Analysis of Wind with Battery Connected to Microgrid System

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Abstract. Nowadays, distributed generation technology had gained more popularity by many countries. Recently, there are many problem with power system. One of the problem is high electricity price. The price in power generation rely largely on the type and market price of the fuel used, government subsidies, government and industry regulation, and even local climate patterns. In order to supply a better power system, this thesis introduces a model of wind turbine and a battery storage connected to microgrid system. The microgrid is the small scale which widely used in power generation system. Microgrid can operate with renewable and non-renewable energy. Through this project, microgrid will be modelling by using wind turbine and battery storage system using MATLAB simulink software.

Keywords: Battery Storage, Grid connected, Microgrid and Wind Turbine

1. Introduction

This project shows the analysis of distribution generation (DG) units refer to the small generators that used as stand-alone systems at an isolated area (rural areas) or utility-connected. It is having the ability to lift the poor nations to new levels of prosperity. The renewable energy used in this project is wind turbine. Basically the wind turbine generates from the sources of airflow through mechanical power generator to electricity. This wind turbine suitable at offshore and large area. Offshore had wind more frequent and stronger which can be found at this location and have less impact on the landscape aesthetic than project land but the cost of construction and maintenance costs are high.

There are several issues make this project build up. One of the issue are by using the fossil, coal, oil and natural gas generation to generate electricity. Based on the fossil fuel generation, the fossil will have burned and from that the nitrogen oxide come out to surrounding. It is make the acid rain and effect the greenhouse gas emission. It is also make air pollutant. Besides that, a regular problem in industry when using traditional grid that only ways to flow electricity and communication. The other way by using microgrid that have reliability and secure network and loads with provide efficiency and friendly environment.

1.1 Wind Turbine - Wind energy is renewable energy. It is a clean energy source without requiring chemicals such as oil to generate energy which enable pollution. Wind energy is a
source that needs wind to generate electricity. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. The formula for output power of wind turbine is

\[ P = \frac{1}{2} \cdot \rho \cdot C \cdot A \cdot v^3 \]

Where

\( \rho \) is air density that normally use is 1.23
\( C \) is maximum power coefficient; theoretical maximum is 0.59
\( A \) is area of rotor
\( v \) is wind speed or velocity

Wind turbine configuration can be identifying many ways based on different factors such as:

- Rotor axis orientation: horizontal and vertical
- Rotor position: upwind or downwind of tower
- Rotational speed: constant or variable
- Rotor power control: pitch, stall and active stall

1.2 The Horizontal Axis Wind Turbine - A horizontal-axis wind turbine (HAWT) has the main rotor shaft and electrical generator at the top of a tower and point directly into the direction of wind. Small turbines are pointed by a simple wind vane, while large turbines use a wind sensor coupled with a servo motor. Most system has a gearbox, which turns the blades slow rotation into a quicker rotation that is more suitable for generate electricity. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds.

1.3 Vertical Axis Wind Turbine - Vertical-axis wind turbines (VAWT) have main rotor shaft running vertically. Main advantages of this arrangement are the generator and/or gearbox can be placed at the bottom which near the ground. So the tower does not need to support it and the turbine does not need to be pointed into the wind. Vertical wind turbines have a higher airfoil pitch angle to give improved aerodynamics while decreasing drag at low and high pressures.
1.4 Microgrid - Microgrids have the ability to enhance the reliability of the electric power grid from the point of view of their local loads means that the uninterruptable and high quality power is delivered to the loads, particularly critical loads. Microgrid can provide reactive power to support local voltage levels (415VL-L) not only for their own local loads but also for nearby loads. Microgrids operate in parallel with the utility grid to feed a certain load. This prevents the grid being overloaded during peak load periods, which may consequently result in blackouts. By using microgrid, it can reduce the transmission losses (economic benefit) means the power that is delivered to areas where microgrids are installed are lower and losses on the lines are lower too.

