POWER MANAGEMENT IN WIND DIESEL HYBRID SYSTEM WITH BATTERY ENERGY STORAGE

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2015/2016

" I hereby declare that I have read through this report entitle "Power Management in Wind Diesel Hybrid System With Battery Energy Storage" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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Supervisor's Name : ……..

Date : ……..

I declare that this report entitle "*Power Management in Wind Diesel Hybrid System With Battery Energy Storage*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This project is about energy hybrid system for generating electricity. Energy is considered as a major component in the generation and significant factor in economic development. Using a wind turbine as a medium to generate electricity produce no air and water pollution and no greenhouse gasses while producing electricity. The common problem of using a wind as a main energy to generate electricity is the speed of a wind that can't be constant. Sometimes the wind is too strong and sometime the wind will be zero strength. In order to overcome this problem, the hybrid system technologies is use. The expected result was shows the active power and frequency variation of wind diesel hybrid system with battery energy storage. The expected result was defined based on previous research of wind diesel hybrid system. From the result, the conclusion can be made that wind diesel hybrid system much more effective and low in power consumption. As for the recommendation**,** the performance and efficiency of the wind diesel hybrid system will be increases if there is an additional system controller that can manage the power consumption of wind diesel hybrid system. Hence, the improvement can be made in order to achieve the performance and efficiency of the wind diesel hybrid system.

ABSTRAK

Tenaga dianggap sebagai komponen utama dalam generasi dan faktor penting dalam pembangunan ekonomi. Menggunakan turbin angin sebagai medium untuk menjana tenaga elektrik dapat mengurangkan menghasilkan pencemaran udara, air dan tiada gas-gas rumah hijau. Masalah biasa menggunakan angin sebagai tenaga utama untuk menjana elektrik adalah kelajuan angin yang tidak sekata. Dimana ada keadaan angin terlalu laju dan ada keadaan angin terlalu perlahan atau tidak ada angin. Masalah ini dapat diatasi melalui pengunaan teknologi sistem hybrid. Tujuan proses ini dijalankan adalah untuk memantau kuasa dan frekuensi sistem hibrid diesel angin bersama tenaga bateri. Keputusan yang diperoleh telah ditakrifkan berdasarkan penyelidikan yang dilakukan sebelum ini mengenai sistem angin diesel hibrid. Daripada hasil yang diperolehi, kesimpulan boleh dibuat ialah sistem diesel angin hibrid adalah lebih cekap dan rendah penggunaan kuasa berbanding sistem penjanaan lain. Prestasi dan kecekapan system angin diesel hibrid akan meningkat jika terdapat satu sistem pengawal tambahan yang boleh menguruskan penggunaan kuasa sistem angin diesel hibrid. Oleh itu, penambahbaikan boleh dibuat untuk mencapai prestasi dan kecekapan sistem angin diesel hibrid.

ACKNOWLEDGEMENT

Assalamualaikum W.B.T.

Alhamdulillah, I will complete my progress report for PSM 1. First of all, I would like to express my gratitude to Allah The Almighty for giving me the health to complete my Final Year Project successfully. I would like to express my special thank for both my parents for their continuous support and help in order to complete my research. I would also like to express my deepest appreciation and thank to my supervisor, En. Alias Bin Khamis who willing to spare his time in guiding and share his experience for me to complete this research. Without his help, I would not be able to complete this research on time.

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BES	-	Battery Energy Storage
SOC	-	State of Charge
CCI	-	Current Control Inverter
WDHS	-	Wind Diesel Hybrid System
m	-	Meter
s	-	Seconds
FKE	-	Fakulti Kejuruteraan Elektrik
Hz	-	Hertz
Zn	-	Zinc
%	-	Percent
WO	-	Wind Only
DO	-	Diesel Only
WD	-	Wind Diesel

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays the electricity demand among many country has been increase. Because of that, engineer has been introduce the hybrid system technologies to overcome the problem with power system reliability and stability. For a certain areas that is far from the grid such as rural area, the hybrid system with renewable energy sources, like wind energy, biomass, and hydroelectric is the best way to solve the power supply problem. But every generation method has their disadvantages. Like wind energy itself, the main problem of using wind to generate electricity is the velocity of wind that might be unstable. If the speed of wind is at a good circumstance, the wind turbine generator can sustain electricity at a lowest cost possible but if speed is low or not constant there will be a problem to the generation system and become inefficient generation during the cycle.

By using hybrid system technologies such as wind diesel hybrid system the problem can be solve. The main reason why diesel generation is used in this system is to obtain a maximum contribution by the intermittent wind resource to the total produced power thus providing continuous high quality electric power [1]. The battery energy storage is added in the system to prevent reverse power in diesel generator during wind diesel modes. All the simulation and concept will be used Matlab Simulink software for the analysis purpose.

1.2 Problem Statement

The energy demand has increased observably in the past period of time and it is expected to increase even faster and significantly in the near future. The non-renewable sources of energy are a natural resource which cannot be produced and its existence is limited, where the renewable source is a natural resource which can be replenished naturally. The supply of non-renewable sources is quite limited.

That is why modern researchers have been concentrating on non-conventional and renewable resources like wind, solar, biomass, and hydroelectric. By combining any two or more than two energy resources a hybrid power system can be obtained. The hybrid system require to be proved its stability, durability and life cycle. On the previous research related on this topic state that normally domestic load on urban areas demand 25kWh a day. Therefore, the best solution to overcome and provide that big amount of load is by using wind diesel hybrid system for the generation.

1.3 Objectives

The following are the objectives of this project:

1. To study the operation of Wind Diesel Hybrid technologies electricity supply with various condition.
2. To design and simulate Wind Diesel Hybrid System with Battery Energy Storage System using Matlab Simulink software.
3. To analyze the frequency variation of the system in all Wind Diesel Hybrid System condition.

1.4 Scopes

The scopes of this project are:

1. To apply the Battery Energy Storage (BES) in Wind Diesel Hybrid System.
2. Observe the power management of Wind Diesel Hybrid System in deference condition of wind speed.
3. The project has been done using Matlab Simulink Simulation Software.

1.5 Structure of Report

This report contains five chapters covering all details of the project. The first chapter is about the introduction of this project as the project background, problem statement, objectives, and scope. It was followed by Chapter 2 provides a literature review of previous research on Hybrid Systems Wind Diesel (WDHS). Chapter 3 describes the methodology used in the manner or method used in the projects, operations with appropriate description and flow chart. Next, in Chapter 4 describes the data analysis, the results obtained from the simulation project, and discussions on this issue will show and discussed in detail. And for the last is chapter is Chapter 5, which discussion about the results of the simulation project will be concluded by the end of this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter about the general project concept and theory that has been use in the project. The main objective for this chapter is to explain and interpret method use by the former researcher or conference paper that related to this project. Besides that, this chapter will present the solution to troubleshoot the project simulation error and problem. Theoretical information is very important in order to help researcher improve understanding about the research.

2.2 Hybrid System

In engineering dictionaries, the hybrid system is define as a combining or collection of two or more energy of different electricity generation mode either renewable or non-renewable energy. There are various size of the hybrid system that is from a standalone to large centralized electricity grid with different size of power supplies. They are many type of hybrid power system used to generate the electricity such as wind turbine with diesel engine, and solar photovoltaic (PV) with diesel engine. The hybrid power usually used renewable technologies such as wind, biomass and hydroelectric in order to reduce power consumption in other modes of generation and improve system efficiency [2].

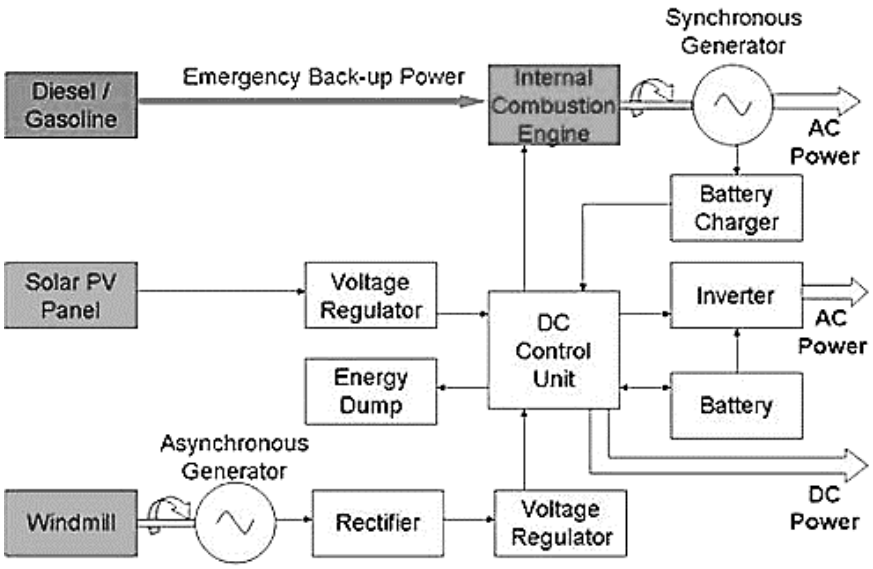

Figure 2.1: Control System for Hybrid Power [7]

2.2.1 Characteristics of Hybrid Energy Systems

The characteristic of the hybrid system that will be use is depends on the requirement needed. The most important characteristic that need to be considered to the hybrid system is whether the system is isolated or connected to the utility grid [3].

2.2.2. Central Grid Connected Hybrid Systems

The voltage and frequency need to be controlled by the utility system to reduce the number of component that need to be used and simplify the design of the hybrid system that is connected through the utility grid same as diesel generator application. The utility grid usually supply a reactive power. When the energy required by the hybrid system is insufficient, the utility grid will provides the energy to the hybrid system immediately. In addition, if anything happen and energy supplied in the hybrid system is exceed to a certain amount of value the excess energy in hybrid system will be absorbed by the utility grid. Thus, the hybrid system

will need an additional component such as system controller to be added in the system to manage the energy and power flow to achieve stability and reliability [3].

