Modeling and Analysis Microturbine and Battery Storage System Microgrid System Based on Green Energy

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***Abstract*— Nowadays, many countries have shown their interest in distributed generation technology. Recently, there are many problems with the power system. One of the problems is high electricity price. The price in power generation relies largely on the type and market price of the fuel used, government subsidies, government and industry regulation, and even local climate patterns. Other than that, the usage of fossil fuel needs to be reduced as its usage results in smog and acid rain, which eventually lead to the greenhouse emission and changes in earth's climate. To supply a better power system, this research introduces a model of MicroTurbine (MT) and battery storage MicroGrid (MG) system based on green energy. The small-scale MG is widely used in power generation system. MG can operate with renewable and non-renewable energy. Through this project, MG will be modeled by using MT as Distribution Generation (DG) and battery storage system as Distribution Storage (DS). The MG system will be simulated using MATLAB Simulink. The MG system will be analyzed in grid connected or grid-disconnected mode. The simulation shows the results of different modes of MG system. The factors and causes affecting the MG system will be discussed.**

***Index Terms*—Battery Storage; Microturbine; Microgrid**

I. Introduction

Distributed Generation (DG) and Distributed Storage (DS), which are included in the Distributed Energy Resources (DER) act as sources of energy located near local loads. It can give many benefits if this system functions properly in the electrical distribution system. Microgrid (MG) is a system contains at least one type of DER and associated load. It can form intentional islands in the electrical system. DG technologies, such as Microturbines (MT), Photovoltaics (PV) and fuel cells are gaining a broad range of attention as the DG technologies have many benefits: They are well-founded and have a better condition for power supply and environment protection, as well as the ability to reduce energy usage. However, DG technologies have several bad consequences, for example, some parts of the network comprising sufficient generating resources tend to operate in isolation from the main grid, in a restricted and restrained way [1].

MG is a small-scale technology widely used in power generation system. A fundamental capacity of MG is to increase the less dependent energy supplies by ensuring it is not connected to the grid, in case of network faults. In future, MT based on DG will have a significant role in this distribution network. The generation of MT has the potential to give excellent impact in terms of system management and planning. There are two different types of MT designs, which are the single shaft design and the split shaft design. The DS technologies are also used in MG applications, where the generation and loads of MG cannot be matched. It gives a link in meeting the power and energy requirement of the MG. There are many forms of energy storages, such as batteries, supercapacitors and flywheel.

II. Design Microgrid System

A. Design of Microturbine System

A review of literature has been conducted to address the problem identified and possible answers for the identified problem. The first stage of the research is to conduct a literature review drawn from journals and past research papers obtained from IEEE website. When conducting a literature review, the first important step was to master all the definitions and the basic knowledge regarding MT and battery storage system. First, the review focused on information of MT system followed by the operation of MT. Then, an analysis of MT in distributed energy resources was carried out. The second focus is the battery storage that can be used as DG power. There are many types of batteries, and each has its own advantages and disadvantages. Finally, the third focus of the review is the effect to the MG system when the system is either in grid-connected or grid-disconnected mode. These types of mode will affect the MG system with respect to the changes of voltage, current, power and frequency.

Figure 1 shows the subsystem that consists of MT. As shown in Figure 4, the MG system that consists of MT is connected to the grid, in which the MT is in grid-connected mode. The three-phase source is used as the source for the transmission line. The three-phase transformer is used to step-up or step-down the voltage and current, while the three-phase load is used as resistance or load demand. Figure 2 shows the PMSM block. It can operate either in generator or motor mode. If the PMSM is operated as a generator, the mechanical torque will be negative, and if the PMSM operates in a motor mode, the mechanical mode will be positive. The sinusoidal model assumes that the flux established by the permanent magnet in the stator is sinusoidal, so the electromotive forces are also sinusoidal.

