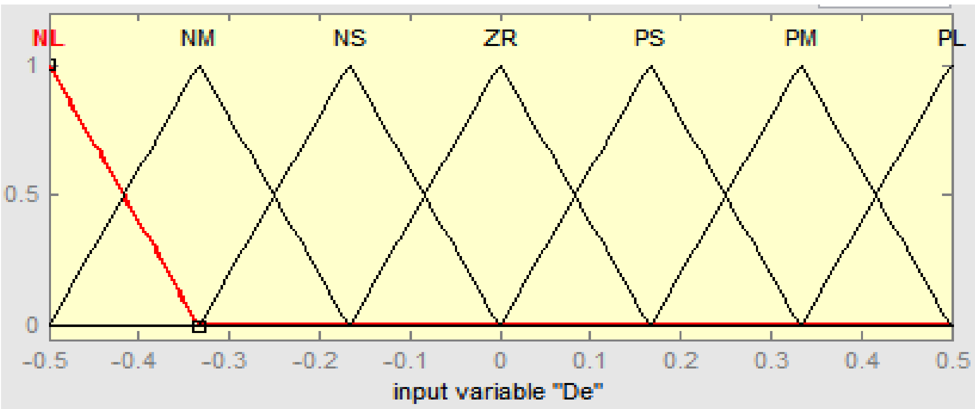


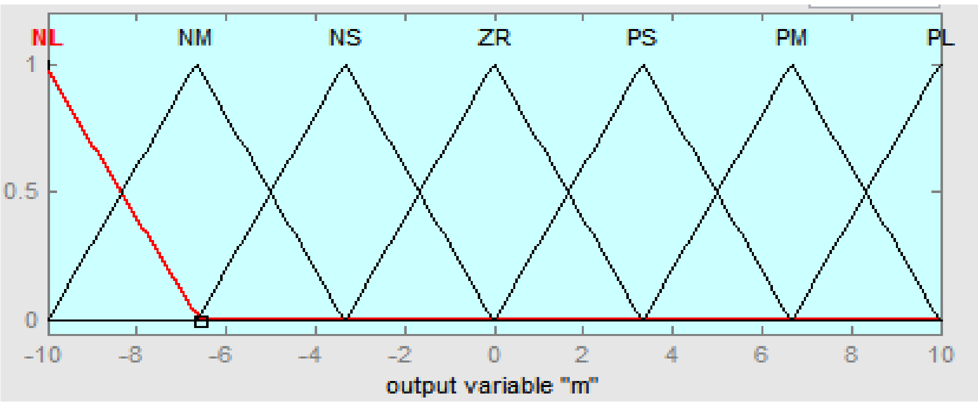
Figure 4.4 Fuzzy Logic Interface (FIS)



(a)



(b)



(c)

Figure 4.5 Membership Function for Input and Output of Fuzzy Logic System

(a) Input Variable “error(e)”, (b) Input Variable “d/dt error(De)”, and (c) Output Variable “output(m)”

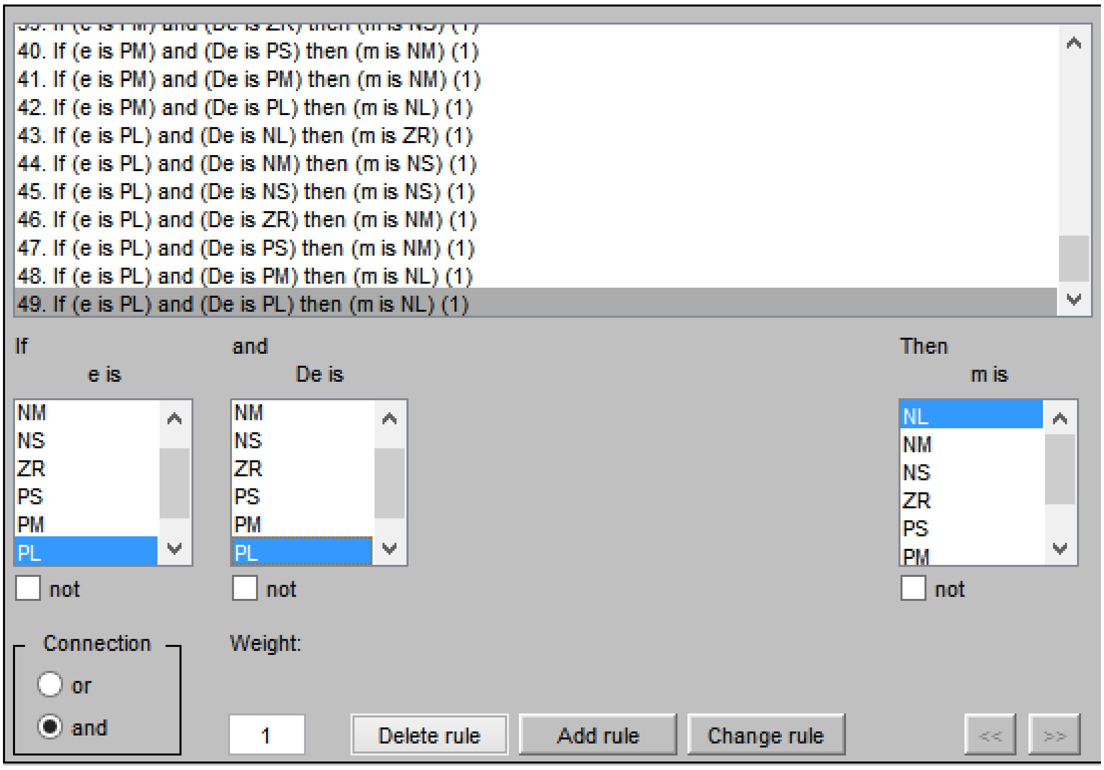


Figure 4.6 Fuzzy Logic Rules Editor

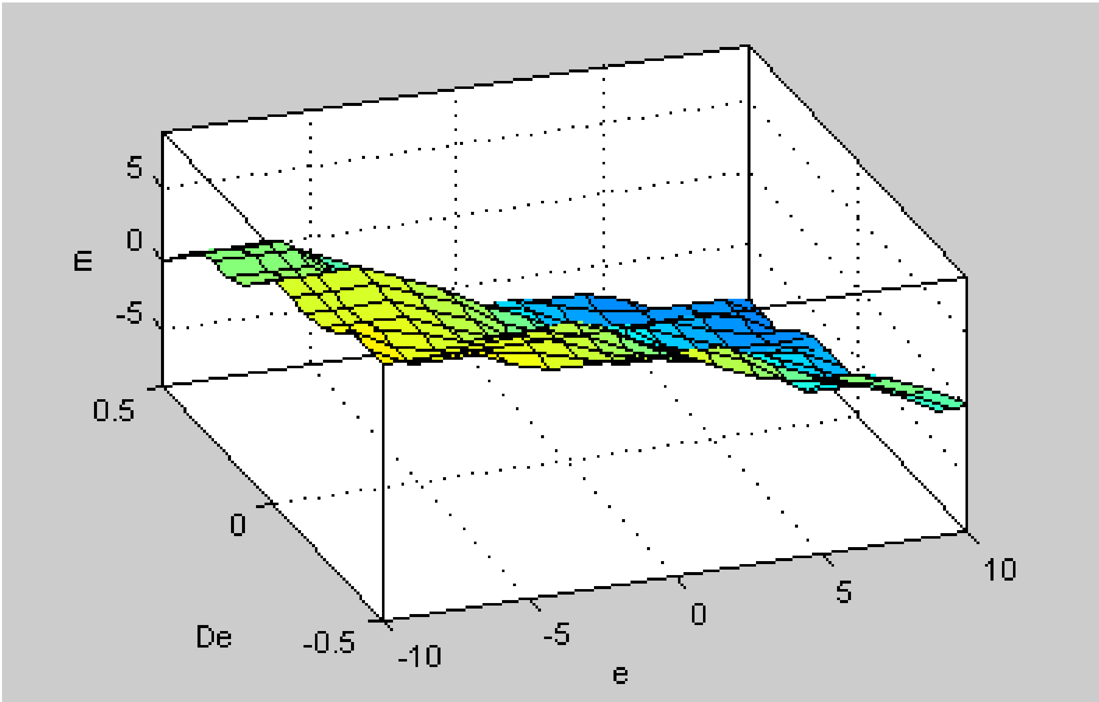


Figure 4.7 Surface of Rule

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

In this chapter the designed simulation system has been used to carry out the measurements and tests, to verify the predicted results of the system. The results obtained from the MATLAB simulations and practical implementations are compared.

5.2 The Simulation Results of Standalone Hybrid Micro-Grid System

The SIMULINK MATLAB package version 2014a (8.3.0.532) has been used for modeling and simulating of the system. The Standalone hybrid system variable input and constant output voltage and frequency have been designed.

In any system and in anywhere when collected several different systems in one net have been facing difficulties to an ability for controlling on them, because of non-linearity of the overall system which depends on more than one parameters. It was captured this difficulty by implemented the intelligent control of it. As in this work which we used the two intelligent control methods fuzzy logic and PI controller, and compared to gather that it was proved which of them is better. In this project, we took four cases to make this comparison.

5.3 The Case Studies on Dynamic Performances of Controllers System

The comparison between the dynamic performances of conventional PI and fuzzy controller on frequency and voltage control was tested in a model system as shown Figure 3.11. A system consists of four sources to supply one load bus, which was one of them used as a bidirectional source for controlling the systems voltage and frequency. For getting more reliable and high performance of control system was taken several cases to tested type of the controller which was used in this project.

The change applied is three phase load as a time Interval below, when the loads change, as presented in Table 5.1, as an optimal scenario, with normal/abnormal operating conditions, and taken those cases:

When changed the three phase loads according to its time setting as presented in Table 5.1, as an optimal scenario, with normal/abnormal operating conditions, and taken in four cases as followings:

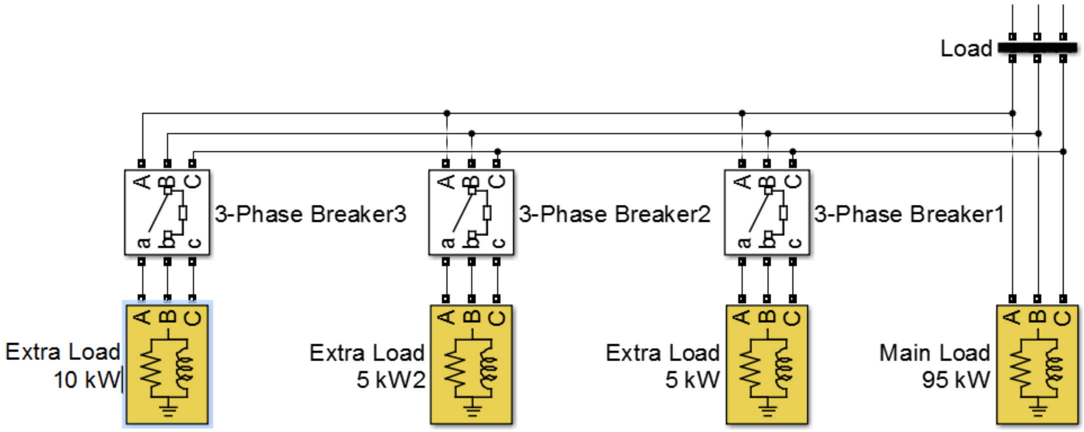


Figure 5.1 Load Profile Modeled

Table 5.1 Load Profile with Time Interval

From Time (Sec)	To time (Sec)	Increasing of power load (KW)	Decreasing of Power load (KW)	Power load (KW)
0	1	95	-	95
1	2	5	-	100
2	2.5	5	-	105
2.5	3	10	-	115
3	3.5	-	5	110
3.5	4	-	10	100
4	6	-	5	95

5.3.1 Case Study One

In this case compared the dynamic performances of PI and fuzzy controller on frequency and voltage control when the load changes (as shown in the load profile as an optimal scenario) when the wind, temperature and solar irradiation are constant.