2.2.3 Isolated Grid Hybrid Systems

The isolated grid characteristic for hybrid system is against with the hybrid system that is connected to utility grid. The most important specification that have to be considered in isolated grid hybrid system is it must have an enough energy or have a backup system such as battery storage to supplies on the grid no matter in what condition at any time. The hybrid system must be able to control the frequency and voltage for its system and able to provide a reactive power to the system as needed. In some case, renewable energy such as wind turbine generator will produce energy more than the required energy needed. The exceed energy produce from the generator need to be dissipated to make hybrid system stable [4].

2.2.4 Special Purpose Hybrid Systems

There are other characteristic of hybrid system besides isolated or connected to the utility grid. It is used for utilize or specific purpose without use real distribution network. The example of application that use this characteristic is such as water pumping, heating, and grinder. The frequency and voltage in this system is not a general problem in designing this system. In certain condition. Even though the renewable source is temporarily unavailable there are energy needed to be provide to supply the system. Basically renewable generator such as wind turbine and hydroelectric does not running in parallel with the diesel generator [4].

2.3 Wind Diesel Hybrid System

Wind diesel hybrid system is one of type of the hybrid power generation system from a combination of two elements which is diesel generator and wind turbine generator. The main reason of using this type of hybrid system is to reduce the fossil fuels consumption cost in electricity generation while reducing greenhouse gas emissions. Besides, the wind diesel hybrid system is used to solve the problem of irregularities in velocity of the wind in wind turbine generator. Wind diesel hybrid system consists of three main components that is diesel generator, wind turbine, and battery energy storage. Battery energy storage is used as a backup in case if the diesel engine run out of fuel or during the maintenance period of diesel engine [5]. Combining renewable hybrid system with the battery can increase the stability and reliability of the hybrid system.

Ideal design is very important for this hybrid system because it can guarantee battery bank working at best performance at the best condition as possible it can be. In addition, the battery life time can be prolonged to the maximum and energy production cost decrease to the minimum [6].

2.4 Wind Energy

Wind power is the process that convert the kinetic energy that was obtained from the wind into mechanical energy using a wind turbine generator. The mechanical used to produce electricity is called as turbines or power plants but if the mechanical used is based on drive machine the device is called as windmill or wind pump. Even though there are many name, but the purpose of the machine is all same that is to produce electricity. Wind power are widely use in the country that have an average good condition of wind velocity or speed all year such as Denmark, Ireland and Germany. Wind power are widely available and are not limited to the banks of fast flowing rivers, or later and requires no fuel source makes it very suitable for electric power generation [6].

Wind power system depend to a devices such as wind turbine in order to generate clean, and low cost renewable energy. Its means that human can used the wind energy by convert the kinetic energy in wind into mechanical power to produce electric energy [7]. Wind turbine act as a main part to generate electricity using wind energy. It is a machines that have a rotor with three propeller blades that is specifically arranged in a horizontal manner to propel wind for generating electricity. Wind turbines are placed in areas that have high speeds of wind, to spin the blades much quicker for the rotor to transmit the electricity produced to a generator.

Thereafter the electricity produced is supplied to different stations through the grid. One wind turbine can generate enough electricity to be used by a single household. Generally common wind turbine used today are 15m to 30m in diameter and produce approximately 50kW to 350kW. The mechanical power produced by a wind turbine is:

$$P_{T\text{-}MEC} = \frac{1}{2}\ \rho A v^3\ C \qquad \text{Eq (2.1)}$$

P = Power accessible in wind turbine generator.

C = Efficiency factor known as the Power Coefficient.

A = Area of the wind front intercepted by the rotor blades.

p = Density of the air (averaging 1.225 Kg/m^3 at sea level).

v = Wind velocity.

2.4.1 Operation of Wind Turbine

The generator is include with a magnet moving past the stator to generate a current and producing alternating current (AC) electricity. This condition happen when the gear shaft spin the generator. In some case of wind turbine, in order to synchronize the frequency and phase of the grid, the current flow is converted to direct current (DC) using a help from rectifier and converted back to alternating current using an inverter. Even so, normally wind turbine generation nowadays using double fed induction generator that is directly connected to the grid [8].

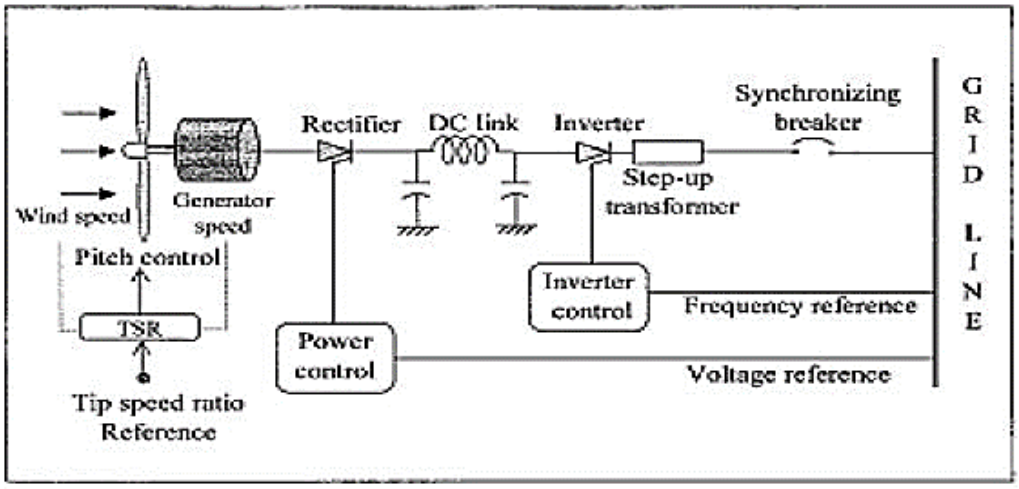

Figure 2.2: Electrical schematic of the grid-connected variable speed wind power system

With the grow in technologies, many design for wind turbine has been introduced. Commonly the design of wind turbine nowadays have the variable of speed. The basic schematic for the wind turbine connected to the grid is shown as in Figure 2.2. The changeable frequency generator is rectified to direct current before inverted back to fixed frequency alternating current. There are inductor and capacitor in order to filter out a rectifier harmonic from the direct current. The grid lines is taken the frequency for the inverter and voltage for the rectifier phase angle control. The value extract from measured speed of the wind and rotor of the system is then compared to the optimum reference value of the tip-speed ratio stored. The velocity of the turbine generator is consequently changing to make the maximum power generate at all condition and time.

2.4.2 Power Curve of Wind Turbine Generator

The Figure 2.3 below showed the characteristic curve for wind turbine between velocity of the wind and the power generate by the wind turbine. So, any relation related to power output produced by the wind turbine generator can be found in the characteristic curve below [8].

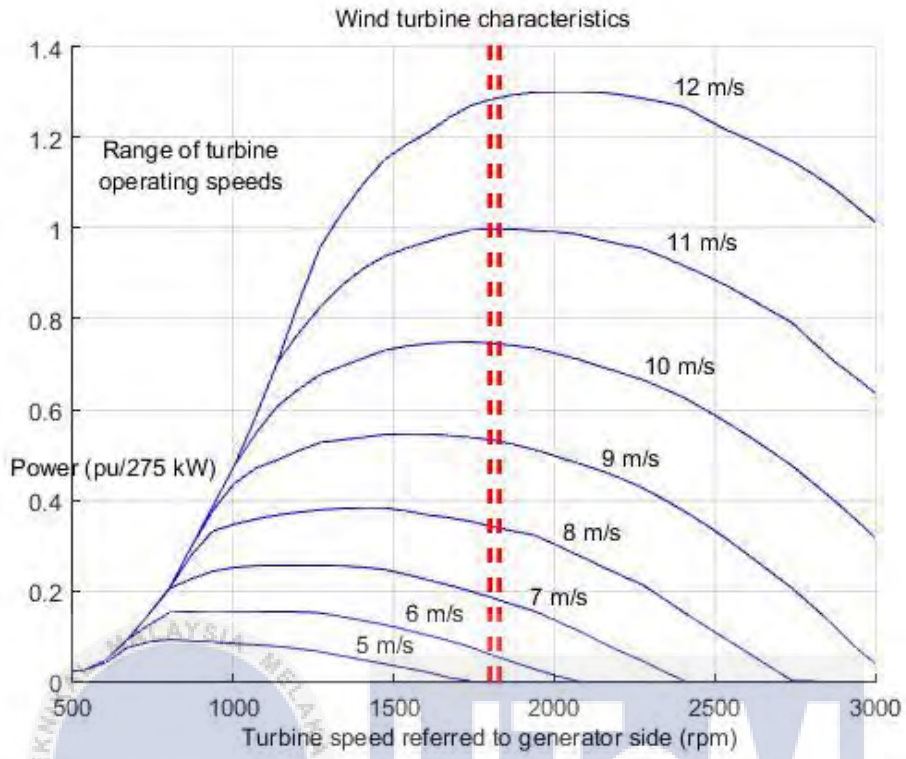

Figure 2.3: A typical wind turbine characteristic curve

This curve comes available from the wind turbine manufacturer or can be plotted by polynomial curve fitting technique using recorded wind speed and corresponding power output data. In order to studies in the relationship of wind turbine, this non-linear relationship can be demonstrated by a function of wind speed, v as following:

$$P = P_{WTG}(v) \qquad \text{Eq (2.2)}$$

Where,

P = Power output of wind turbine

P_{WTG} = The polynomial of wind speed, v.

2.4.3 Advantages Wind Energy

There are so many advantages of wind energy. One of the major advantages of using wind energy is its free and with the modern technology it can be captured efficiently. Besides, when the wind turbine is completely built, it will not produce any greenhouse gases or other

pollutants while producing electricity and at once reducing the global warming problems. The cost of installing and maintenance also relatively low and continue to decrease compare to others renewable energy. The largest wind turbines are capable of generating enough electricity to meet the energy demand of 600 average homes. The wind energy also space efficient as a wind turbine can be placed too close to each other, and the land in between it can be used for other thing.

2.4.4 Disadvantages Wind Energy

However, wind energy is unpredictable. The available of wind energy is not constant. The strength of a wind can be varies from zero to storm force. It's not well suited as a base load energy source. Furthermore, wind turbine give a threat to wildlife such as bird, bats and other flying creature. The creature will have small chances of surviving when taking a direct hit from a rotating wind turbine blade. Wind turbine also produce noise when generate electricity. It is a problem for certain people that live the proximity of wind turbines. Building wind turbine in urban environments should be avoided [9].

