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VisSim Based Modeling and Simulation of Hybrid Diesel and Wind Power Generation

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ABSTRACT

Energy demand pattern in Indonesia continues to increase due to the population growth, economic growth and behavior of energy consumption. Meanwhile, the availability of fossil energy as the main source of energy is very limited and continues to thin out. This paper discusses the modeling and simulation of hybrid power generator system consisting of wind power and diesel generator. Each component associated with this generating system is modeled and simulated in order to investigate the performance of the proposed hybrid generation system. The variations in environmental condition can be analyzed easily and quickly and the changes in generating parameters can be clearly demonstrated using VisSim software. From the simulation results, the simulation model is made to follow the characteristics of wind power, diesel generator for the initial hybrid generation system.

Keywords: Wind power, diesel generator, hybrid power, VisSim software.
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1. INTRODUCTION

Currently, the pattern of energy needs in Indonesia in particular and in the world generally continue to increase due t population growth, economic growth and behavior of energy consumption. Meanwhile the fossil energy that has been the main source of energy availability is very limited and continues to experience depletion trend. The natural process takes very long time to be able to re-provide this fossil energy. Considering the exponential rate of population expansion and rising energy consumption, surely the decline in the availability of energy sources will be much faster. Therefore, the need for utilization of renewable energy sources is also increasing within the energy crisis and also the issue of global warming [1, 2].

The search efforts for alternative energy sources besides the fossil energy encourage the researchers to seek other energy forms called renewable energy. Renewable energy can be defined as energy that can be rapidly reproduced through natural processes (water energy, geothermal, solar, wind, biogas, biomass and ocean waves). In addition, the characteristics of energy source are relatively modest to obtain, with free of charge, minimal

waste, they are friendly with the global temperature of the Earth, and not be affected by the rise in fuel prices [3, 4].

Various renewable energy sources have been developed by researchers, such as wind power, micro/mini hydro power, solar energy, marine tide, biomass, biofuel, geothermal, and many others. Specifically, the wind energy is one of the most popular renewable energy sources that are clean and freely available on Earth. The main problem of this type of energy is not available continuously. The wind energy is available at times that are often unpredictable (sporadic) and highly fluctuate depending on weather or season. To overcome these problems, hybrid techniques are widely used to combine several types of power plants based renewable energy, such as wind power, solar energy and conventional power generation, such as diesel power engines. In this case, the modeling performance of hybrid power generation is highly needed to facilitate the design and analysis of the generating system due to the variable environmental parameters that determine the output of wind energy generator.

In this study, the hybrid power generation is modeled with the combination of wind power and diesel generator using VisSim software. The model is basically the combination of several models that have been developed by previous researchers. In addition, the model is used as a tool in designing, building and analyzing the hybrid wind and diesel energy generation systems.

A. Hybrid Power Generation Systems

Hybrid Power Plants is a generating system consisting of several types of integrated power plants. The hybrid power system can be a combination of power generation from renewable energy sources and power plants from non-conventional or non-renewable energy sources or a combination of renewable power plants. In other definition, the hybrid power plant system combines several types of power plants based on renewable energy sources.

The hybrid power generation is a solution to overcome the fuel crisis and the absence of electricity in remote areas, small islands and in urban areas. Generally, it consists of solar modules, wind turbines, diesel generators, batteries and integrated control equipment. The purpose of the hybrid power generation is to combine the advantages of each plant while covering the weaknesses of each plant for certain conditions, so that the whole system can operate more economically and efficiently [5, 6].

This paper discusses the hybrid wind power and diesel generation systems. Diesel power plant is categorized as a source of conventional electric energy using fossil fuels. The diesel generator converts the combustion energy of diesel fuel into electrical energy, so the usual diesel power plant is also referred to as a fossil energy source. Meanwhile, the wind power generation is one of the fastest growing renewable energies in the world today. The wind energy is a very flexible renewable energy. The wind power plant utilizes wind as

a source of energy to generate electrical energy. This plant can convert wind energy into electrical energy by using wind turbines or windmills [7, 8].

The software tools to model the proposed hybrid power generation called VisSim. It is a visual block diagram programming language for creating complex nonlinear dynamic systems. The essence of VisSim software is used for modeling, simulation and application design of control systems. The software is developed by Visual Solutions located in Westford, Massachusetts. VisSim's visual interface has a simple method of building and simulating complex, large-scale dynamic systems. The calculating machine provides fast and accurate solutions for linear, nonlinear, continuous, discrete, and hybrid power system design [9, 10].

B. Configuration of Proposed Hybrid Power Generation

In this system as shown in Fig. 1, the diesel generator (DG) works as a master, controlling the voltage and frequency. Wind speed for the wind turbine (WT) changes with time, as do loads (VL). Therefore, the diesel generator is considered a controlled energy source, whereas wind is an uncontrolled energy source and the load is an absolute energy absorber. The diesel generator balances the difference between the power used by the load and the power generated by the wind turbine.