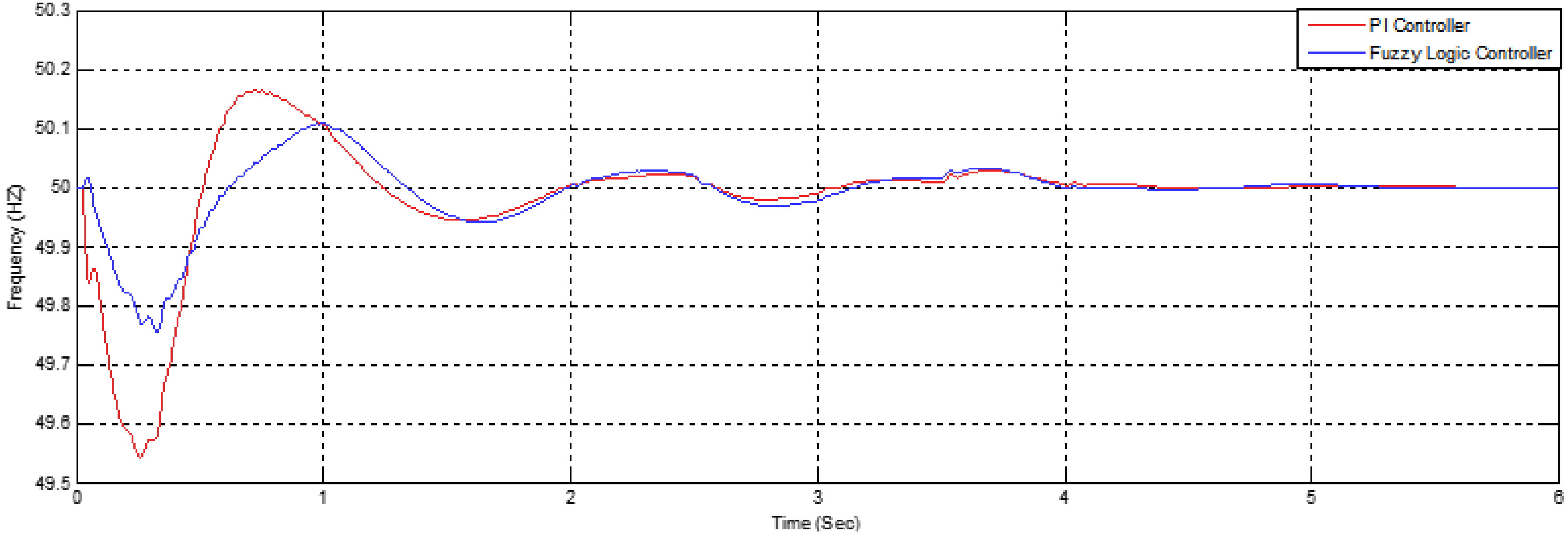


Figure 5.2 Frequency Response

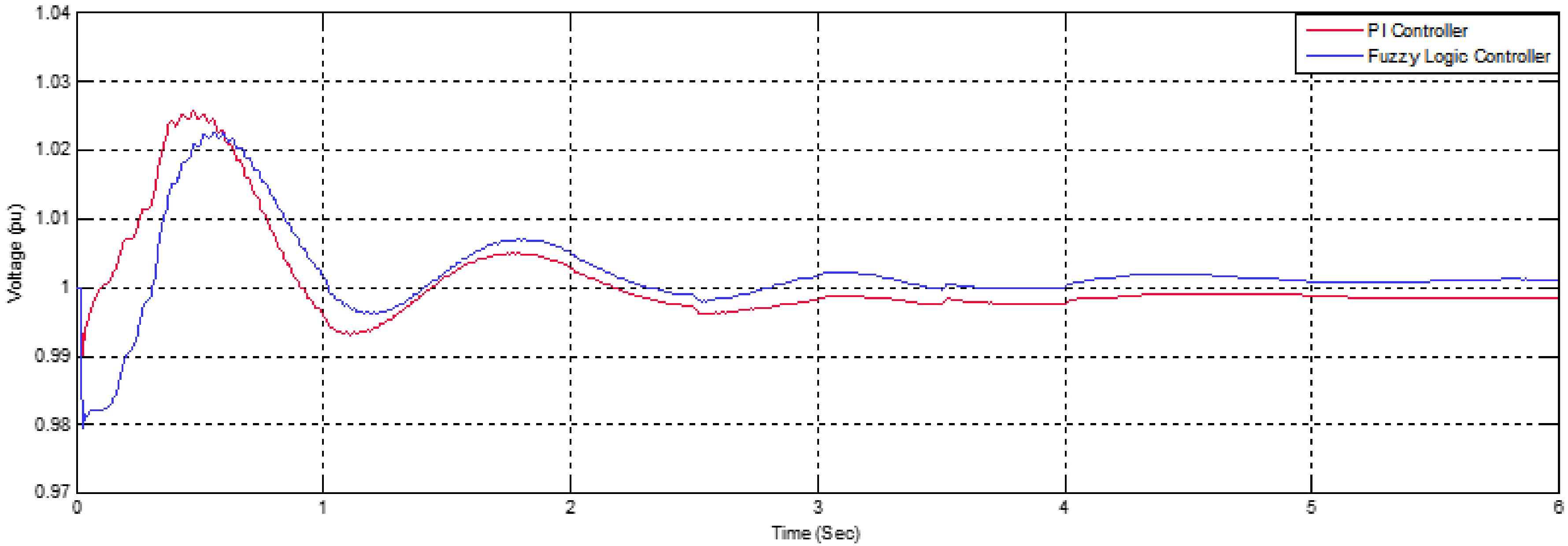


Figure 5.3 Voltage Response

In this case after operation the proposed system under the variation of the loads as illustrated table 5.1, with applied each of the PI and Fuzzy logic controller to stabilize the frequency and voltage during stand-alone mode of micro-grid hybrid system that shows in figure 3.11.

When the change of the load occurred at the times according Table 5.1, from (0 to 6) second. The frequency and voltage output of the system are shown in Figure 5.2 and 5.3. The fuzzy controller seriously improved the control performance compared to the conventional PI controller. The rising and settling time were reduced considerably.

From Figures 5.2 and 5.3 can be more clarifying the situation of dynamics response during the test period the as following:

1 - Frequency response; In this case because of only the loads have changed the response of frequency only change according to a varying of the loads with simulations time from (0 to 6) second, which is shown in Table 5.1, that it is clear from the figure 5.2 the frequency In the beginning or at the zero point near to reference frequency that is (50Hz), after than the signal goes to deformation because of hybrid synchronous systems responses. In the other seconds, we can feel the change that occurred due to the varying of load but it is very small because of compensatory response which it is the battery energy system.

Because of the frequency directly proportional with the active power, and when the load increasing on the system cannot able to compensate the demand from the load so in this time the power flow from come to the opposite direction in BESS by VSC and by discharging of SOC can compensate the power to the system, and then compensated the frequency signal. In another hand the absorbing operation of power by BESS due to decreasing the frequency in the system when it is increased by the decreasing of the load.

2 - Voltage response; As it clearly in point number one, in this case the change only by the loads, then the voltage was changed with respect to the toad variety that it is illustrated in Table 5.1 and figure 5.1.

From the figure 5.3, it is clear the voltage response was changed during the simulation time (0 to 6) seconds, this variation is accursed according to variety of load demand.

As in beginning the change is high, because of synchronization proses, after than the changing is very small due to response from the BESS which it is compensate the voltage of the system by injection and absorbing the reactive power to the system by its capacitor that connected with the battery in a DC side.

Because the voltage is proportional with the reactive power, whenever the reactive power increased the voltage was increased, then by compensate reactive power in system can be regulate the voltage terminal.

5.3.2 Case Study Two

In this case compared the dynamic performances of PI and fuzzy controller on frequency and voltage control when the load changes (as shown in the load profile as an optimal scenario) only wind speed changes and temperature and solar irradiation constant.