2.5 Diesel Generator

Diesel generator is a device used to convert the energy stored in diesel fuel into the electrical energy used by household and industrial devices. Diesel generator consist two main part that is diesel engine and electrical generator. The durability, reliability and the sturdiness of the diesel generator makes it ideal to run for long hours continuously to generate electricity and as a backup in case of power outage or during emergency needed. It is widely used in industrial application because of economical factor and it's environmentally friendly. Diesel generator are being used to supply rural loads are most of the time sized to be able to carry the load even during peak power demand [10].

For safety reason, they are being sized to leave room for upgrades, and they never run at full load and will run around 30% to 60% only due to avoid some mechanical stress. Table 2.1 shows typical fuel consumption figures according to typical manufacturer specifications.

Table 2.1: Fuel consumption according to manufacturer specification.

Generator Loading	**Fuel Consumption (L/h)**	**Fuel Consumption (L/kWh)**
75%	1.98	0.26
50%	1.56	0.31
30%	1.04	0.52

2.5.1 Diesel Engine

Diesel engine is one of the type of combustion engine that is design to produce power. It produce power by burning the fossil fuel, or others fuel inside the part of the engine. Diesel engine convert a chemical energy such as fossil fuel, and diesel to mechanical energy. There are large application of diesel engine nowadays. One of the application is, to as an electric generator to produce electricity.

2.5.2 Operation of Diesel Engine

In the diesel engine there are prime mover that act to rotate the alternator in the generator and generate the electricity. The principle of the diesel engine change over time. Diesel engine work by using the carnot principle. The high air pressure is compressed in the cylinder inside the diesel engine with the injected diesel fuel. After the diesel is injected in the cylinder, the combustion is take places and the energy strength will move the piston in the diesel engine. Piston in the diesel engine will connected to the shaft in order to make the generator work. The generator work by using principle of electromagnetic theory, when the

direct current supply the rotor, the synchronous speed of electromagnetic force induced in static armature.

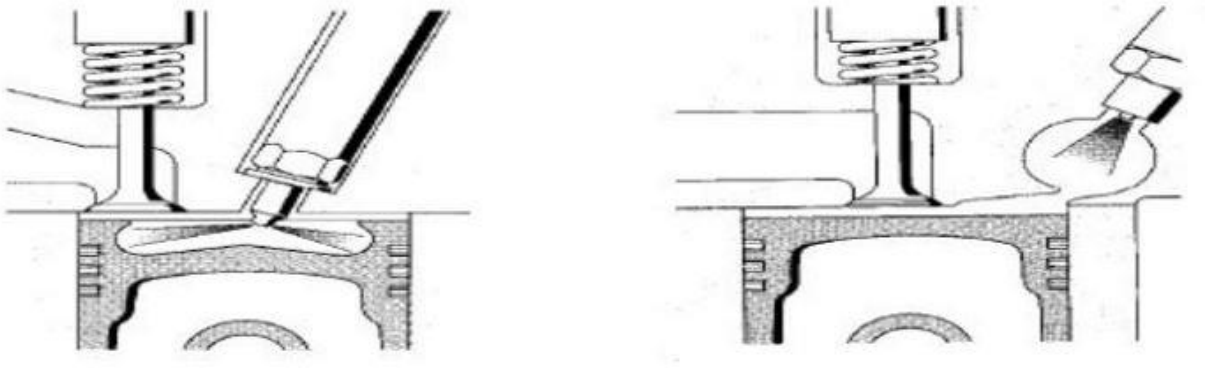

Figure 2.4 Diesel Engine Piston

2.5.3 Advantages Diesel Generator

There are many advantages using diesel generation such as low investment costs, ease of move and generation of electricity on demand, compared to other alternative power supply. They can also be combined with other energy sources and storage systems in hybrid configurations making them well suited for isolated power generation. Nevertheless, diesel generator also more rugged and reliable compare to others. An an example an 1800 rpm water cooled diesel unit operates for 12,000 to 30,000 hours before any major maintenance is necessary. An 1800 rpm water cooled gas unit usually operates for 6000-10,000 hours before it needs servicing. In addition, diesel generator has long life compared to generator that using gas as unit that burn much hotter than diesel generator [10].

2.5.4 Disadvantages Diesel Generator

As for the disadvantages, diesel generator required a continuous supply in fuel for them it's to run, which will increase the cost to generate an electricity. Diesel Generator also need to be run at high loading, close to rated capacities, to allow efficient operation and low

specific fuel consumption. Diesel generator operation can be loud when generate the electricity. It will make diesel generator not very suitable to build in the urban area. Other than that, it will produce nitrogen oxides while producing electricity, at once will pollutes the air of generation area.

2.6 Battery Energy Storage (BES)

Energy storage is a devices or physical media that stored energy to perform useful processes. Battery Energy Storage System (BES) is one of many example of energy storage devices. BES also is a complete energy storage system that integrates battery storage, advanced battery management, power conversion for both charging and generation, and energy management in a fully integrated. BES is applied to maintain the rated frequency during micro grid islanded mode operation. There are two type of BES that are commonly use in the industry that is Lead-acid BES and Lithium-ion BES (Li-ion BES).

2.6.1 Characteristics of the Batteries for Wind Diesel Hybrid Systems

The characteristics of the Battery Energy Storage that need to be considered for Wind Diesel Hybrid System are:

1. Medium and high powers (kW to MW) to make it suitable for Wind Diesel Hybrid System to supplying electricity power to a small communities.
2. Short periods of energy storage (minutes).
3. Have high number of charge and discharge cycles due to the continuous smoothing of the wind power.
4. Have wide range of working temperatures due to the harsh climate in the remote locations of the Wind Diesel Hybrid System.
5. Variable depth of discharge (DOD).
6. Long useful life and disposal with no environmental concerns.
7. Easy monitoring of the state of charge (SOC) [11].

2.7 Review of Previous Related Works

In the previous research, the wind diesel hybrid system concept was found but there are some disadvantage from the research. The research founded was about modeling of a wind diesel integrated system with no storage. In this research, the hybrid system presented comprises of a wind turbine generation system acting as the renewable source of energy and a diesel generation system serving as the conventional source of energy. The researcher controlled the frequency is and generator is was set to start and stop automatically when needed. This methodology can reduces the fuel cost and power consumption of the hybrid system. However there are a few disadvantages of the research, due to no battery energy storage, the result shown in the simulation for voltage per unit is quite higher than hybrid system with battery energy storage. The high consumption in this research make it not suitable for an economical reason.

2.8 Summary and Discussion of the Review

Based on previous research, conclusion can be made that since the wind diesel hybrid system was an alternative way to reduce consumption in fuel and electricity, there are many research have been done to find a better solution to overcome the wind diesel hybrid system problem such as intermittent wind power and high cost of fuel for a diesel generator. From that, there are many ways to prevent this problem, but from the observations, the ideal design is very important for wind diesel hybrid system, which can guarantee battery bank working at the best conditions in all condition.

However, all previous research use the same concept of wind and diesel as a mode of generating electricity. Each previous work have each disadvantage, because of that the main purpose of this project was to analyze the power management of the wind diesel hybrid system with battery energy storage simulation

CHAPTER 3

METHODOLOGY

3.1 System Layout

The schematic system layout using Matlab Simulink is shown in Figure 3.1.

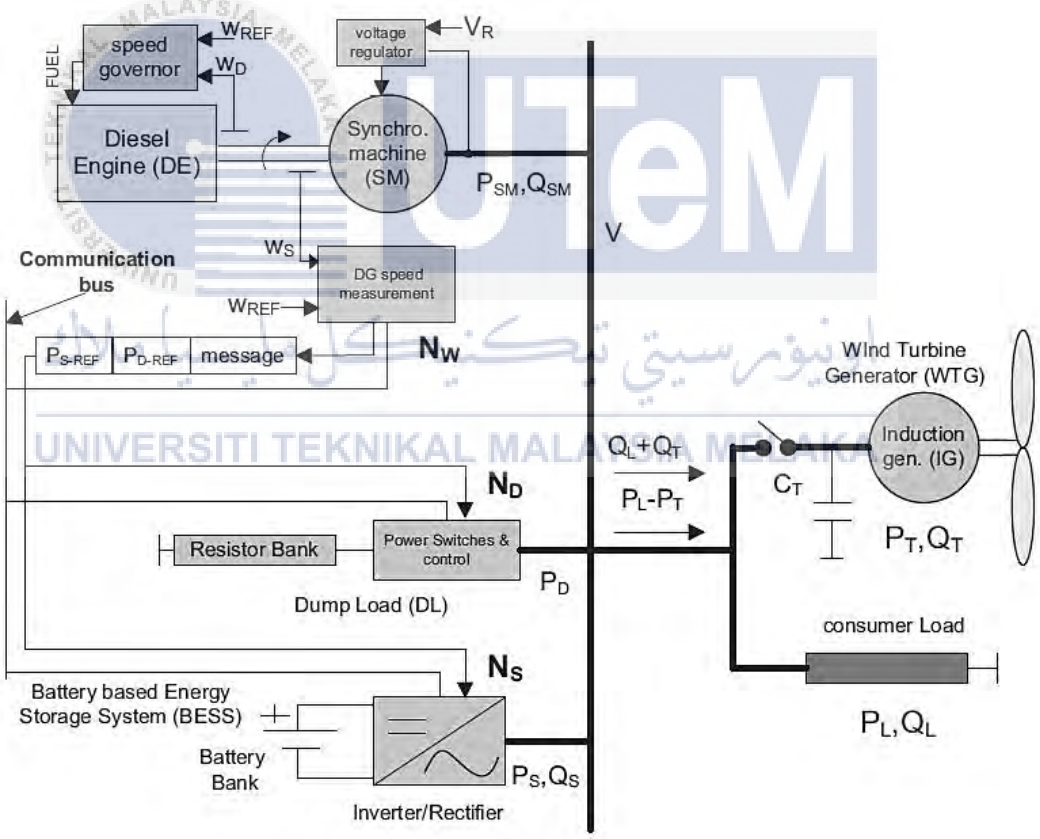

Figure 3.1 Schematic layout of the WDHS

The wind turbine generator consists of a wind turbine driving an induction generator directly connected to the autonomous grid conforming a constant speed stall-controlled wind turbine generator with no pitch control.