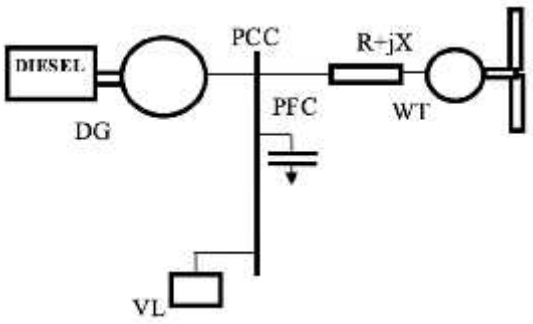


Fig. 1. Configuration of proposed systems

In this modeling, the generator parameters are taken based on the existing name plate of diesel generator. The diesel generator is a synchronous generator with a power rating of 200 kW and a frequency of 50 Hz, with technical parameters as shown in Table 1.

Table 1. Technical specification of diesel generator

Moment of inertia	2
Pole	4
Voltage flux constant	0.0032 p.u
Viscous friction coefficient	0.0003 p.u
Field winding resistance	50 p.u
Field winding inductance	20 p.u
Stator inductance, q component	0.000005 p.u
Stator inductance, d component	0.0001 p.u
Stator Resistance	0.0001 p.u

Meanwhile, the module parameter of AC wind turbine model is the induction generator parameters based on the existing name plate of generator. Two types of induction generators with the same power rating of 200 kW and with the same frequency

of 50 Hz, but with different rotor and stator specifications. These characteristics are performed to investigate the difference in output that occurs with the change of inductor generator parameters. The technical specification of induction generator is presented in Table 2 and Table 3 consecutively.

Table 2. Technical specification of the first-type of induction generator

Stator Resistance	0.087 p.u
Rotor Resistance	0.228 p.u
Magnetizing Reactance	13.08 p.u
Rotor leakage reactance	0.302 p.u
Stator leakage reactance	0.302 p.u
Rotor inertia	1.662 p.u
Poles	4

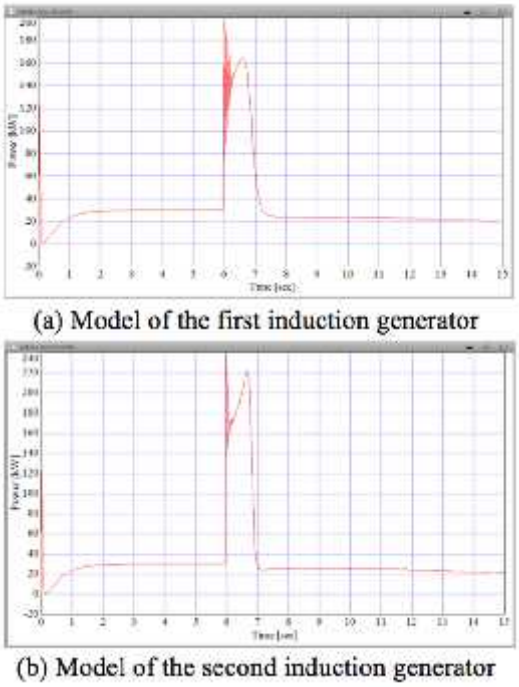
Table 3. Technical specification of the second-type of induction generator

Rotor Resistance	0.0881 p.u
Stator Resistance	0.071 p.u
Load Resistance	0.5 p.u
Rotor Reactance	0.1813 p.u
Stator Reactance	0.1813 p.u
Magnetizing Reactance	3.23 p.u
Frequency	50 Hz

2. RESULTS AND DISCUSSION

In this simulation, there are two different scenarios of modeling. The difference is in the two characteristics of the induction generator used in the Wind Turbine module. As for the synchronous generator used for each model is the same that is contained in the Diesel Generator module.

This simulation is conducted with the aim of finding the most efficient model of diesel and wind power generation to be used to meet the load power requirements. To understand the effectiveness, the output parameters of the power plant are reviewed including the power, voltage and frequency are varied with time. Models and simulations via VisSim display the values of these parameters in graphical form so they are easily observed.



(a) Model of the first induction generator

(b) Model of the second induction generator

Fig. 2. Active power of diesel generator.

The simulation results are shown in Figures 2-5 where the Fig. 2 presents the comparison of active power of diesel generator with two types of induction generator. Meanwhile, the active power of induction generator is shown in Fig. 3. The electrical parameter of voltage per phase is shown in

Fig. 4. And the last figure of wind speed profile for these simulation results is presented in Fig. 5.