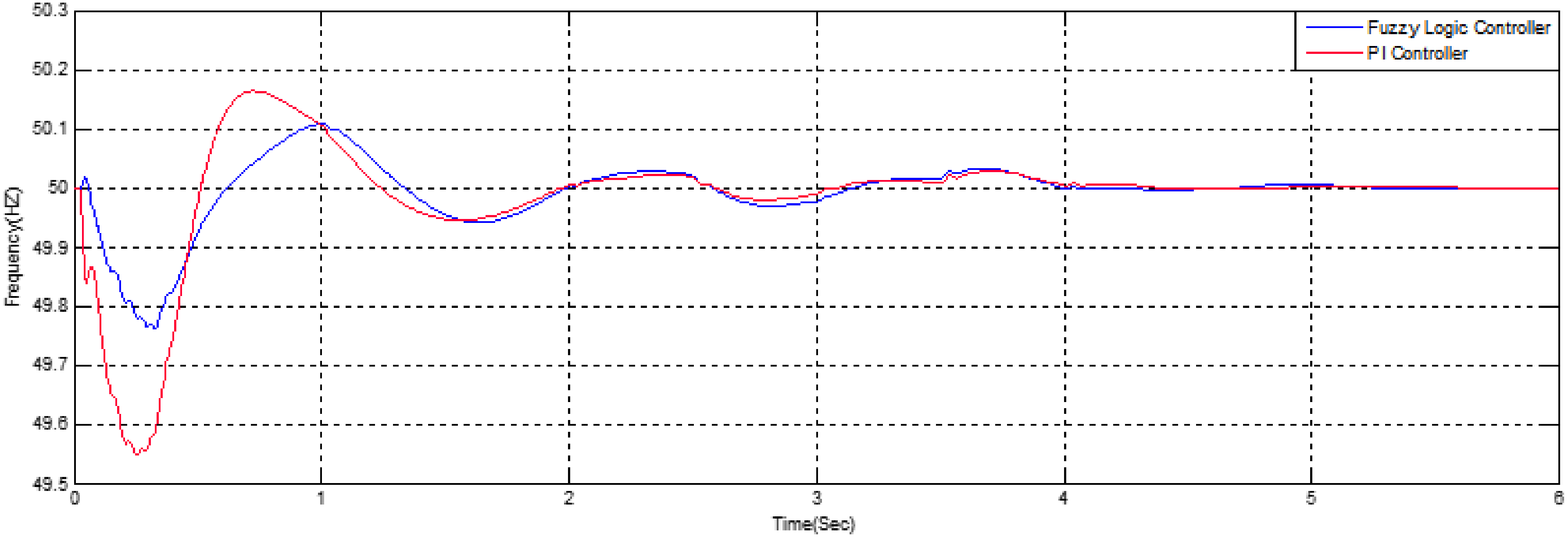


Figure 5.4 Frequency Response

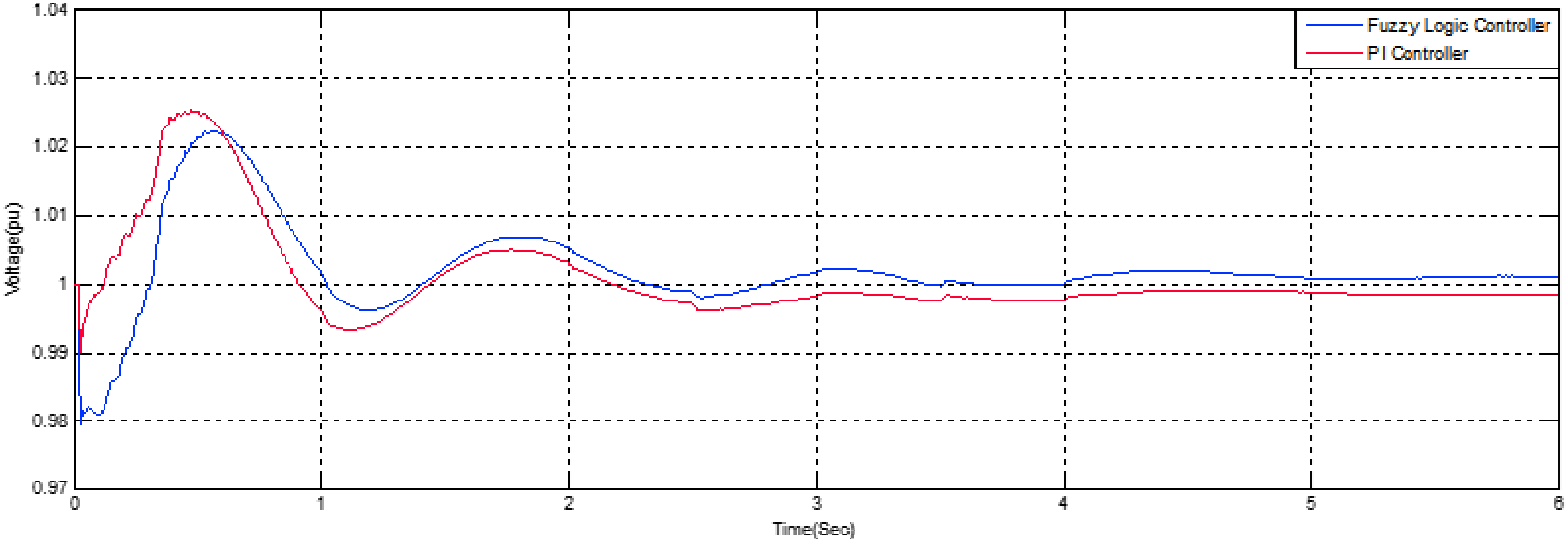


Figure 5.5 Voltage Response

In this case after operation the proposed system under the variation each of the loads as illustrated table 5.1 and wind speed. Applied each of the PI and Fuzzy logic controller to stabilize the frequency and voltage during stand-alone mode of micro-grid hybrid system that shows in figure 3.11

When the changes of the load occurred at the times according Table 5.1, and on the wind turbine speeds by varying from the nature wind, from (0 to 6) second. The frequency and voltage output of the system are shown in Figure 5.4 and 5.5. The fuzzy controller seriously improved the control performance compared to the conventional PI controller. The rising and settling time were reduced considerably.

From Figures 5.4 and 5.5 can be more clarifying the situation of dynamics response during the test period the as following:

1-Frequency response; In this case because of changing from the loads and wind speed the changing is to much more than in case study one the response of frequency change according to a varying each of the loads and speed with simulations time from (0 to 6) second, according to the profile of loads as shown in the Table 5.1 and the characteristic of the wind speed, as illustrated in the figures 3.7 and 3.8 , that it is clear from the frequency curve at the starting point near to reference frequency that is (50Hz), after than the signal goes to distortion because of hybrid synchronous systems responses. In the other seconds, we can feel the change that occurred due to the varying of load and wind speed to gather, but it is small because of the response of compensatory system that is the battery energy system (BESS).

Because of the frequency directly proportional with the active power, whenever the active power increased the frequency was be increase on the system. In another hand the absorbing operation of power by BESS due to decreasing the frequency in the system when it is increased by the decreasing of the load.

2-Voltage response; As it clearly in point number one, in this case the change due by the loads with the speed, then the voltage was changed with respect to the toad varying that it is illustrated in Table 5.1 and figure 5.1 and the wind speed that it is illustrated in figures 3.7 and 3.8.

From the figure 5.5, it is clear the voltage response was changed during the simulation time (0 to 6) seconds, this variation is accursed according to varying of load demand and the wind speed.

5.3.3 Case Study Three

In this case compared the dynamic performances of PI and fuzzy controller on frequency and voltage control when the load changes (as shown in the load profile as an optimal scenario) only temperature and solar irradiation change and wind speed constant.

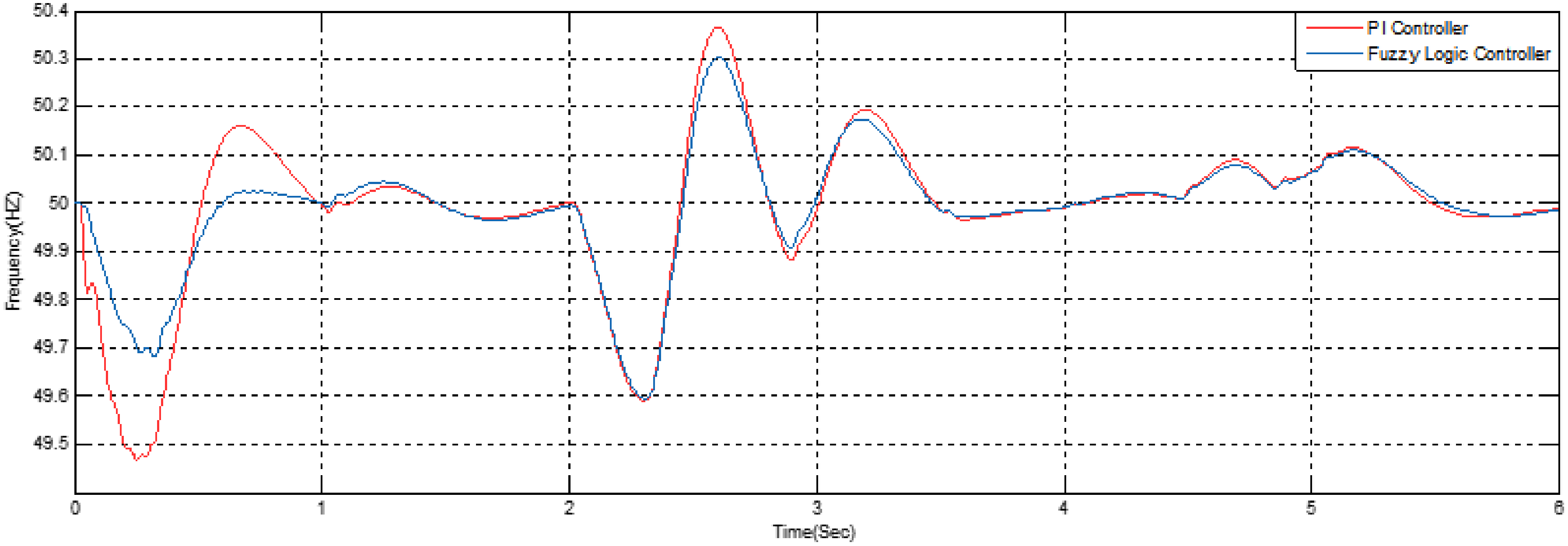


Figure 5.6 Frequency Response

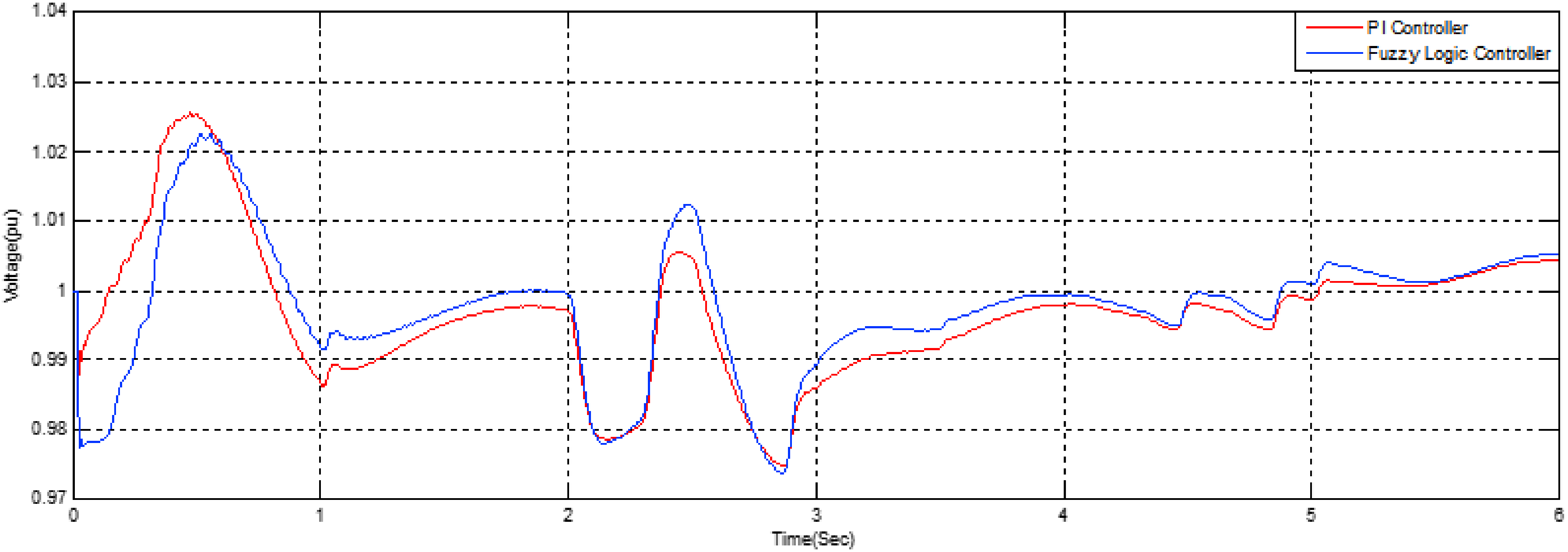


Figure 5.7 Voltage Response

In this case after operation the proposed system under the variation each of the loads as illustrated table 5.1 with the temperature and the solar irradiation. Applied each of the PI and Fuzzy logic controller to stabilize the frequency and voltage during stand-alone mode of micro-grid hybrid system that shows in figure 3.11

When the changes of the load occurred at the times according Table 5.1, and on the PV solar systems by varying from the nature wind, from (0 to 6) second. The frequency and voltage output of the system are shown in Figure 5.6 and 5.7. The fuzzy controller seriously improved the control performance compared to the conventional PI controller. The rising and settling time were reduced considerably.

From Figures 5.6 and 5.7 can be more clarifying the situation of dynamics response during the test period the as following:

1-Frequency response; In this case because of changing from the loads with the temperature and the solar irradiation the changing is to much more than in cases study one and two the response of frequency change according to a varying each of the loads with temperature and solar irradiation with simulations time from (0 to 6) second, according to the profile of loads as shown in the Table 5.1 and the characteristic of the temperature and solar irradiation, as illustrated in the figures 3.5 and 3.6 , that it is clear from the frequency curve in figure 5.6, at the starting point near to reference frequency that is (50Hz), after than the signal goes to distortion because of hybrid synchronous systems responses. In the other seconds, we can feel the change that occurred due to the varying of load with the temperature and the solar irradiation to gather, but it is small because of the response of compensatory system that is the battery energy system (BESS).

Because of the frequency directly proportional with the active power, whenever the active power increased the frequency was be increase on the system. In another hand the absorbing operation of power by BESS due to decreasing the frequency in the system when it is increased by the decreasing of the load.

2 - voltage response; As it clearly in point number one, in this case the change due by the loads with the speed, then the voltage was changed with respect to the toad varying that it is illustrated in Table 5.1 and figure 5.1 with the temperature and the solar irradiation that it is illustrated in figures 3.5 and 3.6.