With the help of the friction clutch can be locked and not slipping and thus helping to transmit torque to synchronous engine of a diesel engine. The wind turbine generator consists of induction generator which runs as a constant speed controlled system. Compensation capacitor bank acts as a support tool for use by the induction generator reactive power. The dump load which consists of a bank of resistors varies discreetly and is a controllable absorber of active power. Furthermore, depending on operating conditions, a battery energy storage system can act as a source of active power.

When wind power is excess the dump load and battery storage will perform the balance of power immediately by loading. The load power (P_L) must be smaller than the power generated by the wind turbine generator (P_T) and power battery energy storage system ($P_{S\text{-}NOM}$). When the constraint does not meet then the distributed control system starts the diesel engine leading to wind diesel. In this report it is assumed that the battery energy storage system operates at unity power factor.

3.2 Flow Chart of Methodology

The flow chart in Figure 3.2 describes the agenda or tasks that should be done at each stage of the project. It is very important to ensure the projects completed in the given time with successfully result.

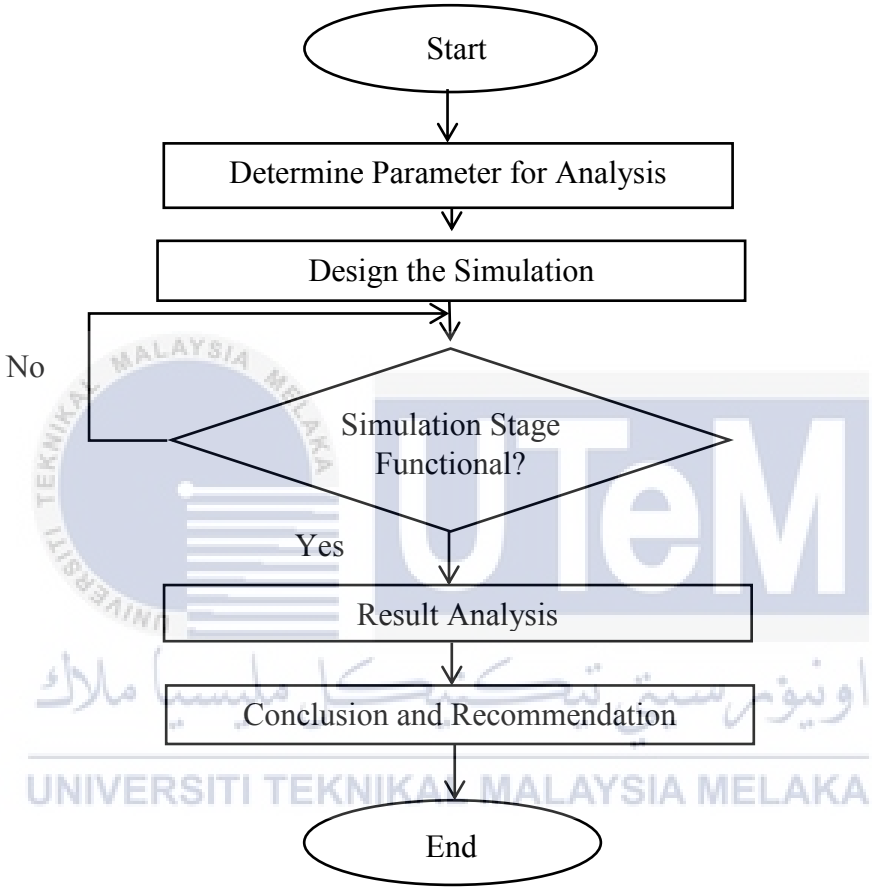

Figure 3.2: Flow Chart of Methodology

3.3 Simulink Model

The Simulink model is shown in Figure 3.3.

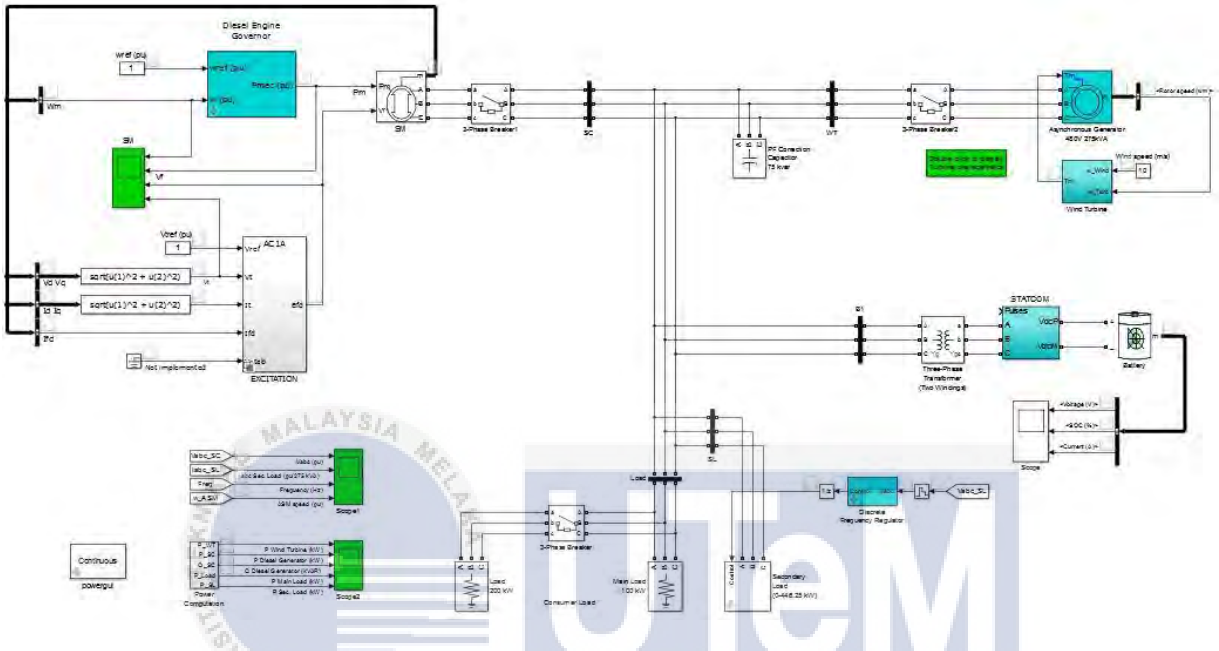

Figure 3.3: Simulink Schematic

Figure 3.3 shows a Matlab Simulink model of wind diesel hybrid system. Some components of the generator system that will be described is induction generator, synchronous machines, voltage regulators and consumer load is include in the block library for Simulink SimPowerSystem.

The diesel engines with a speed controller included in the diesel engine block as shown in Figure 3.3. This block has the current synchronous machine speed (pu) as input and outputs the mechanical power (pu) to take the diesel generator speed to 1 pu speed reference. Diesel generator is simulated using the gain, the rate of fuel to torque, and a dead time, and the firing delay between the piston models. The diesel generator torque has 0/1.1 pu as the lower/upper limits respectively and is multiplied by the synchronous machine shaft speed to calculate the diesel engine output mechanical power. The actuator has been simulated as a second order system and the speed regulator is a PID control. The block diagram in Figure 3.4 is combine

into 1 submodule to become current control inverter (CCI) for battery energy storage system (BESS).

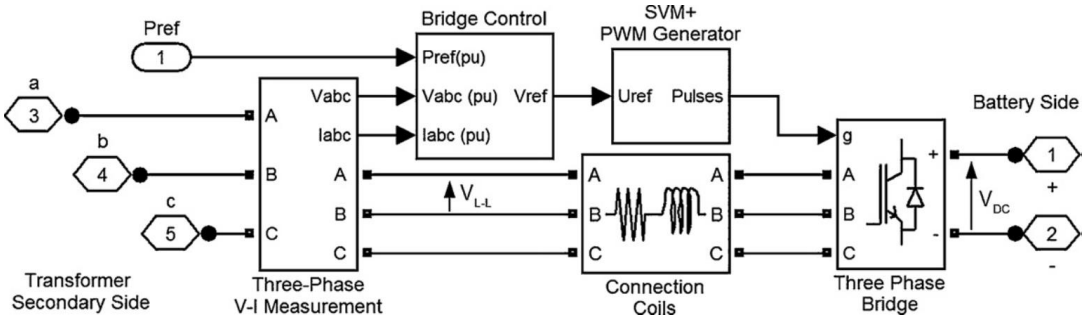

Figure 3.4: CCI Simulink - SimPowerSystems schematic.

The current control inverter (CCI) is used in this simulation to absorbed power from the isolated grid. It also function as a device to charging the battery. In addition, CCI can control the reactive power it consumes and produces its reactive reference power to zero.

Frequency error (e_f), and reference power (P_{REF}) from the frequency regulator is absorb by the secondary load with the combine by the battery storage to supply the system thus balanced the active power and stability of the system. The frequency of frequency regulator can be relate as:

$$e_f = f - f_{NOM} \quad \text{Eq (3.1)}$$

f_{NOM} = The power system rated frequency and f the current system frequency

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter consists of result and discussion of the performance of wind diesel hybrid system with battery energy storage. The data are recorded and graphical result of the experiment is shown.