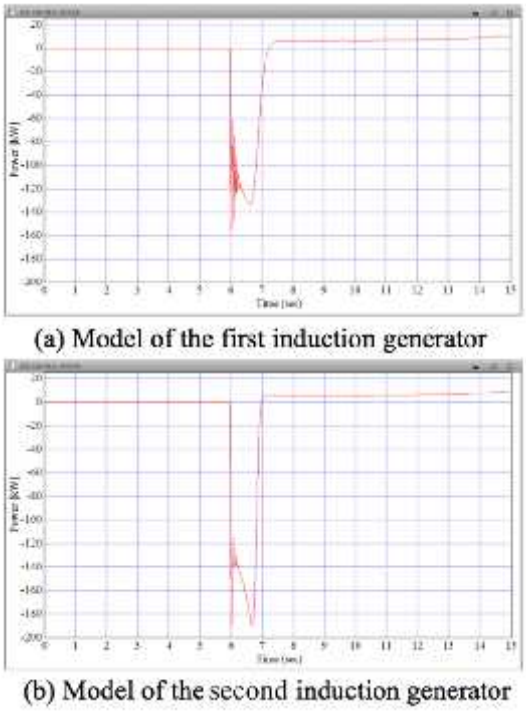


Fig. 3. Active power of induction generator

The first and second modeling in this simulation has a fundamental difference in the value of resistance and reactance, both on the stator and rotor, with the same wind speed. The resistance value of the induction generator influences the power output of wind turbine. A smaller resistance value in the second model increases the output power of diesel generator higher than in the first model. Similarly, the power absorbed by the induction generator at its initial start. However, the time required for the induction generator to generate power in the second model is shorter than the first model. A very obvious difference is also seen in the relative frequencies generated by the plant, where the second model experienced a drastic decrease in frequency compared to the first model when the wind power begins to operate.

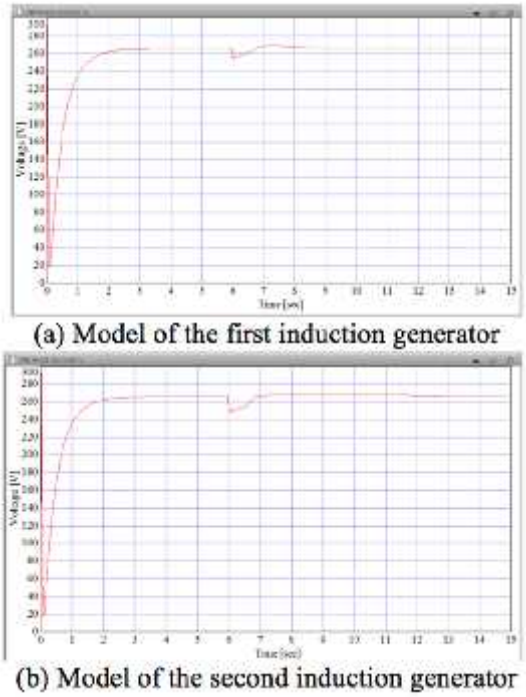


Fig. 4. Voltage per phase

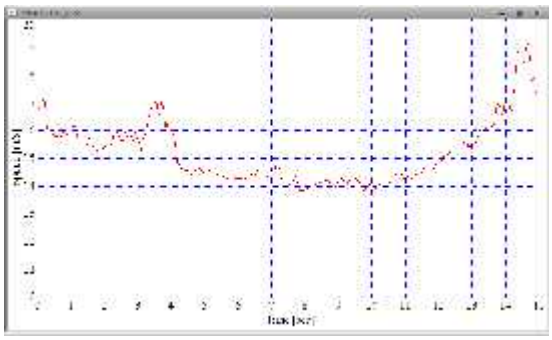


Figure 5. Wind speed profile

Based on the simulations done with the VisSim software as described above, it is clearly seen that the first and second modeling results of diesel and wind power generation systems. Both models are helpful to facilitate

the design and analysis of the hybrid power plant system. It appears that VisSim provides good facilities for modeling. In accordance with the purpose of the VisSim software itself, it is very useful to be used for modeling, simulation and control system application design with a simple method of building and simulating complex dynamic systems.

3. CONCLUSION

Based on the simulation results in the previous section, the conclusions can be drawn as follows.

1. The simulation results using VisSim show that prior the induction generator operates, the diesel generator produces a power of 30 kW and after the induction generator operates, the power generated by the diesel generator slowly decreases.
2. As the wind power by means the induction generator starts to replace the performance of the diesel generator in the induction generator of model 1, the diesel generator produces a power of 215 kW and the induction generator absorbs 160 kW of power. In the induction generator of model 2, the diesel generator produces 325 kW of power and the induction generator absorbs 268 kW.
3. The performance simulation result of the induction generator of model 1 is better than the induction generator of model 2 according to the power generated by the diesel generator as well as the power absorbed by the wind power at the lower initial start.

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