From the figure 5.7, it is clear the voltage response was changed during the simulation time (0 to 6) seconds, this variation is accursed according to varying of load demand with the temperature and the solar irradiation.

This increasing and decreasing of the voltage is from the reactive power whenever the reactive power changed from the system the voltage also change, because of its directly proportional with the reactive power.

5.3.4 Case Study Four

In this case compared the dynamic performances of PI and fuzzy controller on frequency and voltage control when the load changes (as shown in the load profile as an optimal scenario) and all the system variables (wind speed, temperature, solar radiation change randomly.

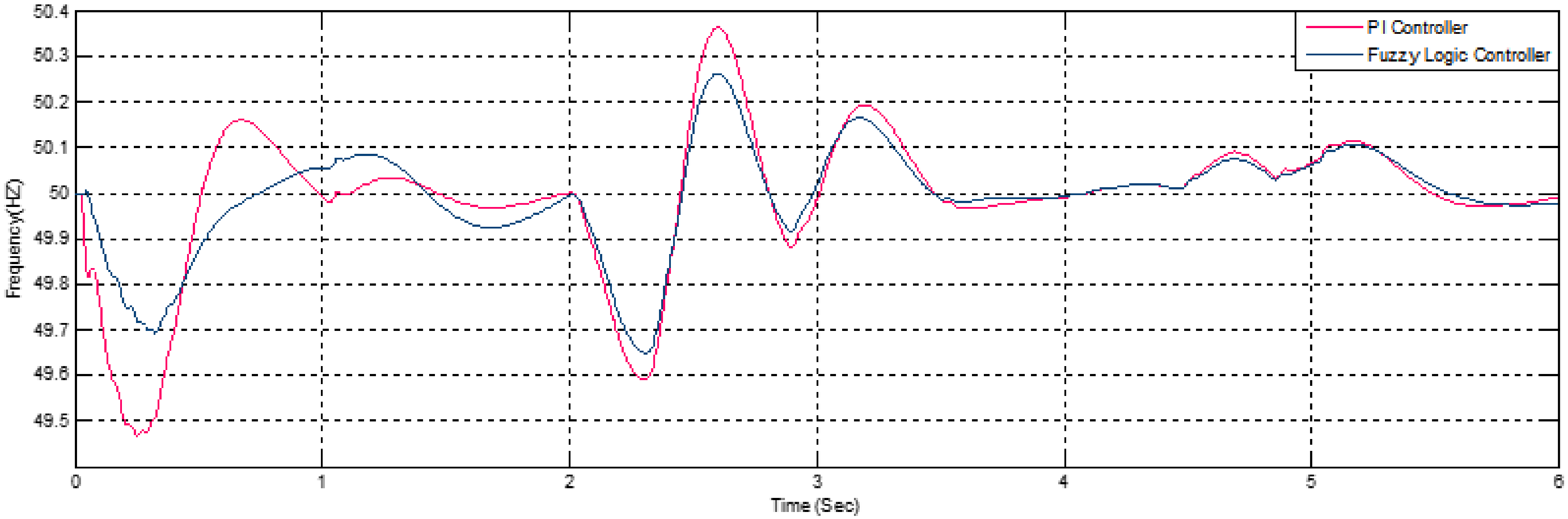


Figure 5.8 Frequency Response

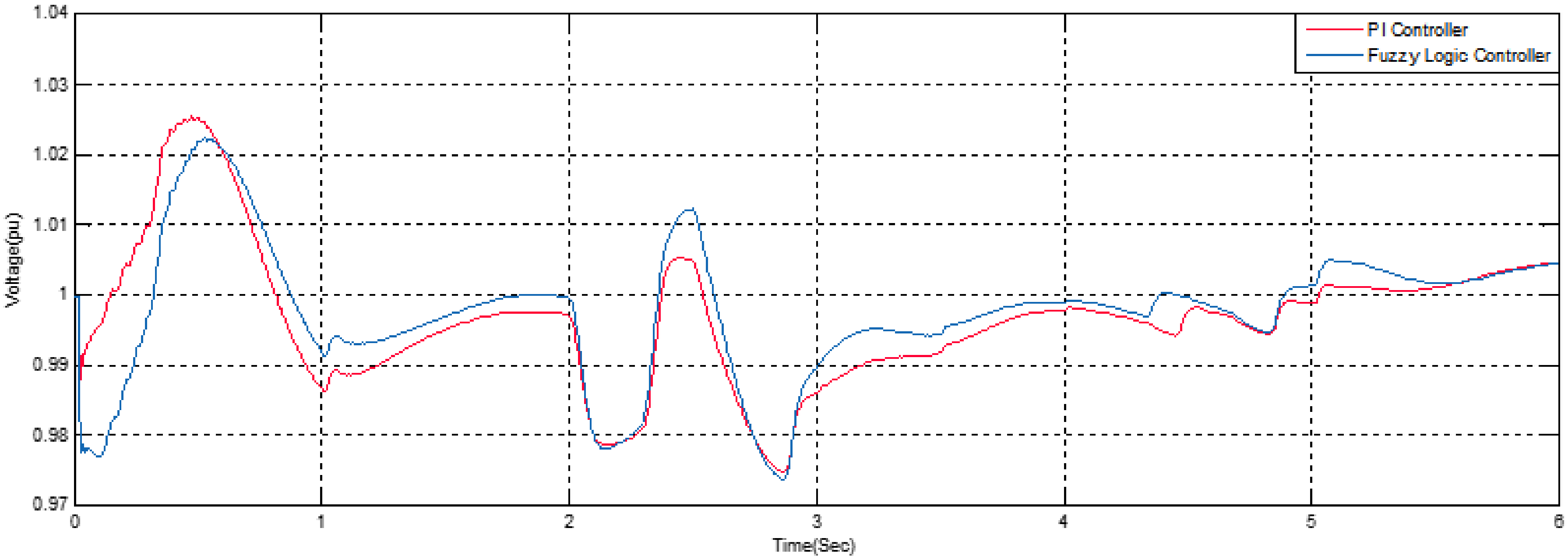


Figure 5.9 Voltage Response

In this case after operation the proposed system under the variation each of the loads as illustrated table 5.1 with the temperature, the solar irradiation and, the wind speed.

Figures 5.8 and 5.9 shows the frequency and voltage response, respectively as illustrated as following:

1-Frequency response; In this case because of changing from the loads with the temperature, the solar irradiation and, the wind speed, the changing is to much more than in cases study one, two and, three. The response of frequency change according to a varying each of the loads with the temperature, the solar irradiation and, the wind speed with simulations time from (0 to 6) second, according to the profile of loads as shown in the Table 5.1 and the characteristic of the temperature and solar irradiation, as illustrated in the figures 3.5 and 3.6 , and the characteristic of the wind speed as illustrated in the figures 3.7 and 3.8 , that it is clear from the frequency curve in figure 5.8, at the starting point near to reference frequency that is (50Hz), after than the signal goes to distortion because of hybrid synchronous systems responses.

In the other seconds, we can feel the change that occurred due to the varying of load with the temperature, the solar irradiation and, the wind speed to gather, but it is minimum variation as the starting point, because of the response of compensatory system that is the battery energy system (BESS).

Because of the frequency directly proportional with the active power, whenever the active power increased the frequency was be increase on the system. In another hand the absorbing operation of power by BESS due to decreasing the frequency in the system when it is increased by the decreasing of the load. In this case the changing of active power from all changeable parameters in the system (loads, PV and, wind turbine).

2-voltage response; As it clearly in point number one, in this case the change due by the loads with the temperature, the solar irradiation and, the speed, then the voltage was changed with respect to the load varying that it is illustrated in Table 5.1 and figure 5.1 with the temperature and the solar irradiation that it is illustrated in figures 3.5 and 3.6, and the characteristic of the wind speed as illustrated in the figures 3.7 and 3.8.

In all of the cases, the fuzzy logic is better controller as a PI controller, when we wanted to investigate this fact.

Generally, the proposed system have two situations states, which are normal and abnormal. The normal state like test study in case number one, at the normal weather, that was obtained as the control system is able to regulate the systems and make them works on normal with the high response for increasing or decreasing the load demand.

And in the abnormal state; Like tests studies in cases number two, three and, four, at the abnormal weather, the control response is good but is not like case one because of the several change that occurs in more one sources.

This study gives the idea on the stand-alone hybrid system, which the Micro-Grid system depends on more than one source. The battery storage system is one important equipment for this type of system because of its ability to charge and discharging during operation of the system that useful for regulating each of frequency and voltage in the system, by injection and absorbing the active and reactive power.

5.4 Discussion of the Results

The suggested developed control strategies for hybrid generating system that is made of PV-Wind-Diesel is that simulated using MATLAB/SIMULINK in different situation for the desire of capturing the response of the control system. In this first state each one of the irradiance and temperature are constant at all simulation time as shown in Figure 3.5, which are 1000W/m^2 and 0C^o, where only the load was variable, as presented in Table 5.1, and the wind speed is constant by 10 m/s . In the second state Otherwise wind speed is constant by 10m/s, the PV irradiance is predicted to decreases from 1000 to 250 W/m^2 at (0.5 -1) s, and increase from 250 to 1000 W/m^2 at (1.5-2)s, also the PV temperature is assumed to increase from 25 to 75 C^o at (2-3)s, and decrease from 75 to 0 at (4-5)s, as shown in Figure 3.6, it is due to changing power flow from the PV system moreover, the frequency and voltage changes on the load, too.

Furthermore, in state three was assumed that the radiance and temperature are constant at all simulation time, only wind speed is changing according to turbine characteristic, as shown in Figure 3.8. Choose assumption range, [12 10 7 5 7 10 12] m/s at times [0 1 2 3 4 5 6] receptivity, it is due to changes of power flow from the wind system moreover, the frequency and voltage changed on the load too. Except the variation of the load as presented in Table 5.1.

In general, the distortion of signals from two disturbance sources, one of them is from changing of the load, and another one by each of the wind and solar sources.

Moreover, the proposed system operated under the above conditions that illustrated from figures 5.2 to 5.9, the compare dynamic response of the fuzzy logic controller to the Proportional-integral (PI) controller of the proposed system, by screening the responses each of them with the fluctuations that occur on the overall of the system as the impact on the voltage and frequency, can be admitted to the presentation of fuzzy logic controller has advanced dynamic response of the hybrid system, and has minimum overshoots, as well as being faster than (PI) controller at overall cases.

CHAPTER 6

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

6.1 Introduction

This work is presented design and simulation of standalone hybrid micro grid power system and implements an intelligent control system for voltage and frequency of the standalone hybrid system.

This paper investigates the three important works in one project by using MATLAB Simulink.

Throughout the results obtained, the following conclusions can be made:

1. The work shows a connection four different generation system that consists of PV/Wind/Diesel/Battery and operated together to support the load, and illustrated that can be operated more than one sources in one network otherwise they are different in conversion energy sources which in this network it benefited from four different type. The PV system generate electrical energy from the sunlight, the wind turbine system generate electrical energy from wind kinetic energy, the diesel generator induced electrical energy from fuel chemical energy, and the battery that used as a storage energy system, from charging and discharging by a bi-direction converter device can be injected and absorbed power of the system model. This system was tested in a period of simulation time to showing the performance of the system with any varying from the load demand and natural sources. In the standalone mode during operation in the micro-grid system, the voltage and frequency in the system rapidly changed because of the unbalance between the loads with the sources generate, because of it is necessary to compensator system and controlling on it.