4.2 Simulation Results and Analysis

The parameter of wind diesel hybrid system in this report is set related by the previous research. For a synchronous machine it use voltage of 480V and rated power of 300kVA, wind turbine run in 480V and 275kVA for induction generator. Consumer load is set to 100kW at the initial condition. During the low speed condition the induction generator and synchronous generator is provide the power for the load. If the wind turbine generator power is exceed the load, it is suggest to shut down the diesel generator to reduce the power consumption

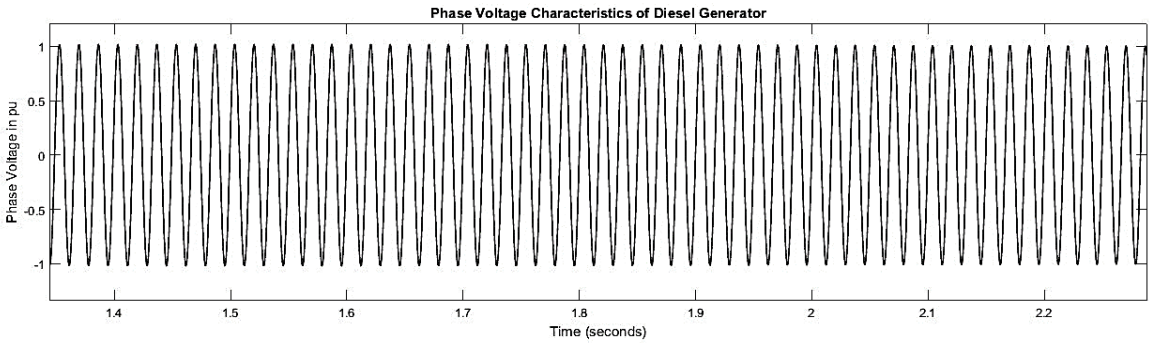

Figure 4.1 Phase Voltage of Diesel Generator in pu

The simulation is run in 3 mode that is Diesel Only (DO), Wind Only (WO), and Wind Diesel (WD) mode. The mode is trigger by 3 phase breaker. During the DO mode, the Diesel Generators supply the active and reactive power demanded by the consumer load. Figure 4.2 showed the active power produce at the main load during DO mode.

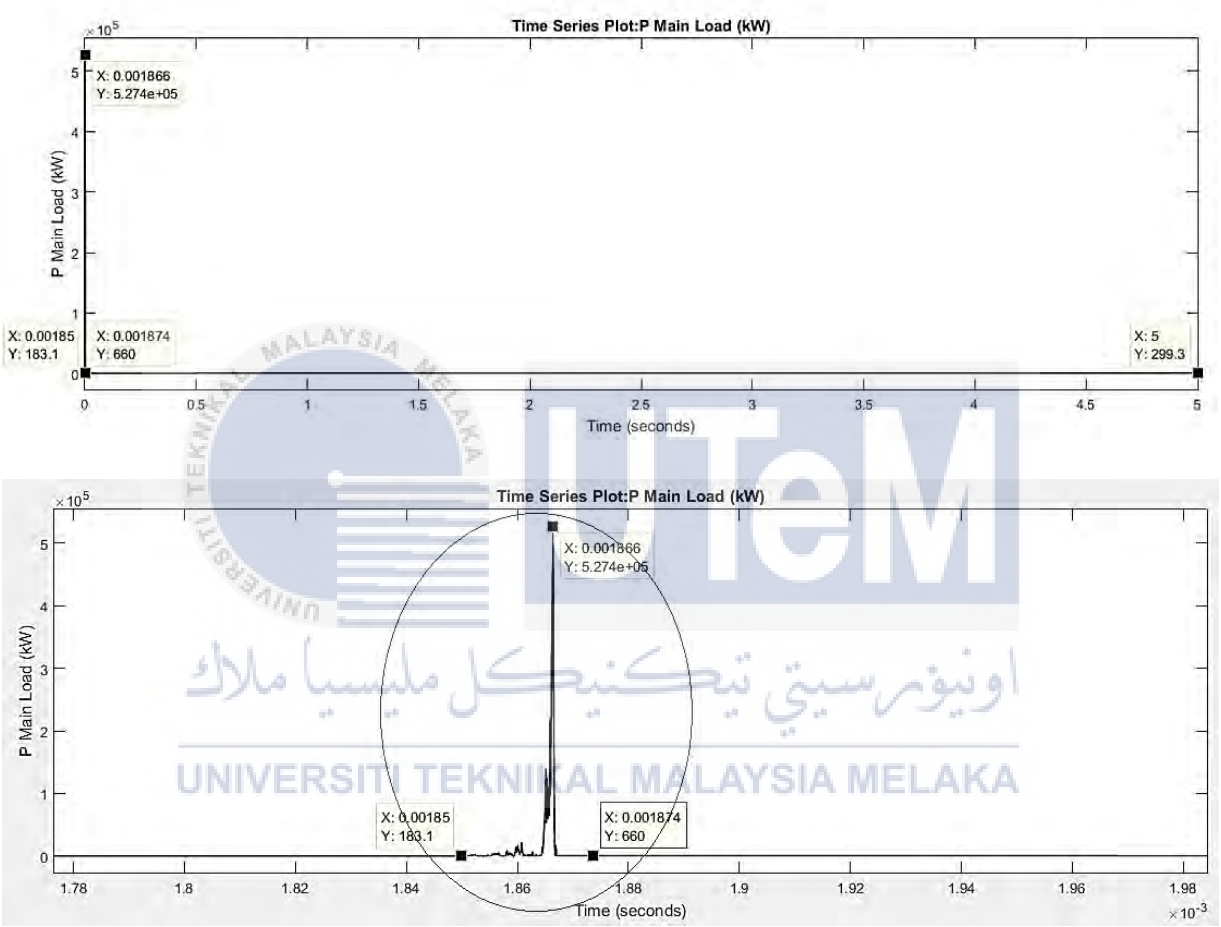

Figure 4.2 Active Power at main load during DO mode

The main load is assumed to consume 100KW. Under this condition the energy produced by the diesel generator is sufficient to meet the load demand. At time 0.5 seconds the three phase breaker is switched on adding an additional 200KW of consumer load. Due to the losses the total active power produce by the main load is not exactly 300kW but 299.3kW. There are spike in the active power graph at 1.84 second. This high spikes are a result of high

inrush current for synchronous motor start-up. The wind turbine will not generate power and set to open circuit during this mode as showed in Figure 4.3.

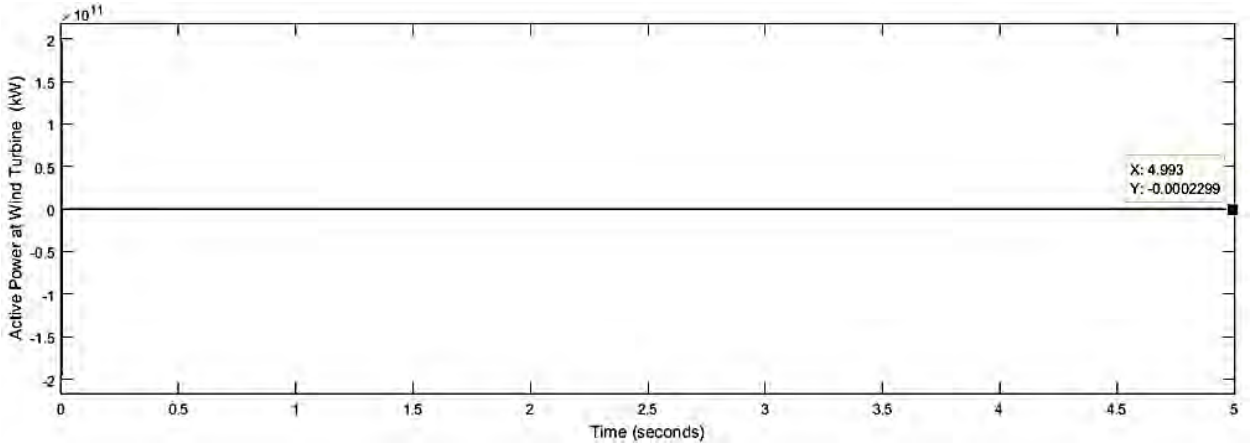

Figure 4.3 Active Power at Wind Turbine during DO mode

The WO mode is simulate in two condition of wind speed that is 10m/s and 3m/s. There are a big differences in an active power produce by both condition. During this mode Diesel Generator will not generate any power and set to open circuit. There are only a small difference in active power for both condition during this mode. Both condition of wind velocity does not have enough power to supply the load at time of the simulation run at 0.5 seconds where additional load of 200kW is adding in consumer load as showed in Figure 4.4.

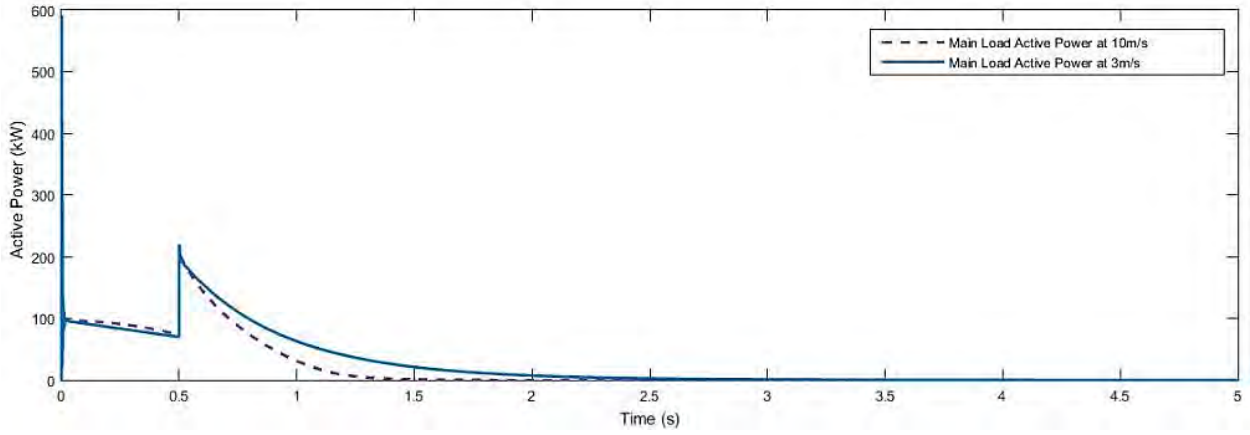

Figure 4.4 Active Power at main load during WO mode

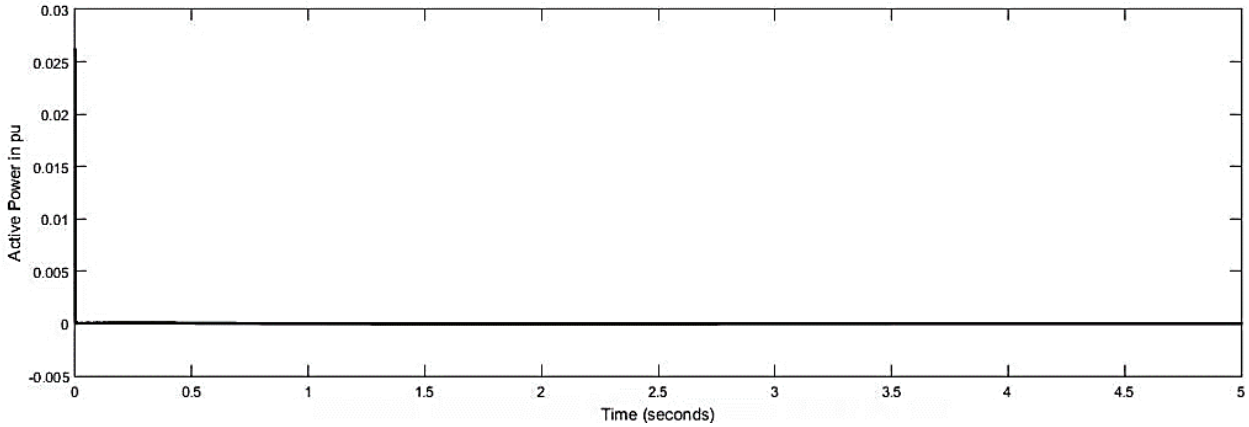

Figure 4.5 Active Power in pu at Diesel Generator at both condition during WO mode