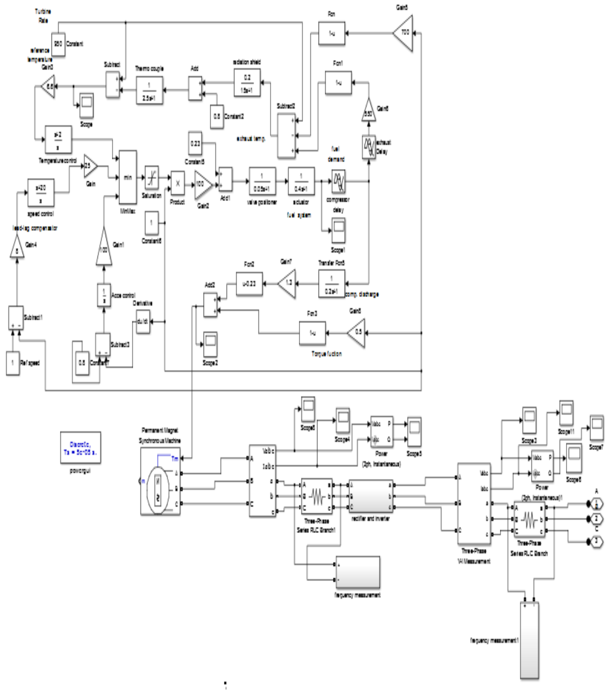

Figure 1: Design of MT

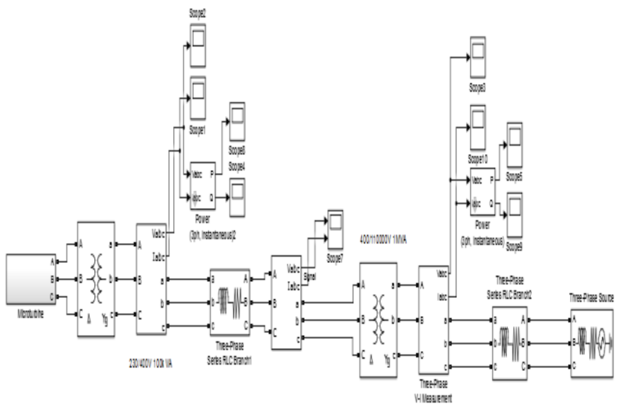

Figure 2: Design of Microturbine Microgrid System

B. Design of Battery Storage System Microgrid

The model of battery stack is designed based on the example on MATLAB Simulink. The battery used for this design is Lithium-ion. Figure 4 shows the block parameter of the battery. The nominal battery voltage was set to 400V (DC) and 50Ah and the state of charge was set for 100%. The three-phase inverter is shown in Figure 3. The power electronic used for the inverter is MOSFET. All of the power electronic devices in this inverter are operated simultaneously in this simulation. The function of the inverter is to invert the DC to AC voltage.

The battery storage MG system is shown in Figure 8. From this design, there is an inverter to convert DC voltage to AC voltage, three-phase transformer to step-up and step-down the voltage and current and three-phase series RLC load. The three-phase source, known as the grid was used as the source for the transmission line.