2. Applied dq0-axis theory in a voltage source converter controller to controlling each of the frequency and voltage of standalone hybrid micro-grid system by supporting of a charging and discharging of the storage system with a capacitor in DC side. Whenever the active power is increased in the network, due to increasing of the frequency on its system. Also whenever the reactive power is increased in the network, due to increasing of the terminal voltages on the system. Which investigated the two condition in here. In the other hand the transformation system applied to ability of control on the systems main parameter which are frequency and voltage by using axis transformation which are directed axis and quadrature axis from three phase voltages lines, by using two blocks PLL (Phase Locked Loop) and (a-b-c to d-q-0) techniques in the MATLAB simulation software, because it is easy to controlling.

3. The ability of controlling on Modulation index of PWM by the dq0-axis could be controlling of the voltage and frequency by increasing and decreasing of the width and amplitude of the pulse trigger signals of transistors in the VSC converter, in this way could be controlling each of active and reactive power flow and them direction from the system to the BESS system by bi-directional convertor which is responsible to convert current from AC to DC when the power flow from Micro-Grid system to BESS, in this time it was worked as a rectifier to charge the battery. And DC to AC when the power flow from BESS to the Micro-Grid system, in this time it was worked as an inverter to discharge the battery.

4. Ability to transfer maximum power from photovoltaic system by using MPPT with (P&O) techniques, which is controlled of the duty cycle to regulate the booster and DC voltage in the PV array system to be constant with changing accorded by the sunlight energy.

5. These systems were friendly to the environment, because of using renewable sources instead of the fossil fuel engine system. And these systems were healthy by zero polluting emissions and had minimal operation cost

6. This type of system has the difficulty of control because of the different sources and independent on the main grid system, and by fluctuations in the air that effects to it during of annual and period of day and night.

7. Intelligent control is one of the important technique which was used in this system for controlling the power flow and charging or discharging of the battery system, in this way to controlling of the main parameter in overall the system, which were voltage and frequency. The Fuzzy logic control could be used in the MATLAB Simulink software and it is easy to use compared to other techniques. By using Fuzzification and Defuzzification could be designed the fuzzy control system as a feedback control in the hybrid micro-grid power plant.

8. A comparison between the performance of PI and Fuzzy logic on voltage and frequency controller. The comparison examined hybrid power system, when occurred change on the three phases RL load and taking four cases,

   a) When the wind, solar irradiation, and temperature are constant.

   b) When the only wind speed changes, while temperature and solar irradiation are constant.

   c) When the both temperature and solar irradiation change however wind speed is constant.

   d) When the wind speed, temperature, and solar radiation all change according to its characteristics.

These cases are shown that the Fuzzy controllers are more robust and able to alleviate the frequency and voltage of the Micro-Grid as compared to the PI controllers.

This work proposes a version method to using a fuzzy logic for voltage and frequency controller in a standalone hybrid power system, and so this method has been evaluated in simulation form in this study.

The ability of maintained to a certain level, without transgression on the balance of the terminal voltage and output power, as demonstrated in the obtained results.

The study of qualified comparative a dynamic response between the proposed controller and the conventional PI controller, with the fluctuations that has an effect on the voltage and frequency of the proposed hybrid power system.

As a result, under different operating conditions, where recognized fuzzy logic controller was more effective than on the stability of the systems' frequency and voltage terminal in a standalone hybrid power system compared to the PI controller.

6.2 About Something New Which Can Be Done In The Future.

The future work of this study can be extended to design:

1- A standalone hybrid PV-Wind-Diesel-Battery with Artificial Neural Network (ANN) controller can be studied, and compared it to the Fuzzy logic controller.

2- The modeling and intelligent control can be done for the grid connected mode of operation.

3- The present study work can be enlarged by using another renewable sources to get more energy from nature and increasing generating electrical power to covering load demand.

4- The purpose control system in this work, can enlarge it by controlling the sources in which situation can be operated or shut down according to changing each of the weather and the load.

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APPENDIX - A

Internal Blocks for PV Model.

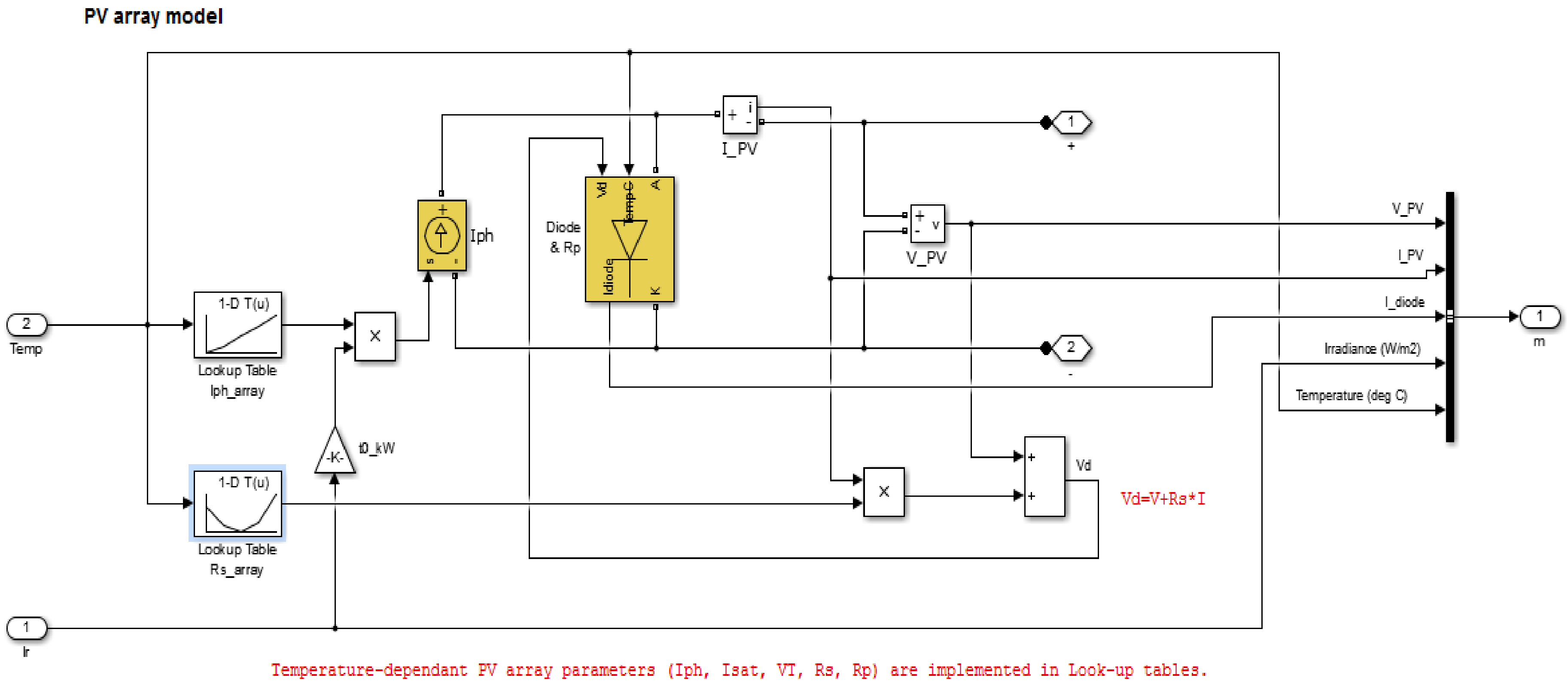

Figure A-1 Under Mask Block of PV Array [31]

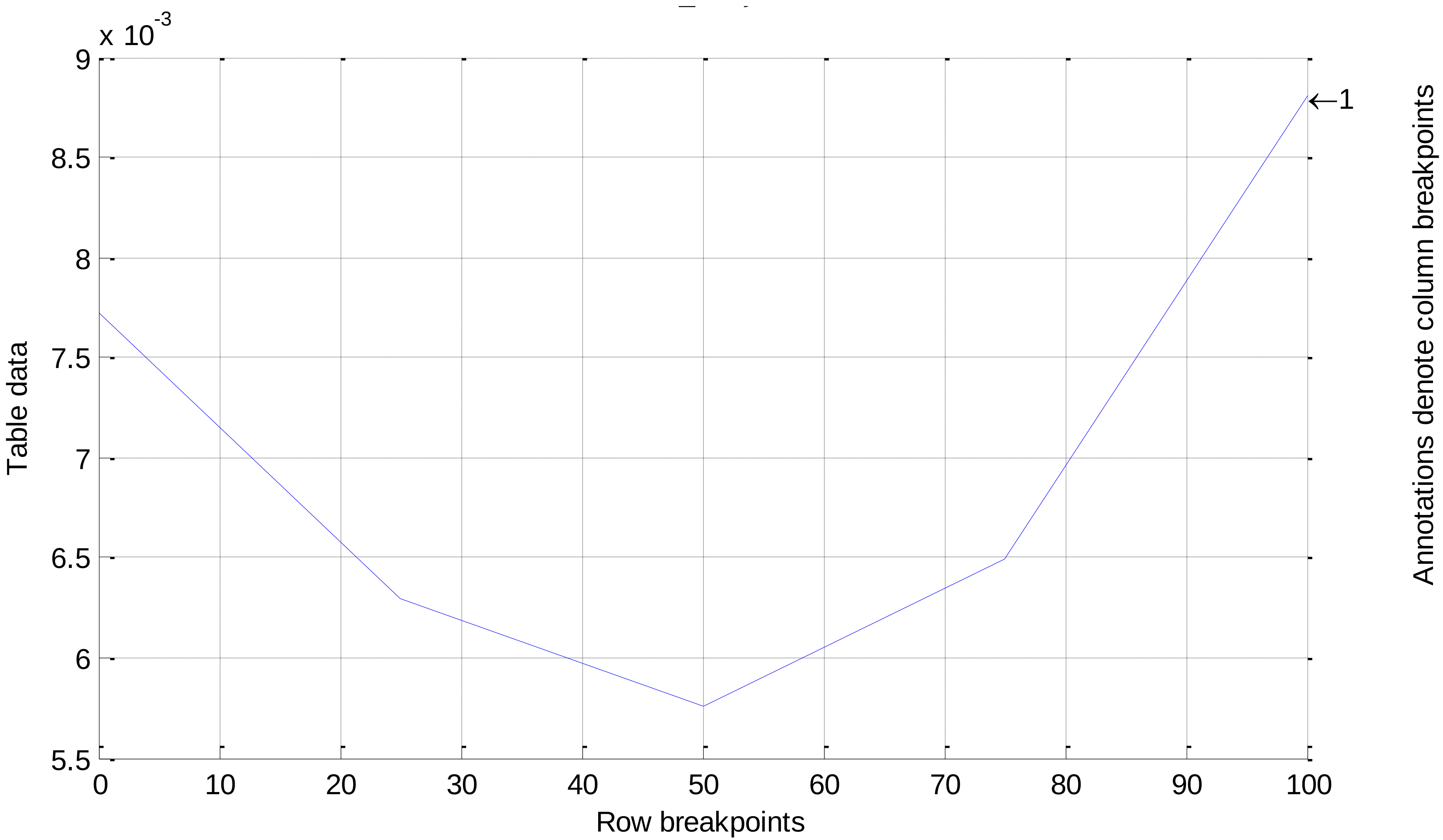

Figure A-2 Table and Breakpoints Data of PV Array [31]