In WD mode, the Wind Turbine and Diesel Generator supply active power and Wind Turbine normally consume reactive power. Both of the supply, Wind Turbine and Diesel Generator is run simultaneously to supply the load. The result for the active power produce by the main load is showed in Figure 4.6.

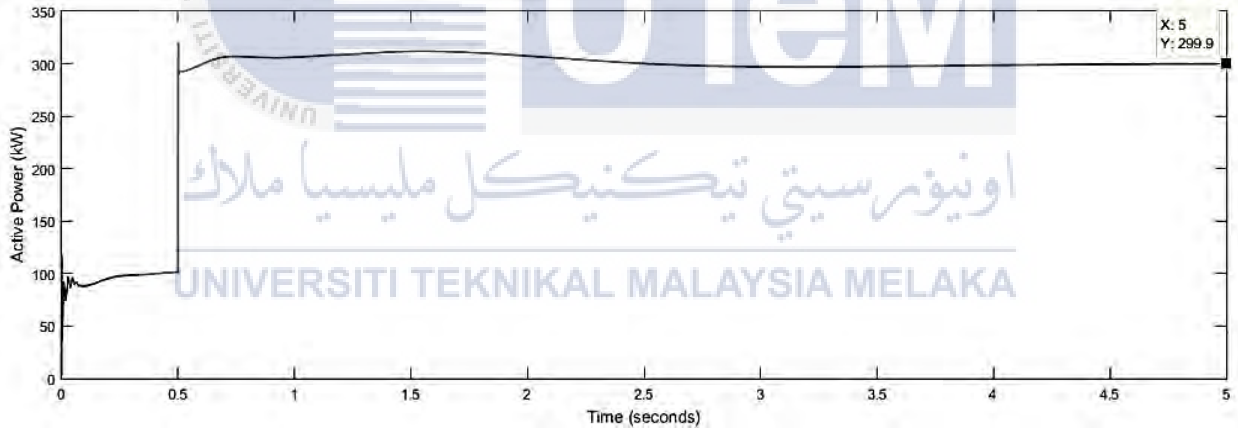

Figure 4.6 Active Power at main load during WD mode

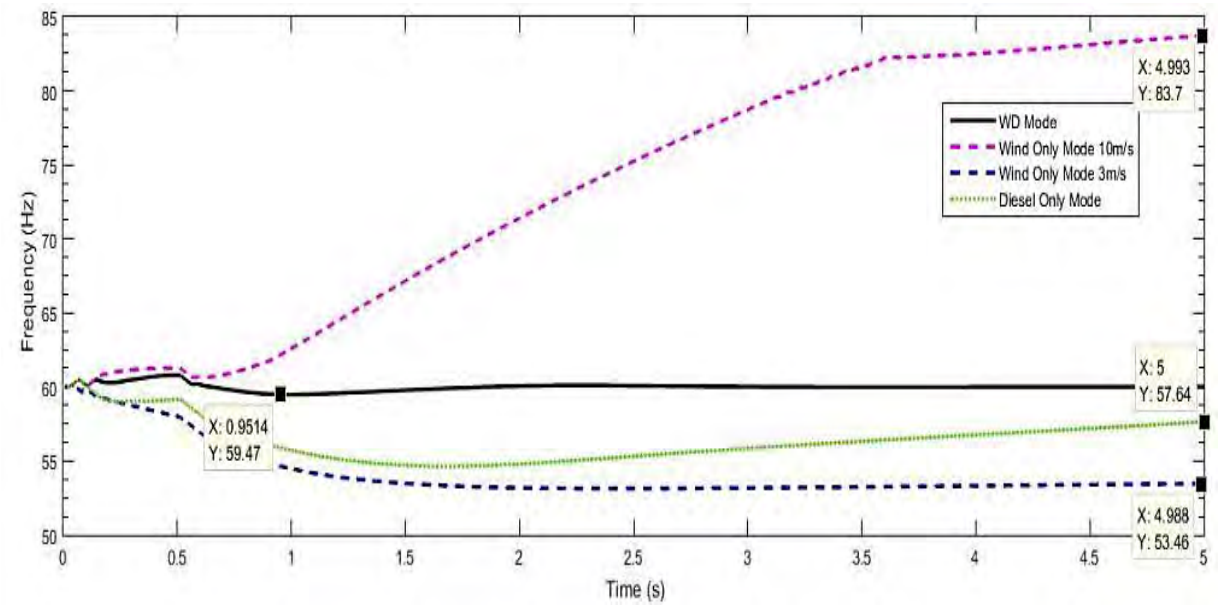

Figure 4.7 Frequency variation Wind Diesel Hybrid system

According to turbine characteristics, for a 10 m/s wind speed, the turbine output power is 0.75 pu (206 kW). Because of the asynchronous machine losses, the wind turbine produces 200 kW. As the main load is 100 kW, the secondary load absorbs 100 kW to maintain a constant 60 Hz frequency. The comparison of frequency variation between three modes is shown in Figure 4.7. The trend in system frequency is a measured of mismatch between demand and generation. The change of the frequency system are an unavoidable result of changing a demand. As for the WD mode the frequency momentarily drops to 59.47 Hz and the frequency regulator reacts to reduce the power absorbed by the secondary load in order to bring the frequency back to 60 Hz. With a sudden increase of more load the current will increase. This will cause a reduction of terminal voltage because of the generator's internal impedance. In WO mode at wind speed 10m/s, the frequency increased far from its initial value that is 83.7 Hz because of the generation is exceed the load. It is consider the turbine generator is ideal and run in full speed during the cycle in the simulation but in the real condition, it is hard to maintain the speed due to velocity of wind that might be unstable. The frequency suddenly drop to 53.46 Hz at the 3m/s wind speed condition, because of the load is greater than a generation. The overload effect the frequency of the system by drain a rotational energy from the generator set thus slow it down. In DO mode, frequency also decrease but the value is not far from its initial value that is 57.64 Hz.

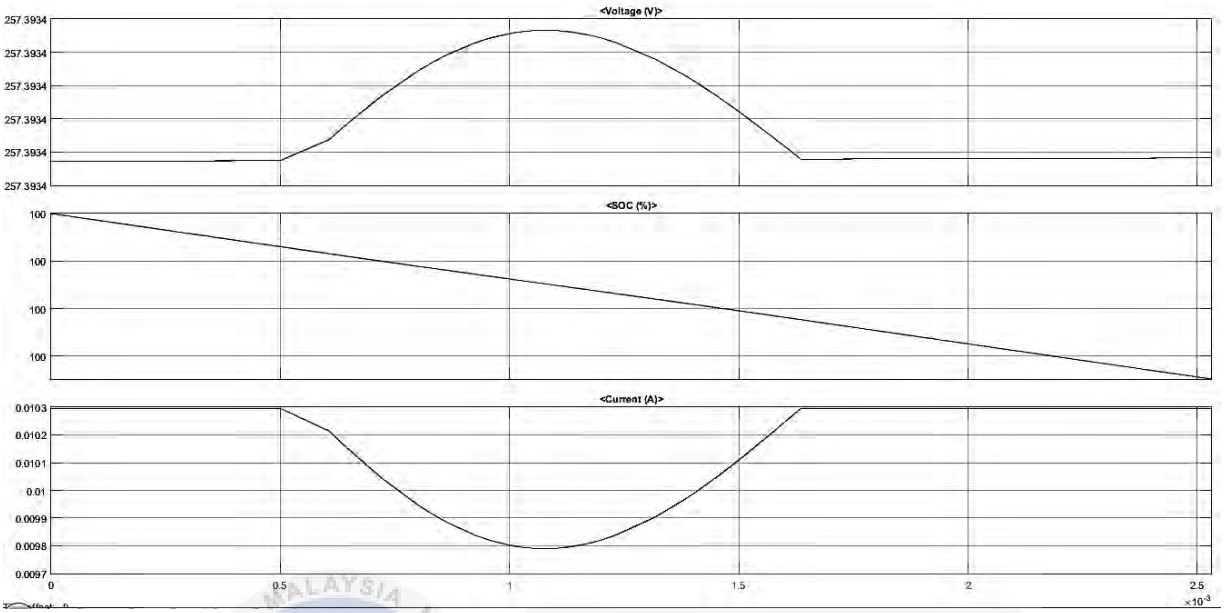

Figure 4.8 BES voltage, current, and state of charge

The battery current is considered positive if the battery is discharging and negative if charging. Figure 4.8 shows that the battery current resembles a scaled version of the BES active power due to the almost constant value of the battery voltage during the simulation. The current peak is 0.0103 (discharging) during the 300 kW load step. The steady state current values for both steps are 0 since the system reaches the equilibrium. The battery SOC, initially set at 50%, barely changes due to the short simulation time and its relatively great capacity. The variations of the normalized battery voltage during the test are small from 240V to 256.95V. These variations follow the current variations due to the internal battery resistance since SOC variations are negligible. The highest voltage is due to negative peak current after the 3m/s wind step.