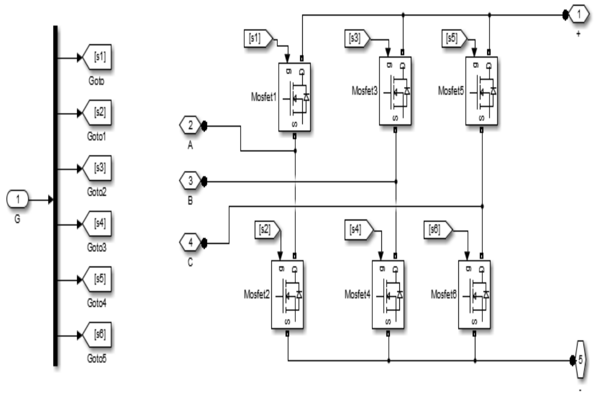

Figure 3: Three-Phase Inverter

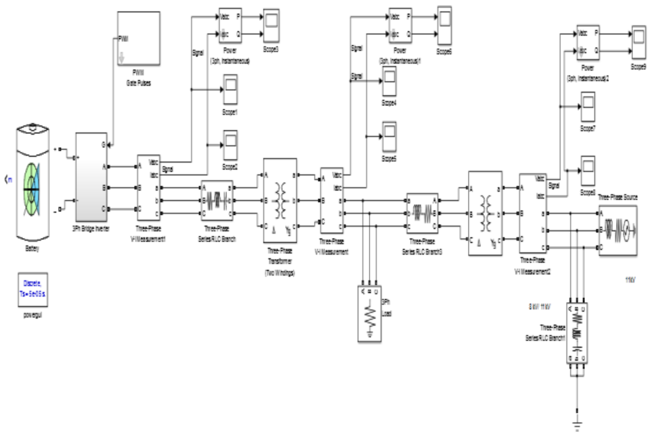

Figure 4: Design of Battery Storage Microgrid

C. Design of Microgrid System in Grid-Connected Mode and Grid-Disconnected Mode

Figure 5 shows the distributed generation of MT and battery storage system, which is connected to the grid. Each distributed generation is connected to delta-wye transformer to step-up the three-phase voltage and current. The grid is connected to a delta-wye transformer to step-down the three-phase voltage and current. This power system is connected to the load and supply the load demand. This power system is running for two seconds. The three-phase voltage and current are measured by three phase VI measurement block. Meanwhile, the active power and reactive power are measured by power measurement block. The frequency at the load is measured by frequency measurement block. The rectifier and converter were used after MT subsystem. Its function is to ensure compatibility in voltage and frequency with the electronic power system to which it is connected and contain necessary output filter. The filters used are LC filter, which functions to filter noise to obtain synchronous voltage and frequency. The use of inverter after battery storage system is to convert DC voltage to AC voltage.

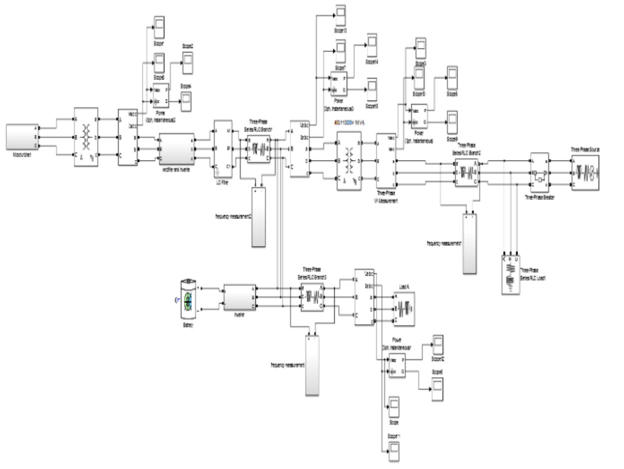

Figure 5: Design of Microturbine and Battery Storage System Microgrid

III. RESULT AND DISCUSSION

A. Grid Connected Mode

For the grid-connected mode, the breaker is closed. The voltage of MT is at 40 V, which is then step-up to 60 V. The active power of MT is 80 W, in which after the step-up, the active power is at 50W. The voltage of the battery is 240 V. The active power of the battery is 2620 W. The frequency for this system is 50.04 Hz. Figure 20 shows the frequency during the grid-connected mode. The results obtained from this simulation are shown in Figure 6.

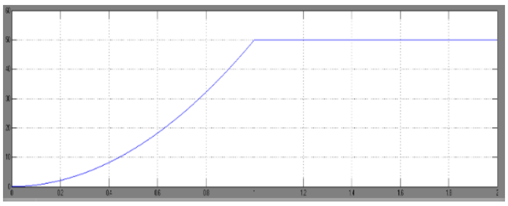

Figure 6: Frequency in grid-connected

For 415 V Distribution System:

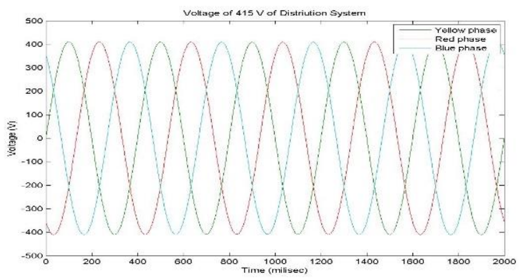

Figure 7: Three-phase primary voltage

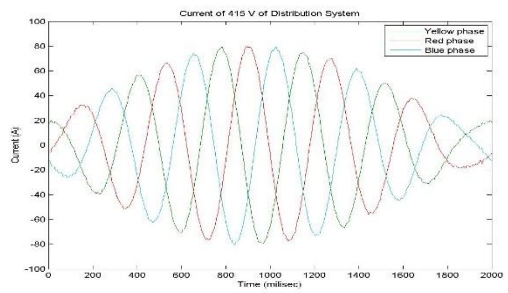

Figure 8: Three-phase primary current

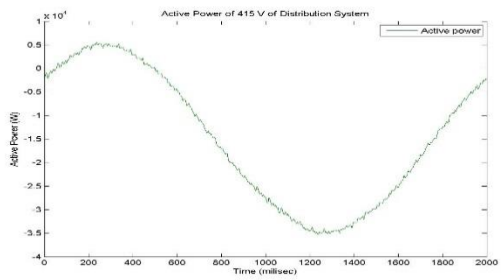

Figure 9: Primary active power

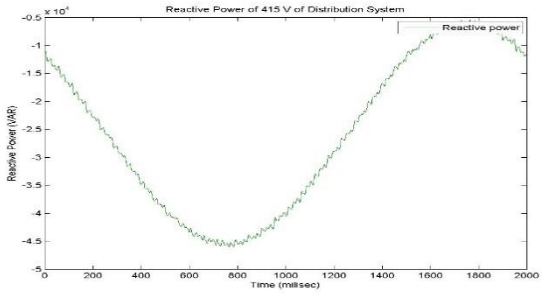

Figure 10: Primary reactive current

As shown in Figure 7, the three phase primary voltage is 415 V, while in Figure 8, the three phase secondary current is 80 A. Figure 9 shows the active power is 5000 W and Figure 10 shows the reactive power is -5000 VAR. This result is shown at 415 V of the distribution system.

For 11 KV Distribution System:

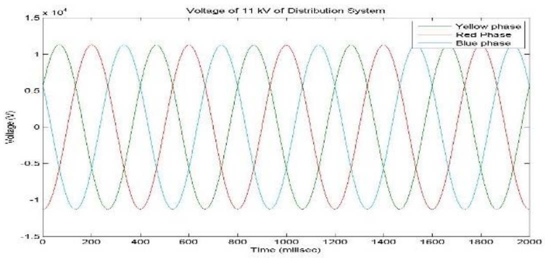

Figure 11: Three-phase secondary voltage

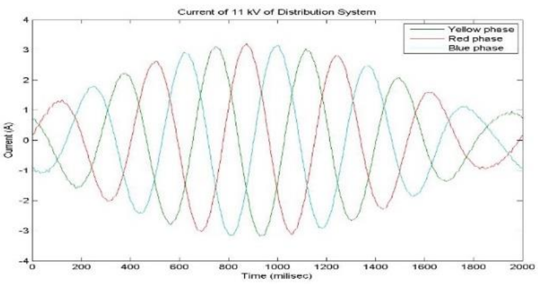

Figure 12: Three-phase secondary current

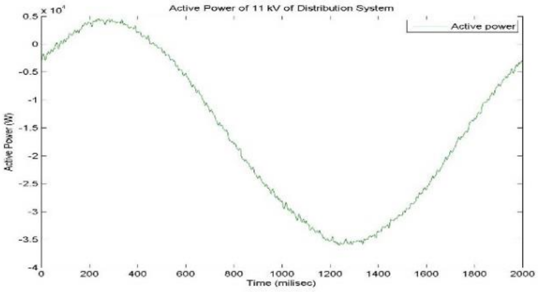

Figure 13: Secondary active power

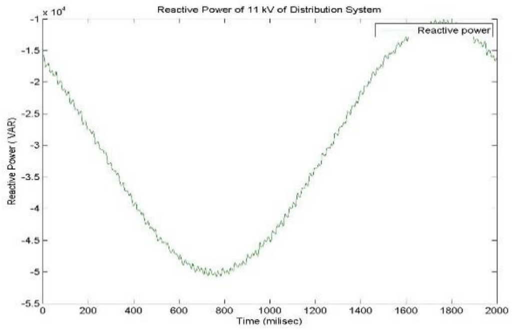

Figure 14: Secondary reactive power

Figure 11 shows the three phase primary voltage is 11 kV and Figure 12 shows the three phase secondary current is 3 A. Meanwhile, Figure 13 shows that the active power is 5000 W and Figure 14 shows that the reactive power is -10 kVAR. This result is shown at 11 kV of the distribution system.

B. Grid Disconnected Mode

For the grid-disconnected mode, the breaker is open. The voltage of MT is 30 V, in which after the step-up, it goes up it reaches to 50 V. The active power of MT is 80 W, and after step-up, the active power is 40W. The voltage of the battery is 130 V and the current is 4 A. The active power of the battery is 780 W. The frequency for this system is 59.89 Hz. Figure 29 shows the frequency during the grid-disconnected mode. The results obtained from this simulation are as shown in Figure 15.