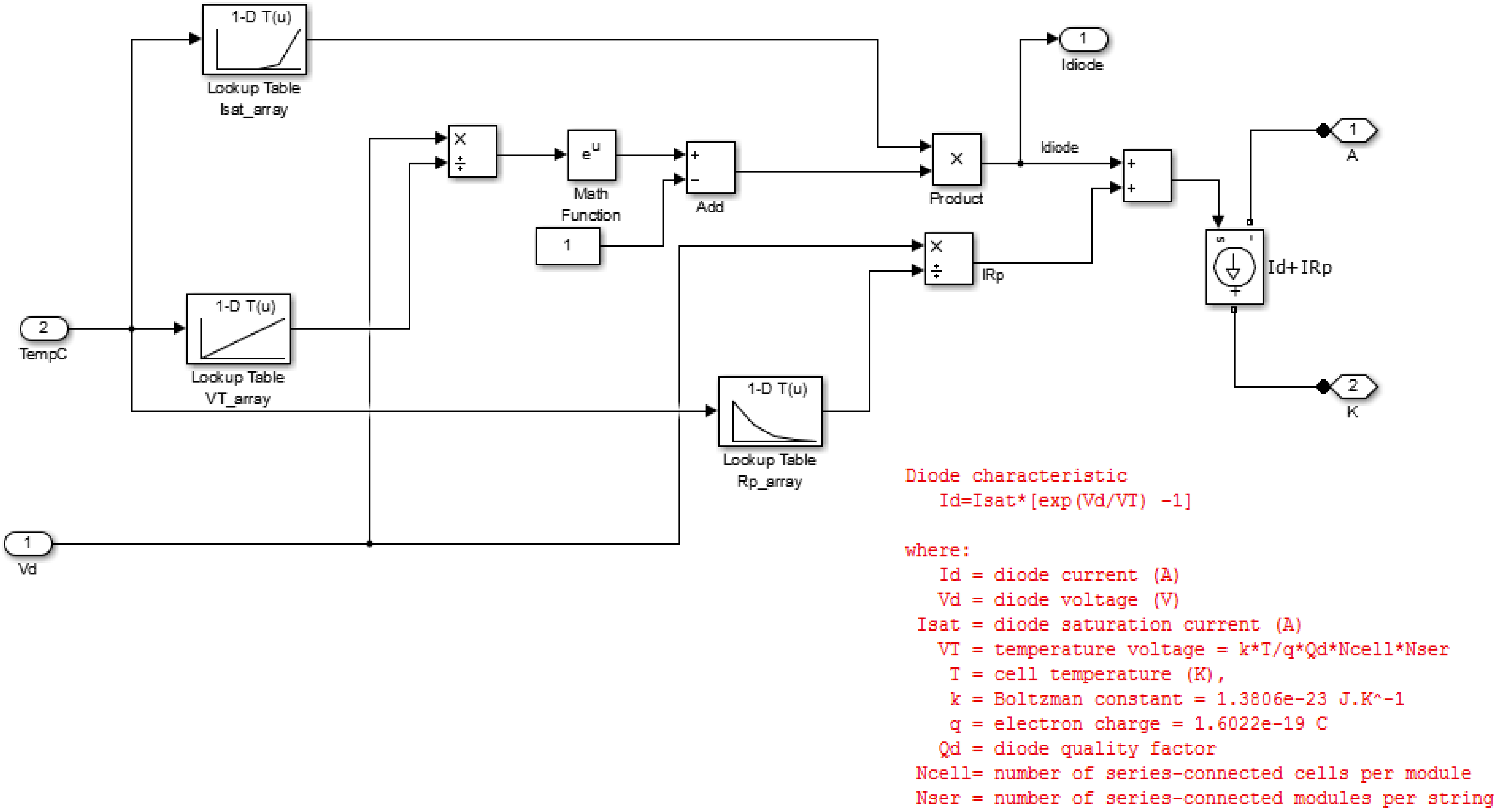

Figure A-3 Diode Characteristic Diagram of PV Array [31]

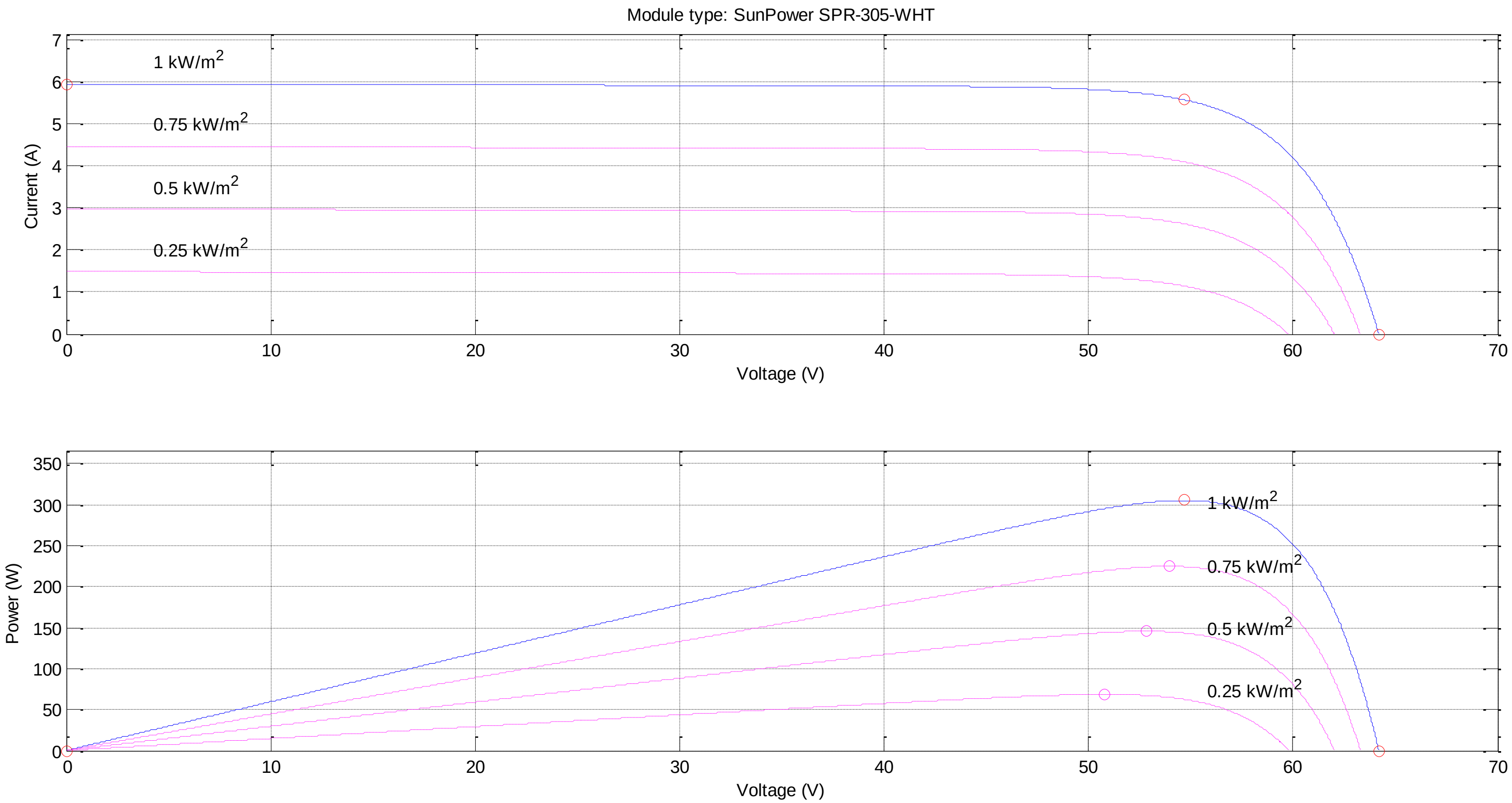

Figure A-4 I-V and P-V Characteristic of Module [31]

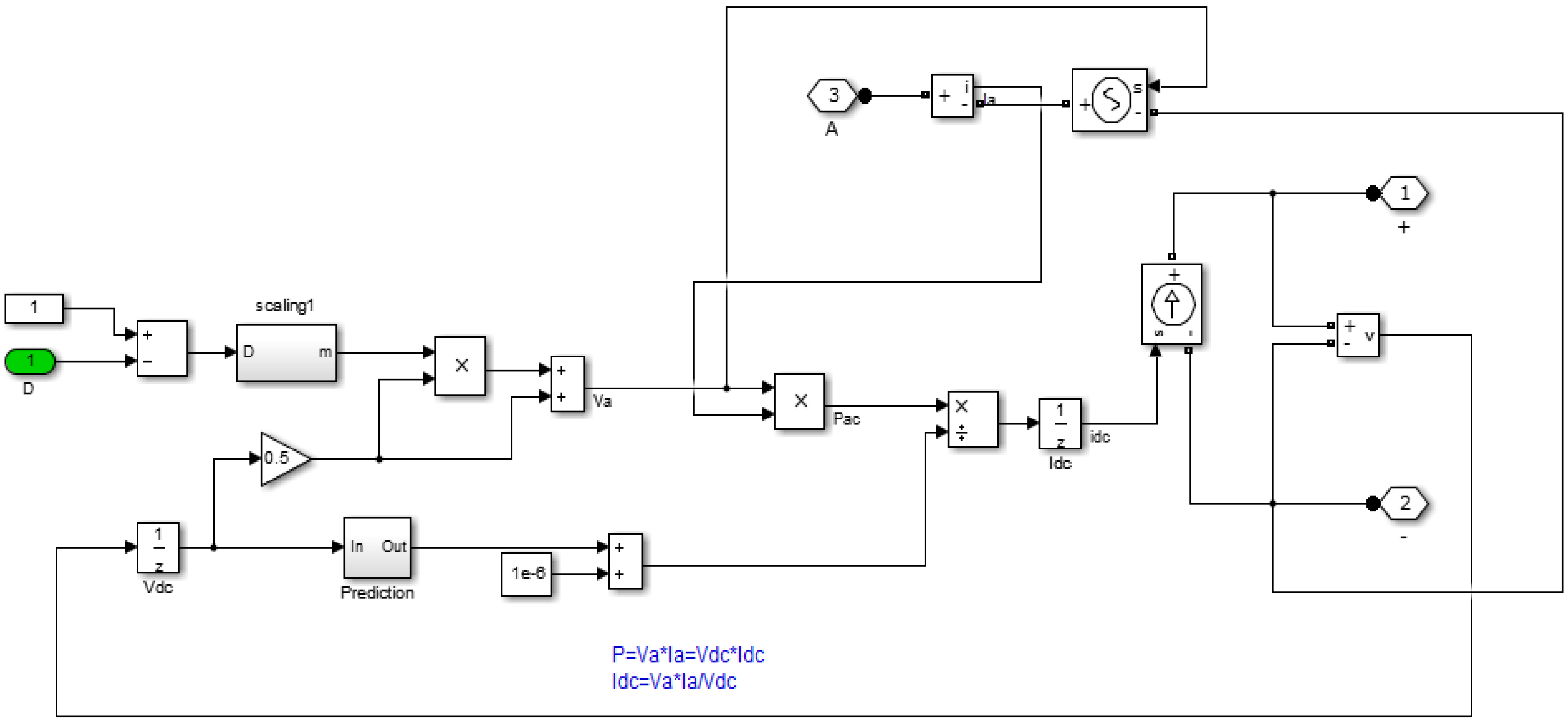

Figure A-5 Booster Block Diagram of PV Array [31]

MPPT Controller Based On the Perturb & Observe Algorithm

From figure (3.4) the PV array system the short m-file program are written for MPPT controller based on the Perturb & Observe algorithm by the designer of the system in MATLAB library helper as [31]:

```
% MPPT controller based on the Perturb & Observe algorithm.
% D output  = Duty  cycle of the boost converter (value between 0 and 1)
%  Enabled  input  =  1  to  enable  the  MPPT  controller
% V input  = PV  array  terminal  voltage  (V)
% I input  =  PV  array  current  (A)
% P a r a m  input :
D= P and (P a r a m , Enabled , V  , I )
D init = P a r a m(1);  %Initial value for D output
D max = P a r a m (2);   %Maximum value for D
D min =  P a r a m (3);   %Minimum value for D
Delta D = P a r a m (4); %Increment value used to increase/decrease the duty cycle D
% (increasing   D = decreasing V ref)
Persistent V old P old D old;
Data Type = 'double';
If is empty (V old)
   V old = 0;
   P old = 0;
   D old = D init;
end
P = V * I;
D V = V – V old;
D P = P – P old;

if d P = 0 & Enabled  ~ =0
   if d P  <  0
      if d V  <  0
         D= D old - delta D;
      else
         D = D old + delta D;
      end
   else
      if d V  <  0
         D = D old +  delta D;
      else
         D = D old – delta D;
      end
   end
else   D =  D old;
end
if D  > = D max  |  D <  =D min
   D=D old;
end
D old = D ;
V old = V ;
P old= P ;
```

APPENDIX - B

Wind - Turbine Asynchronous Generator in Isolated Network

Description:

From figure (3.7), a wind turbine system which consist of: A synchronous Generator (blue block), 480V 110v kVA, and wind turbine (green block), that is varying with changing of wind speed [31].