CHAPTER 5

CONCLUSION AND RECOMMENDATON

5.1 Conclusion

The project scope was to design a wind diesel hybrid system with battery energy storage for a commercial used. In addition, the project was to studies the frequency variation in a wind diesel hybrid system simulation. The wind diesel hybrid system was tested for consumer load and wind speed steps. The result shown in this report was compared the frequency between four condition that is Wind only (WO) for two condition of wind velocity, Diesel only (DO) and Wind Diesel (WD) condition. The objective has been achieved to analyze the frequency variation of wind diesel hybrid system from the result obtained. All the design was carried out using Matlab Simulink simulation software for power system analysis. The wind diesel hybrid system was very useful in the power system to make the most available renewable energy and hence get the benefit to the environment.

5.2 Recommendation

As for the recommendation**,** the performance and efficiency of the wind diesel hybrid system will be increases if there is an additional system controller such as frequency controller that can manage to adjust the frequency for the generator when suddenly load was added to wind diesel hybrid system. Hence, the improvement can be made in order to achieve the performance and efficiency of the wind diesel hybrid system in the future.

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APPENDIX

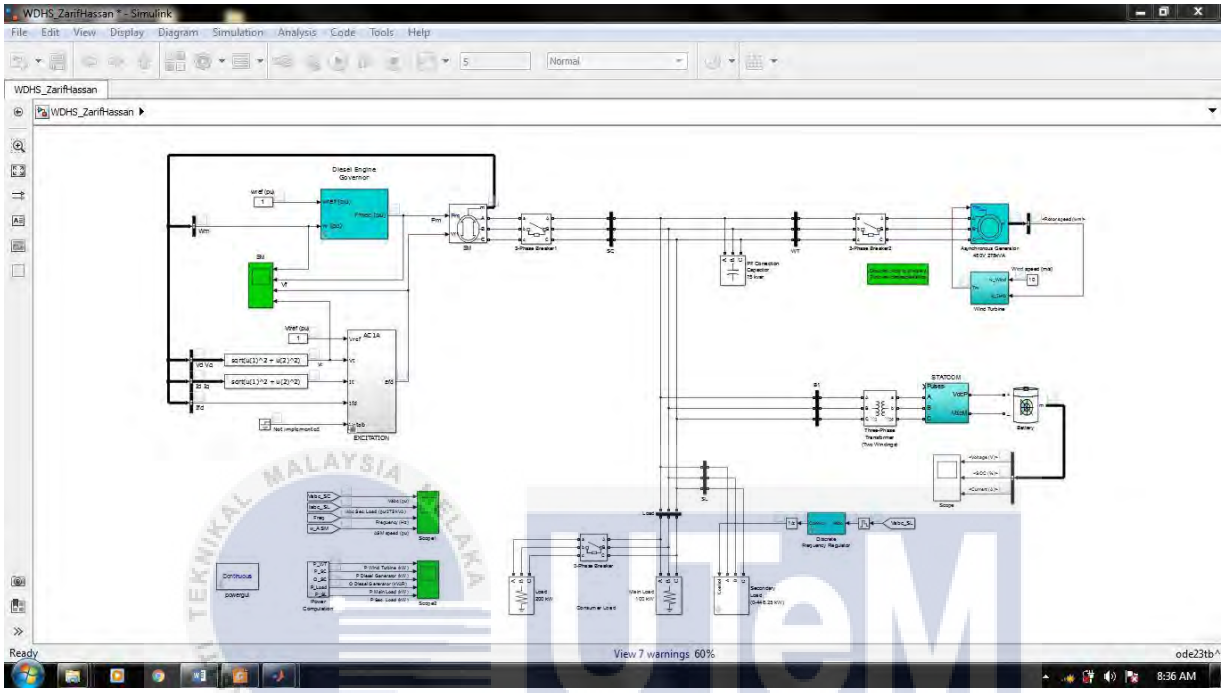

Figure 7.1 Simulation Circuit using Matlab Simulink

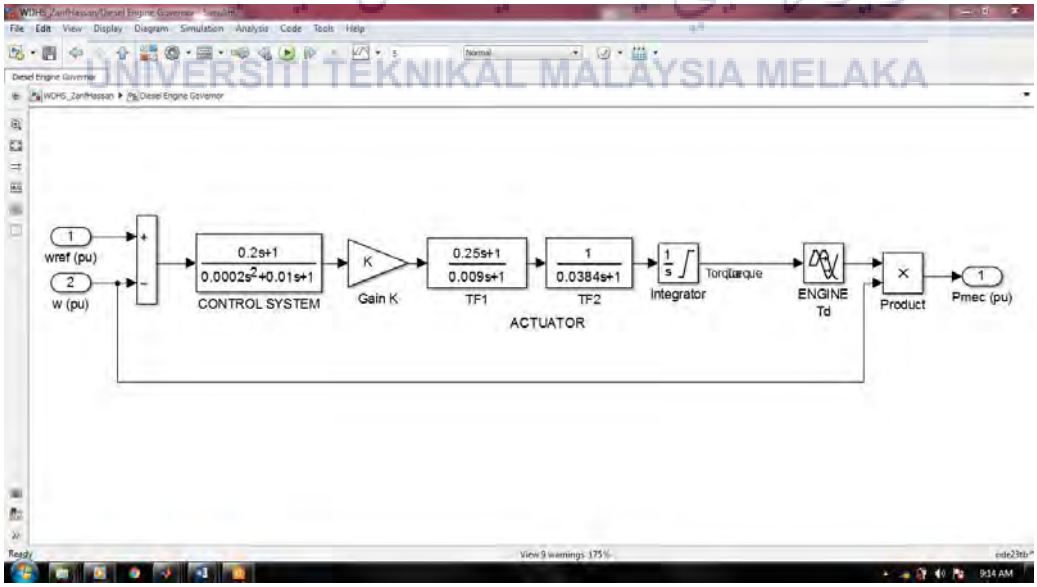

Figure 7.2 Diesel Engine Block Diagram

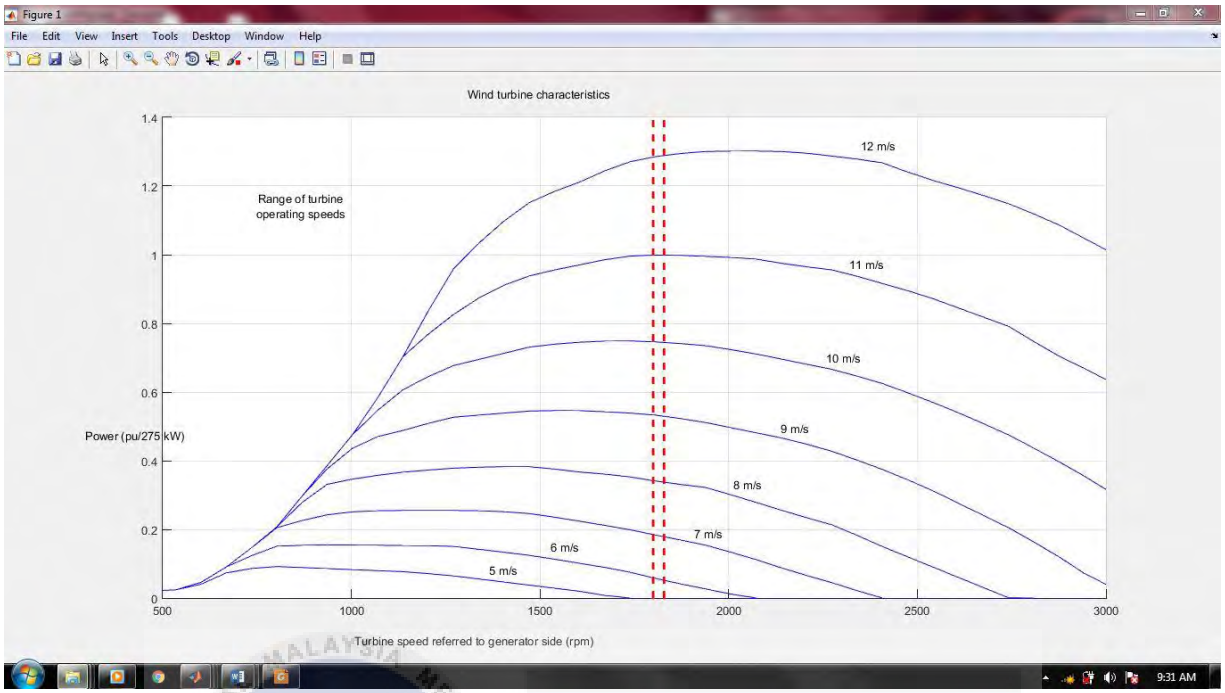

Figure 7.3 Wind Turbine Characteristic curve

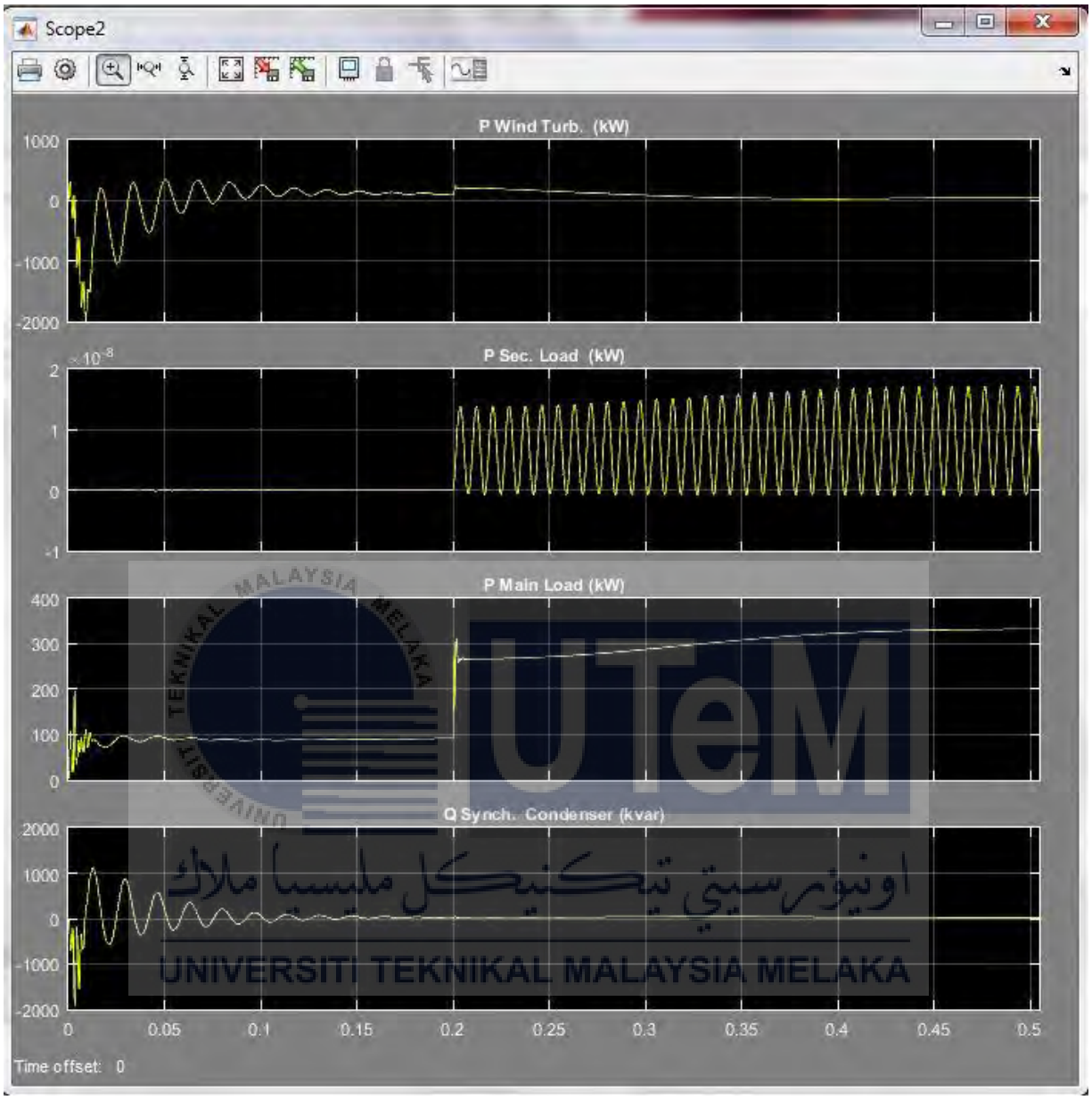

Figure 7.4 Simulation Result (a)

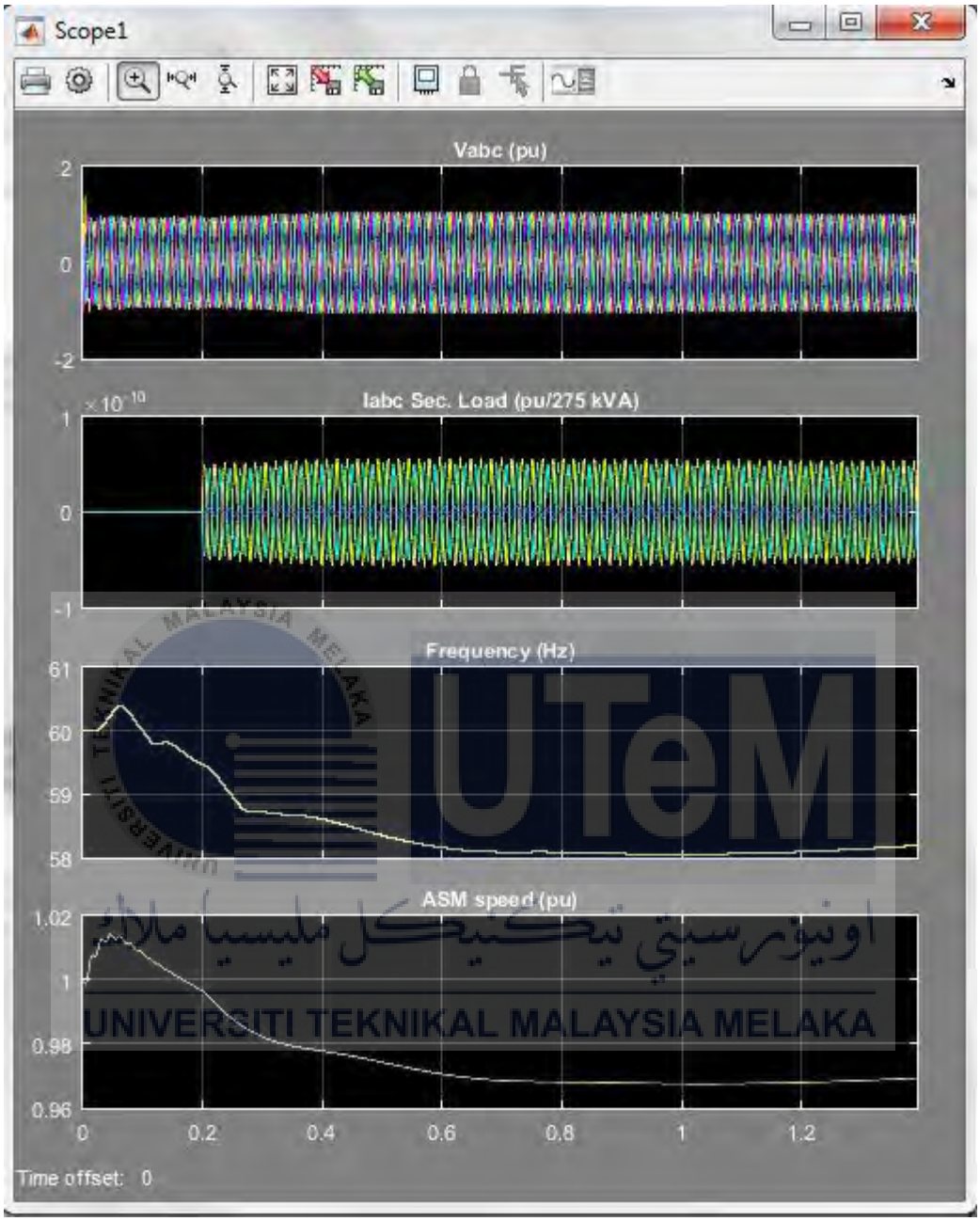

Figure 7.5 Simulation Result (b)

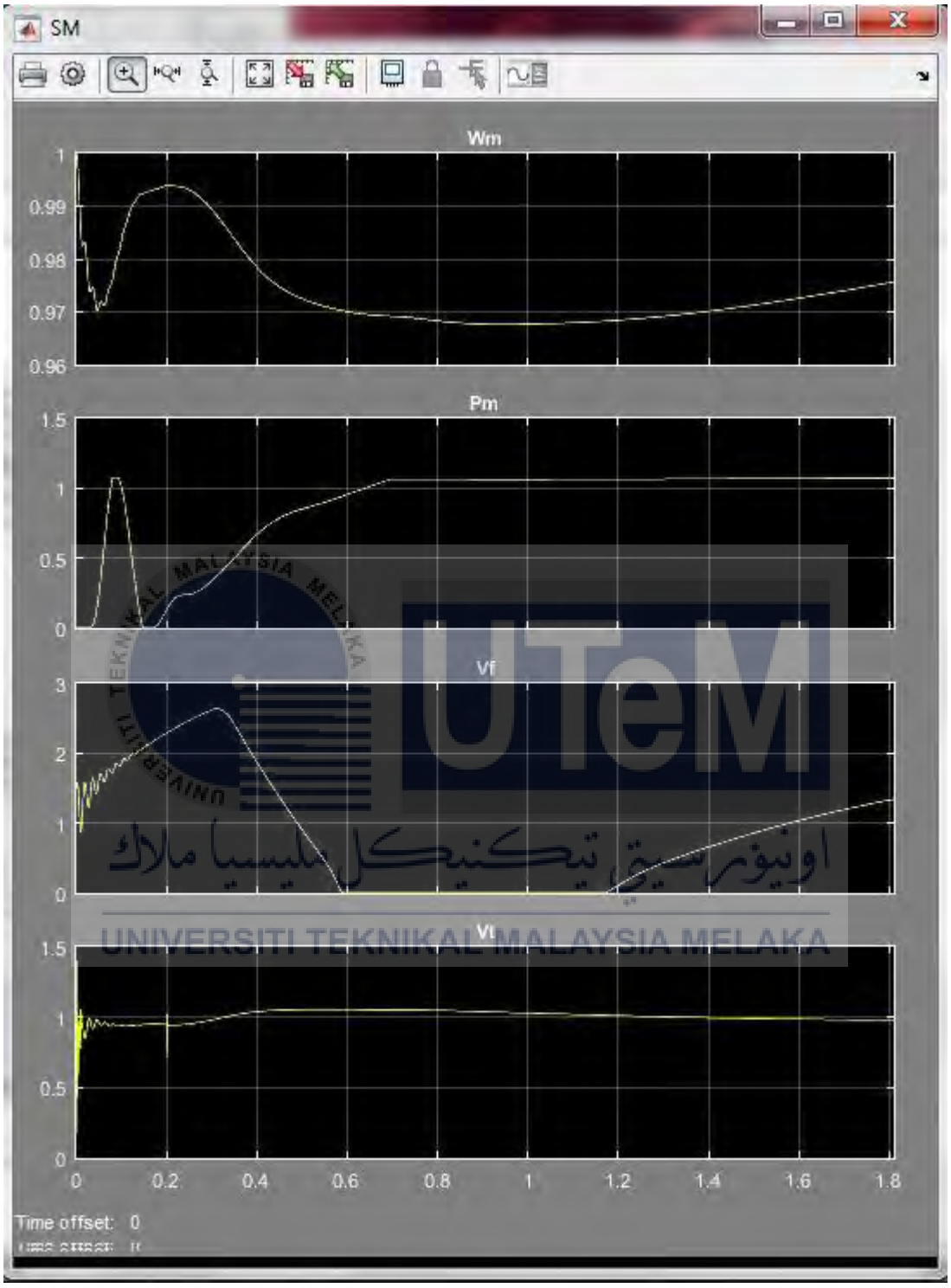

Figure 7.6 Simulation Result (c)