1.5 Battery Storage - A battery stores electrical energy in a dual direction chemical reaction. The renewable energy source produces the energy and the battery stores it for times of low or no energy production. Most renewable energy systems have batteries which store between ten and hundreds of times more energy than a car battery. It needs backup power in case batteries become discharged due to lack of renewable energy system or an over consumption of energy.

There are many brands and types of batteries available for renewable energy systems. With proper care, renewable energy system batteries have a lifetime of five to ten years, but there are more expensive batteries. In batteries consists of dangerous chemicals, which is hydrogen and oxygen gas while being charged, so they should be vented to the outdoors. It tops and connections must be periodically cleaned to avoid energy losses. Batteries should also be regularly topped up with distilled water.

The lead acid battery used as energy storage because the lead acid battery is common energy storage device for renewable energy sources with high power density. Several inputs are considered for the modelling of this battery such as battery current, capacity, state of charge and temperature. All these parameters are varied with the operating conditions and affected the capacity of battery to charge or discharge. The battery terminal voltage is considered as an output of the model.

2. Design of Wind Turbine and Battery Storage Connected with Microgrid in Grid-Connected and Grid-Disconnected

Based on figure 3, the wind turbine and battery storage connected with grid. There are rectifier and converter that used after wind turbine and battery storage. Its function to compatible in voltage and frequency with electronic power system to which it will be connected and contain necessary output filter. The filter used is LC filters which to smooth the graph and filter noise to obtain synchronous voltage and frequency. Before transmit to
Microgrid, the supply need transformer to step-up the voltage to synchronize with Microgrid due to frequency and voltage. The grid voltage is 415V and the frequency is 60Hz. The supply will go through the load demand.

2.1 Microgrid in Grid-Connected and Grid-Disconnected Mode

Figure 4: Design of 11kV Microgrid

Figure 4 shows the design of 11kV microgrid. The grid is added after the 415V side to become 11kV. It related with supply from wind turbine and battery storage and then the transformer is step up the voltage to 415V. After that the 415V where step up again until to 11kV. The reading is taken at 415V side and 11kV side. There have 2 condition of grid which is grid-connected and grid-disconnected. The breaker is placed at 11kV grid to connect or disconnected the grid.

3. Result and Discussion - Wind And Battery Storage Connected With Grid-Connected And Grid-Disconnected

Based on figure 3, show the distributed generation of wind turbine and battery storage connected with Microgrid. When this Microgrid system in grid-connected, the breaker will CLOSE means the grid can gives supply for the system. Meanwhile, if the Microgrid system in grid-disconnected, the breaker will OPEN means the grid cannot give supply for this system. The design were stimulate based on different cases which are

1. Wind turbine supply to grid connected
2. Battery supply to grid connected
3. Wind turbine and Battery supply to grid connected
4. Wind turbine supply to grid disconnected
5. Battery supply to grid disconnected
6. Wind turbine and Battery supply to grid disconnected
Case 1

Figure 5: Wind Turbine Supply in Grid-connected

Figure 6: Result of Primary voltage, current, active power and reactive power

Figure 7: Result of Secondary voltage, current, active power and reactive power

Figure 8: Result of Frequency
Case 2

Figure 9: Battery supply in Grid-connected

Figure 10: Result of Primary voltage, current, active power and reactive power

Figure 11: Result of Secondary voltage, current, active power and reactive power

Figure 12 Result of Frequency
Case 3

Figure 13: Wind turbine and Battery supply in Grid-connected

Figure 14: Result of Primary voltage, current, active power and reactive power.

Figure 15: Result of Secondary voltage, current, active power and reactive power

Figure 16 Result of Frequency
Case 4

Figure 17: Wind turbine supply in Grid-disconnected

Figure 18: Result of Primary voltage, current, active power and reactive power

Figure 19: Result of Secondary voltage, current, active power and reactive power.