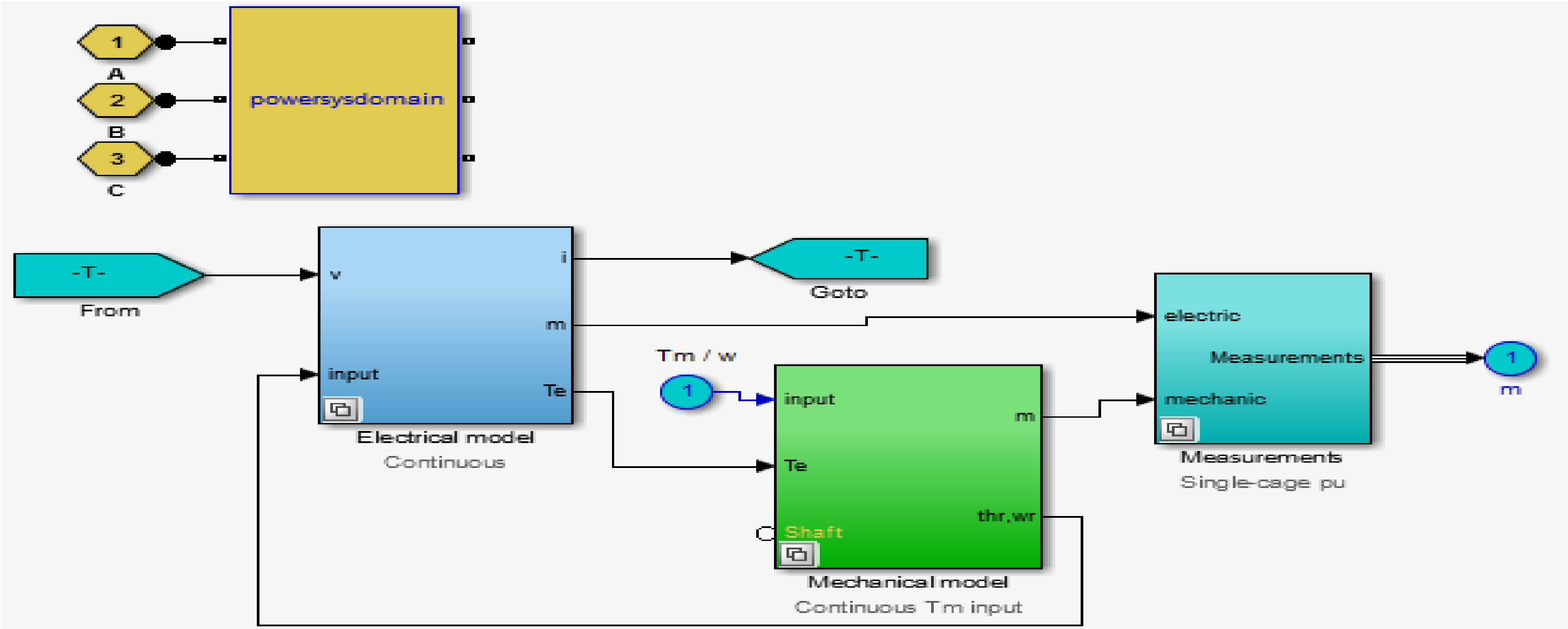

Figure B-1 Under Mask of Bblock Diagram of Synchronous Wind Generator [31]

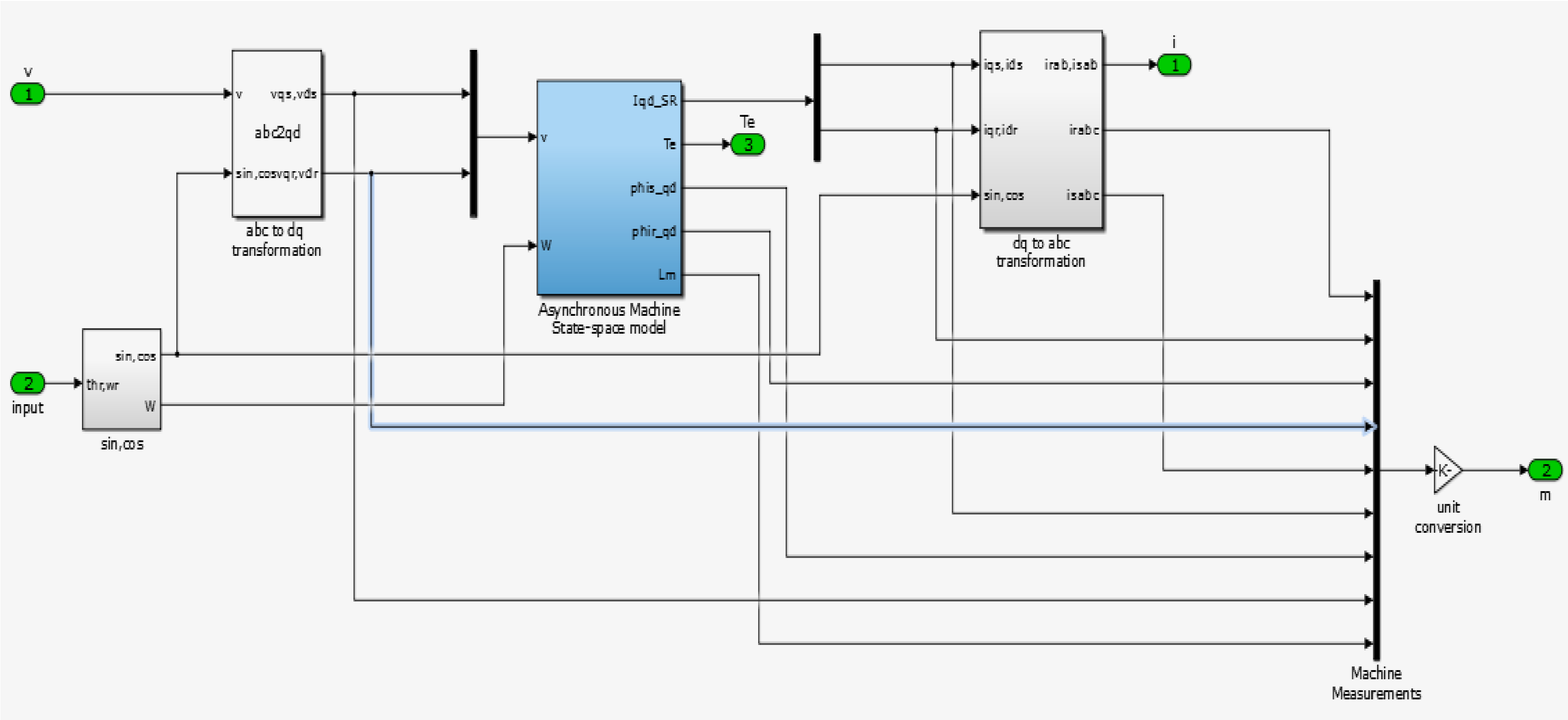

Figure B-2 Electrical Mode [31]

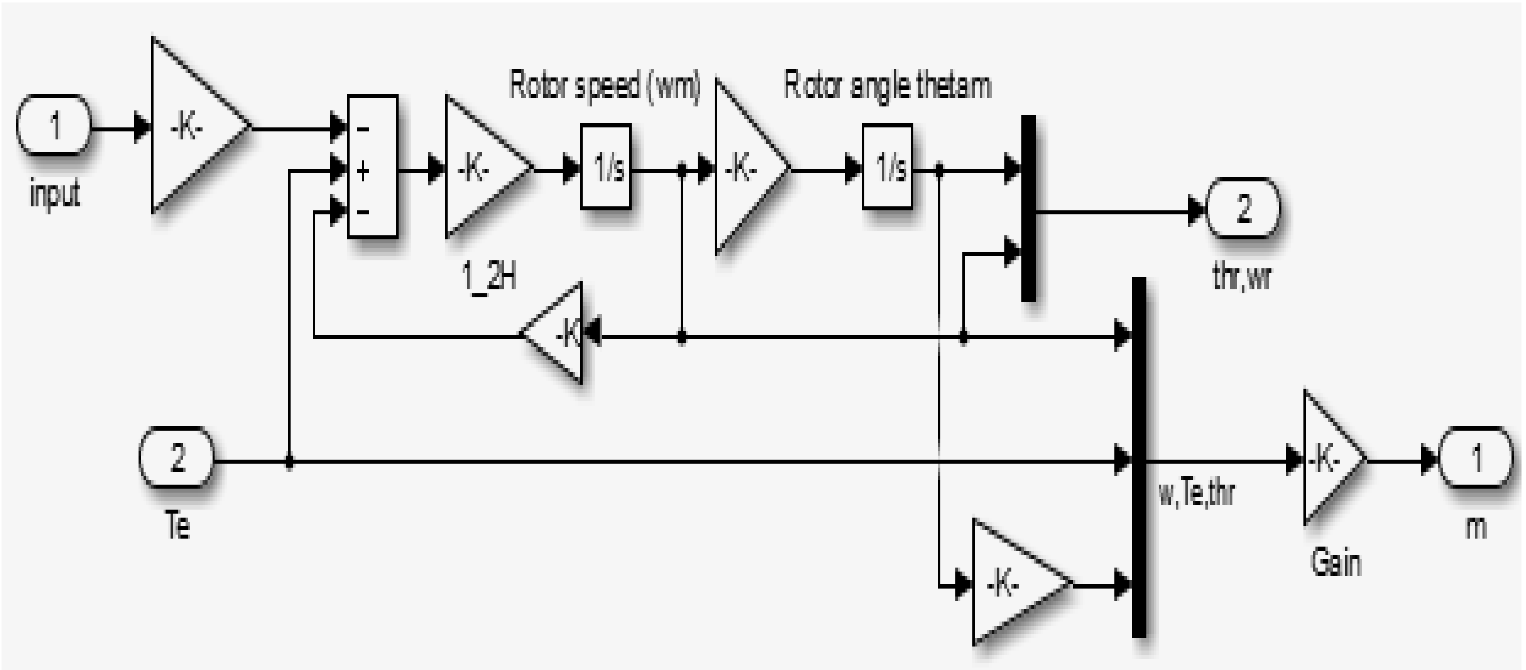

Figure B-3 Mechanical Mode [31]