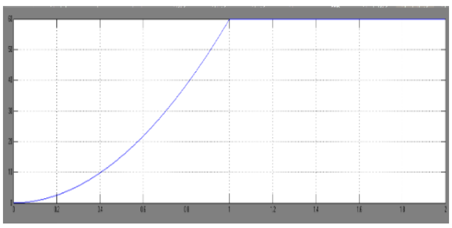

Figure 15: The frequency in grid-disconnected

For 415 V Distribution System:

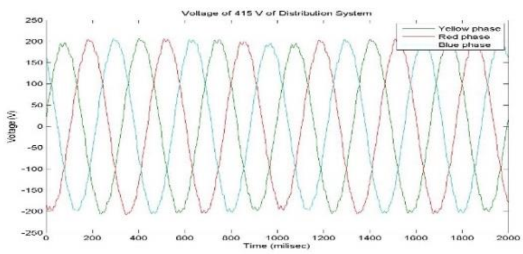

Figure 16: Three-phase primary voltage

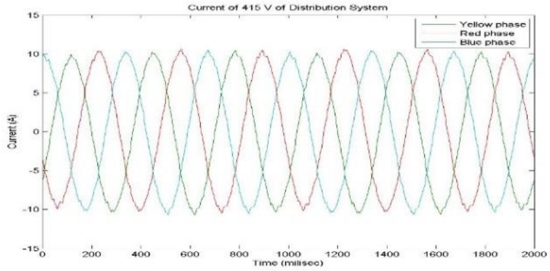

Figure 17: Three-phase primary current

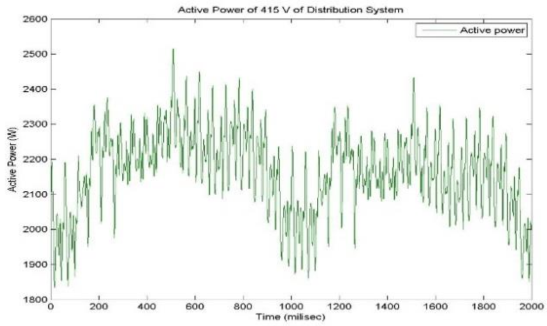

Figure 18: Primary active power

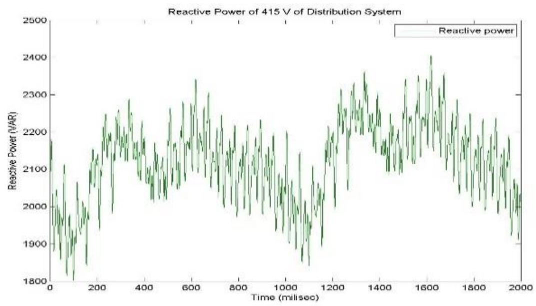

Figure 19: Primary reactive power

As shown in Figure 16, the three phase primary voltage is 200 V and Figure 17 shows the three phase secondary current is 10 A. Figure 18 shows the active power is 2500 W and Figure 19 shows the reactive power is 2300 VAR. This result is shown at 415 V of the distribution system.

For 11 KV Distribution System:

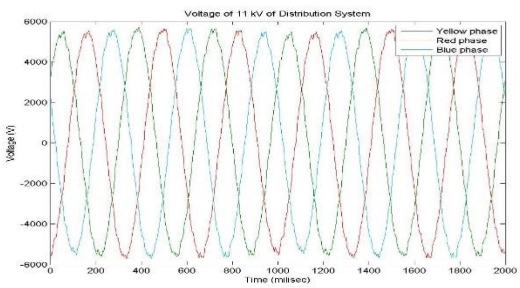

Figure 20: Three-phase secondary voltage

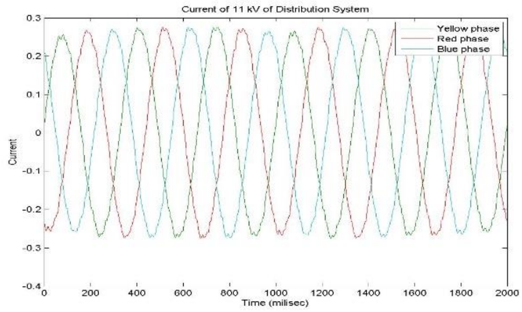

Figure 21: Three-phase secondary current

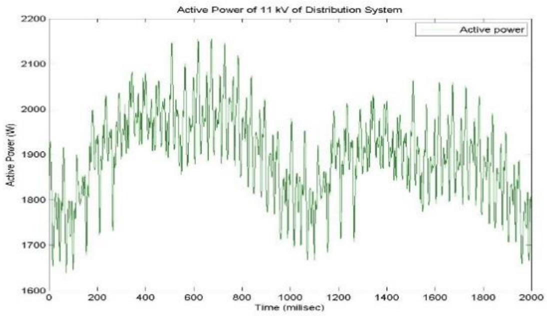

Figure 22: Secondary active power

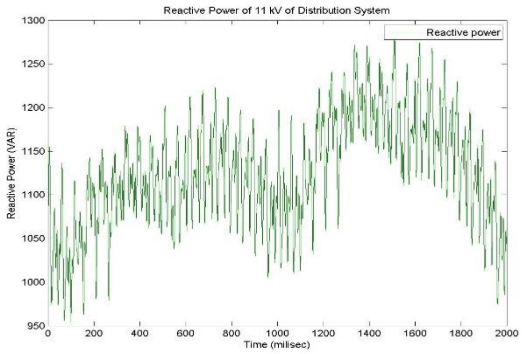

Figure 23: Secondary reactive power

As shown in Figure 20, the three phase primary voltage is 6000 V and Figure 21 shows the three phase secondary current is 0.3 A. Figure 22 shows the active power is 2100 W and Figure 23 shows the reactive power is 1250 VAR. This result is shown at 11 kV of the distribution system.

C. Comparison between grid-connected and grid-disconnected

Table 1 shows the comparison of the system in grid-connected and grid-disconnected at 415 V and 11 KV distribution system. Table 2 shows the frequency for this system either in grid connected or grid-disconnected mode.

From Table 1, the voltage at 415 V and 11 KV distribution system in grid-connected mode is satisfied with the required voltage, which is 415 V and 11 kV. For the grid-connected mode, the voltage and current at 415 V distribution system are 415 V and 80 A. The voltage and current at 11 KV distribution system are 11 KV and 3 A. For the grid-disconnected mode, the voltage and current at 415 V distribution system are 250 V and 0.4 A. Meanwhile, for the voltage and current at 11 KV distribution system are 7 KV and 0.01 A. The voltages at the grid connected mode are higher than the grid-disconnected mode. This condition is due to the high load demand and the lack of voltage support from the grid.

Table 1
Comparison of System in Grid-Connected or Grid-Disconnected

Distribution system	Parameter	Grid-connected	Grid-disconnected
415 V	Voltage	415 V	200 V
	Current	80 A	10 A
	Active Power	5000 W	2500 W
	Reactive power	-5000 VAR	2300 VAR
11 Kv	Voltage	11 Kv	6 KV
	Current	3 A	0.3 A
	Active Power	5000 W	2100 W
	Reactive Power	-10 kVAR	1250 VAR

The active power in the grid-connected mode is higher than the system in grid-disconnected mode. This is because the voltages at the grid-connected mode are higher than the grid-disconnected mode. The load demand A is 10 kW. The power supply to the load A is 2620 W in the grid-connected mode and 780 W in grid-disconnected mode. Meanwhile, the load demand B is also 10 kW. The power supply to the load B is 5000 W in the grid-connected mode and 2100 W in the grid-disconnected mode. It shows that the power supply cannot supply enough power to the load demand A and B. In order to get enough supply, the power load needs to be reduced. The power output can be increased by adjusting the value of the load. The reactive power in the grid-connected mode is negative. The generated negative reactive power means that the reactive power is flowing from the grid to the MT. This condition happens when MT field is under-excited or induction MT is being used.

To get a proper and synchronous system, there are many important parts that make the system works well. For example, the important concern for making MT as DG that controls the inverter that results in the micro-sources to be capable to deliver with the grid. There are two work plans to control the inverter, which are PQ inverter control and voltage source inverter (VSI) control. The PQ controlling are suitable for connection to the grid in dealing the active and reactive power. The second concern is harmonic, which makes the load waveforms become disputable. These harmonics are the effect from switching in the inverter. Table 2 shows the frequency for this system, either in the grid connected or grid-disconnected mode.

Table 2
Frequency of MG System

	Grid-connected	Grid-disconnected
Frequency	50.04 Hz	59.26 Hz

The frequency exists when the grid connected is 50.04 Hz. It shows that there is compatible frequency between the distribution generation and the grid. The frequency of the grid has been set in load frequency control. The frequency exists when grid-disconnect is 59.26 Hz. The frequency is a bit higher than the required frequency, which is 50 Hz. It shows that the frequency is not synchronized since both inverters of MT and battery are not synchronized as well. The inverter had pulse generator and filter connected to set the frequency of the system. The noise and total harmonic distortion also affect the frequency.

IV. Conclusion

In conclusion, the MT MG system by using MT and battery storage system MG had been designed by using MATLAB Simulink Software. The model of MG system consists of MT, battery storage, inverter, three-phase RLC load block, and many more. Each block parameter has its own functions. The system had been simulated and analyzed. This MG system had been simulated in the grid-connected and grid-disconnected mode. The results from both modes had been compared and analyzed. The causes of the system that is not synchronized had been analyzed also.

Acknowledgment

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