Figure 20 Result of Frequency
Case 5

Figure 21: Battery supply in Grid-disconnected

Figure 22: Result of Primary voltage, current, active power and reactive power

Figure 23: Result of Secondary voltage, current, active power and reactive power

Figure 24 Result of Frequency
Case 6

Figure 25: Wind turbine and Battery supply in Grid-disconnected

Figure 26: Result of Primary voltage, current, active power and reactive power

Figure 27: Result of Secondary voltage, current, active power and reactive power

Figure 28 Result of Frequency
The time setting for all cases have transition time which is from 4/60 until 10/60 second at the breaker. It is means on that time the breaker will trigger from open to close and vice versa when it close to open. When the breaker in open condition, the current will flow through the snubber resistance inside of the breaker means the current can flow through at the resistance.

**Table 1 Comparison Grid-connected and Grid-disconnected with Condition of Supply**

| WIND SUPPLY | BATTERY | PARAMETER | GRID-CONNECTED BEFORE | GRID-CONNECTED AFTER | GRID-DISCONNECTED BEFORE | GRID-DISCONNECTED AFTER |
|-------------|---------|-----------|------------------------|-----------------------|--------------------------|-------------------------|
| ON          | OFF     | VOLTAGE   | 240V                   | 415V                  | 240V                     | 415V                    |
|             |         | CURRENT   | 1.2A                   | 0.6A                  | 0.6A                     | 1.2A                    |
|             |         | ACTIVE POWER | 600W                 | 1200W               | 1200W                    | 600W                    |
|             |         | REACTIVE POWER | 220J Wh           | 13000J Wh            | 13000J Wh               | 220J Wh                |
| OFF         | ON      | VOLTAGE   | 240V                   | 415V                  | 240V                     | 415V                    |
|             |         | CURRENT   | 1.2A                   | 0.6A                  | 0.6A                     | 1.2A                    |
|             |         | ACTIVE POWER | 150W                 | 330W                 | 330W                     | 150W                    |
|             |         | REACTIVE POWER | 200J Wh          | 1300J Wh            | 1300J Wh               | 200J Wh                |
| ON          | ON      | VOLTAGE   | 240V                   | 415V                  | 240V                     | 415V                    |
|             |         | CURRENT   | 1.2A                   | 0.6A                  | 0.6A                     | 1.2A                    |
|             |         | ACTIVE POWER | 600W                 | 1200W               | 1200W                    | 600W                    |
|             |         | REACTIVE POWER | 220J Wh           | 13000J Wh            | 13000J Wh               | 220J Wh                |

Table 1 represent the value of voltage, current, active power and reactive power when the grid-connected and grid-disconnect with different condition of supply. Besides that, it shows before and after transformer that means before transformer represent the primary side of the transformer which is from supply and after transformer represent the secondary side of transformer which is from microgrid.

The value of voltage, current and reactive power when grid-connected is higher than when the grid-disconnected before and after transformer. The active power before transformer in grid-connected and grid-disconnected is positive that means the system cannot supply enough power to the load demand. The power output can be increased by adjust the value of load. For active power after transformer in grid-connected and grid-disconnected is negative that means the system have enough power to the load demand. So, the power load can be added or increase. The reactive power before transformer in grid-connected and grid-disconnected is negative means the reactive power flowing from grid to wind turbine and battery storage. For reactive power after transformer in grid-connected and grid-disconnected is positive means that reactive power is flowing from the wind turbine and battery storage to grid.

Frequency for both of grid-connected and grid-disconnected either before or after transformer gets the same value which is 60Hz. The value must same because the synchronization process need before connected to microgrid.