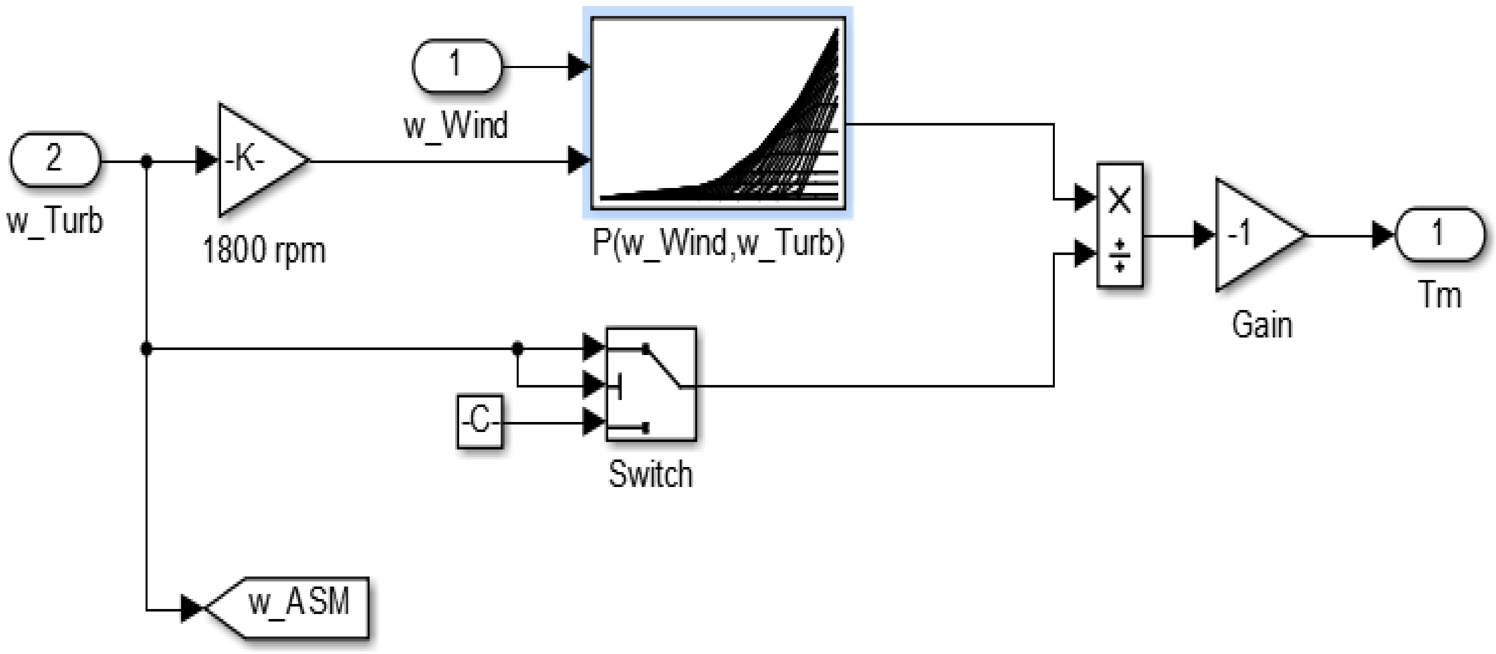

Figure B-4 Internal Diagram of Wind Turbine [31]

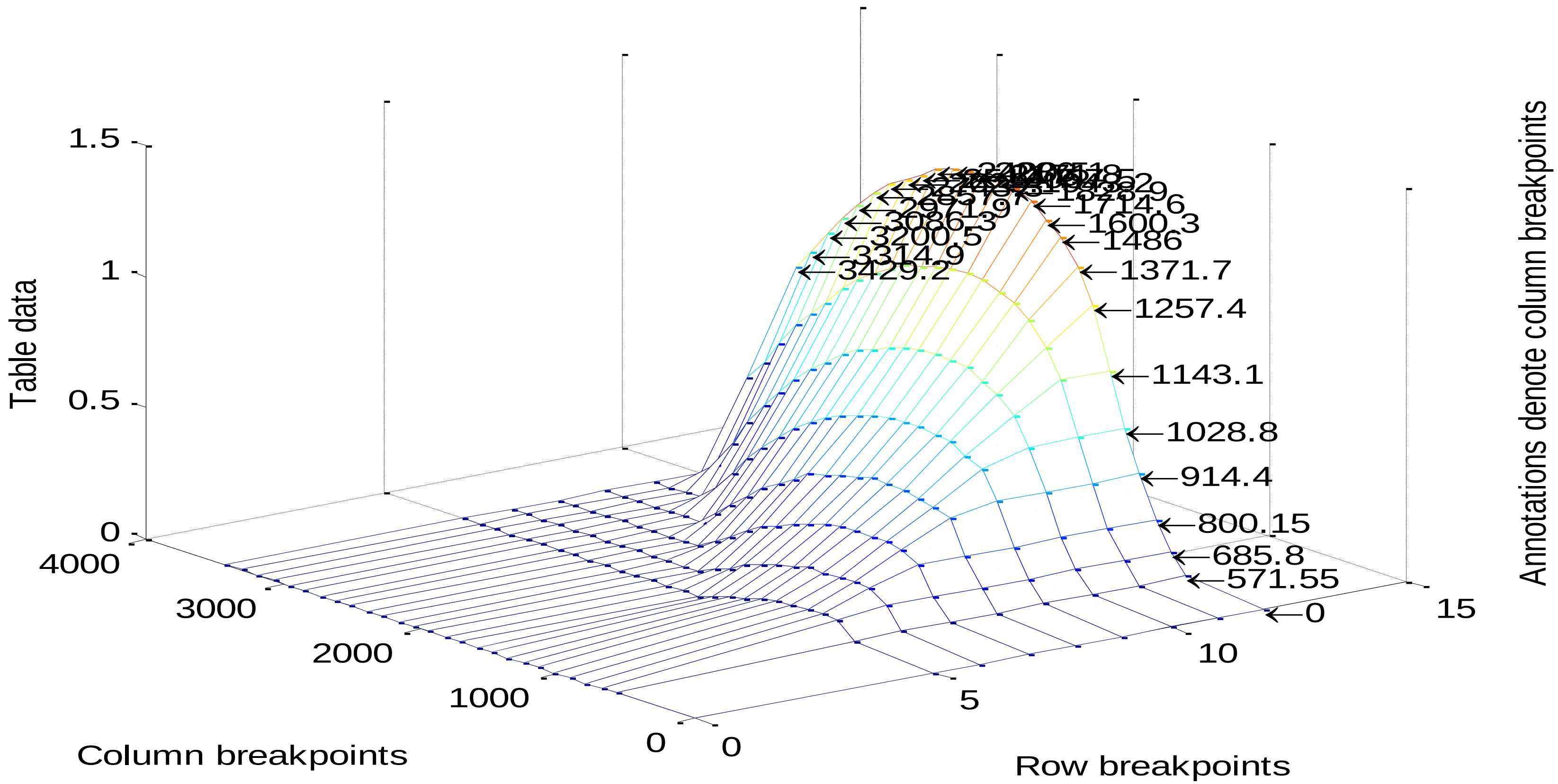

Figure B-5 Table and Breakpoint Data for Block: Power _ Wind Gen / Wind Turbine/P (W _ Wind, W _ Turb) [31]

APPENDIX - C

Diesel Generator Control Model

From figure (3.9) a diesel generator is consist of a synchronous generator and diesel engine.

The block diagram of speed regulator in diesel engine and voltage regulator in diesel generator are designed as [31]:

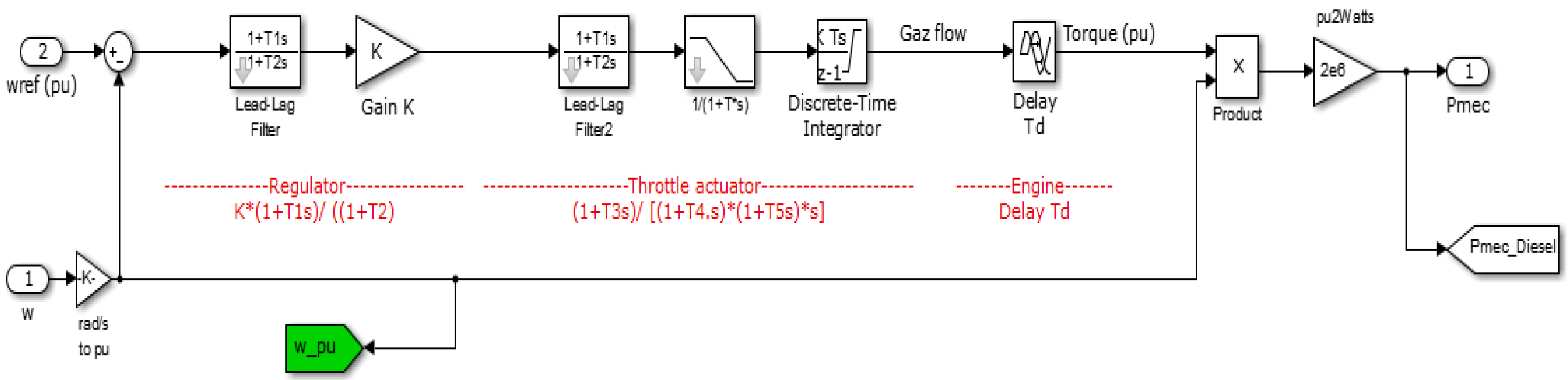

Figure C-1 Speed Regulator in Diesel Engine [31]

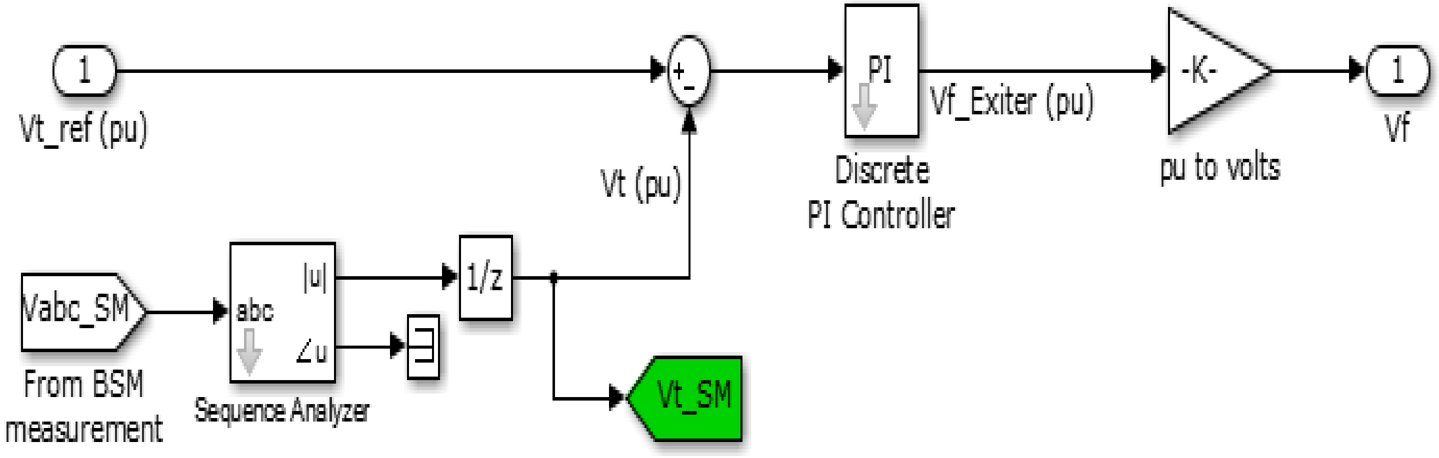

Figure C-2 Voltage Regulator in Diesel Generator [31]