### 3.1 Grid-connected and Grid-disconnected at 11kV

Based on figure 4, shows the design to analyse the voltage, current, active power and reactive after connected to high voltage are 11kV. The 415V are step up by transformer to 11kV. The result was taken for this part at 415V side and 11kV side. There have two conditions which are grid-connected and grid-disconnected. The breaker use to close and open the circuit means when breaker is close, it show the grid is connected and when the breaker is open, it show the grid is disconnected. The reading of frequency also was taken at 415V side and 11kV side.
Figure 29: Design of 11kV in grid-connected

Figure 30: Result of Voltage, Current, Active Power and Reactive Power at primary side in grid-connected

Figure 31: Result of Voltage, Current, Active Power and Reactive Power at secondary side in grid-connected

Figure 32 Result of Frequency
Figure 33: Design of 11kV in grid-disconnected

Figure 34: Result of Voltage, Current, Active Power and Reactive Power at primary side in grid-disconnected

Figure 35: Result of Voltage, Current, Active Power and Reactive Power at secondary side in grid-disconnected

Figure 36: Result of Frequency
The time setting for all cases have transition time which is from 4/60 until 10/60 second at the breaker. It is means on that time the breaker will trigger from open to close and vice versa when it close to open. When the breaker in open condition, the current will flow through the snubber resistance inside of the breaker means the current can flow through at the resistance.

Table 2 Comparison of Grid-connected and Grid-disconnected of 11kV

| Distribution system | Parameter | Grid-connected | Grid-disconnected |
|---------------------|-----------|----------------|-------------------|
| 415 V               | Voltage   | 415 V          | 200 V             |
|                     | Current   | 10 A           | 4.7 A             |
|                     | Active Power | -5600 W      | -1200 W           |
|                     | Reactive Power | 2800 Var     | 550 Var           |
| 11 kV               | Voltage   | 11 kV          | 5.2 kV            |
|                     | Current   | 0.35 A         | 0.15 A            |
|                     | Active Power | -6700 W      | -1200 W           |
|                     | Reactive Power | 1900 Var     | 200 Var           |

Table 2 represent the comparison between grid-connected and grid-disconnected at 11kV. The reading at grid-connected is higher than grid-disconnected. The voltage at 415V when grid-disconnected is 200V and the voltage at 11kV when grid-disconnected is 5.2kV. The current at 415V in grid-connected is 10A higher than in grid-disconnected is 4.7A. The current at 11kV also decrease from 0.35A in grid-connected to 0.15A in grid-disconnected.

The active power at 415V side in grid-connected is -5600W because have supply from grid. The active power at 415V in grid-disconnected increase to -1200W because there do not get supply from the grid. The active power at 11kV side in grid-connected is -6700W because have supply from grid. The active power at 11kV in grid-disconnected increase to -1200W because there do not get supply from the grid. The active power for both distribution 415V side and 11kV side are negative. Negative means the system have enough power to the load demand. So, the power load can be added or increase until the active power become 0. If the active power becomes positive means it not has enough supply.

The reactive power at 415V side in grid-connected is 2800Var higher than in grid-disconnected is 550Var. The reactive power at 11kV side in grid-connected is 1900Var higher than in grid-disconnected is 200Var. The reactive power at 415V side and 11kV side get the positive value. It is means that reactive power is flowing from the wind turbine and battery storage to grid.

4. Conclusion - In conclusion, the model of wind turbine with battery storage connect to microgrid and load using MATLAB Simulink software are designed. The designs were made based on past research that have done before this. The design has wind turbine, rectifier, inverter, battery storage, breaker, load, transformer and grid. The performances of wind turbine with battery storage system connect to microgrid and load by using MATLAB
Simulink Software are being analysed. The part has been analysed are voltage, current, active power and reactive power of the supply and grid. There have condition are being analysed. The performance of grid-connected and grid-disconnected by using MATLAB Simulink software are being analysed. The grid is step up from 415V before this to 11kV. The voltage, current, active power and reactive power were taken make comparison between grid-connected and grid-disconnected. So, the grid-connected performance had higher than grid-disconnected because the loads get the enough supply from supply and grid compared to grid-disconnected.

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