Technology, 14(3), 87-93, (2011)

TECHNOLOGY

SIMULATION AND POWER FLOW CONTROL OF WIND-DIESEL HYBRID POWER GENERATION SYSTEM

Yuksel OGUZ*, Secil VARBAK NESE, Mehmet YUMURTACI***
*Afyon Kocatepe University, Tecnhical Education Faculty, Afyon
**Marmara University, Tecnhical Education Faculty, Istanbul

Abstract

In this study, dynamic simulation of a hybrid power generation system established by being interconnected with a wind-diesel power generation system isolated from a network was realized in the Matlab-Simulink program. Electricity produced with the wind-diesel hybrid power generation system is generally being used for areas in long distance from the network. For the uninterrupted high quality electric energy, the interrupted wind resource problem is solved by using a diesel generator. The components of the Wind-Diesel power system are shown with modules. Changes in electrical output magnitudes (power, voltage and frequency) of the hybrid power generation system under different loads are shown with graphics.

Keywords: Hybrid Power System, Simulation, Matlab-Simulink

1. Introduction

Benefiting from a renewable energy like wind has rapidly increased since 1970's and widely replaced with the energy produced from fossil fuels [1]. The sharp wind speed changes that occur in the wind speed over time can cause variable input moment in wind networks. For this reason, to benefit from this energy resource in suitable manner requires regulated energy resource [2]. The advantage of the hybrid power systems is its continuously obtainable diesel power and combination of the local renewable energy resources [3]. With the hybrid power system, annual diesel fuel consumption can be decreased and at the same time, pollution level can be minimized. [4]. Mufti and his colleagues operated a multi-input and multi-output automatically adjustable regulator in the mathematical model they developed for the Wind-Diesel-Super conductive magnetic energy storing unit. [5]. Bialasiewicz and his colleagues presented a modular simulation device to study the system dynamics for the Wind-Diesel power systems. [4]. Bialasiewicz and his colleagues realized a modular simulation system by using *Vissim* to study the dynamics of an isolated diesel and wind produced hybrid system. [2]. Chedid and his colleagues developed an adaptive fuzzy logic controller for the Wind-Diesel power systems and produced the membership functions and control rules by using ANFIS.

Bowen and his colleagues continuously recorded and analyzed the data from an isolated and small Wind-Diesel power system for six months at a coast farm [7]. Ko and his colleagues developed a neural network based intelligent controller for the Wind-Diesel power system [8]. They examined the information on wind speed per hour for years of 1986-1997 and information on sun radiation for 1991 recorded at a meteorology station and researched them for meeting of load requirements of one hundred two-room housings [1]. Kaldellis developed an detailed mathematical model of a micro-wind convertor, small diesel-electric generator and hybrid system consists of a lead acid battery and to estimate the energy of various configurations of that system, he developed an integrated numeric algorithm [9]. Ko and his colleagues designed a fuzzy-neural hybrid controller to control the wind inclination angle of a wind turbine in the Wind-Diesel power generation system [10].

Corresponded Author; yukseloguz@aku.edu.tr

In the study, by using the SimPowerSystems included in the Matlab-Simulink program, the basic components of the Wind-Diesel hybrid power generation system were established. In the realized hybrid power generation system, dynamic models of the basic components were used. In various consumer load situations, electrical power, load voltage and frequency obtained from the Wind Power Generation System (WPGS) and Diesel Power Generation System (DPGS) are important for the operating conditions.

2. Wind-Diesel Energy Generation System

The hybrid power generation systems are the power generation systems established via parallel connection of two or more traditional and renewable energy generation systems. The hybrid power generation systems are one of the best solution methods to meet the energy need of small housing units and mini networks locate in far distance to energy generation and distribution centers [11]. The Wind-Diesel power generation system shown in Figure 1 is established to realize a reliable, productive, environmental and economic operation effectively. Here, it is used to ensure continuity of the electric energy in the hybrid power generation systems operate as isolated from the DPGS network. When a sufficient power generation is ensured from the hybrid power generation systems established by using renewable alternative energy resources, requirement for fossil fuels will decrease.

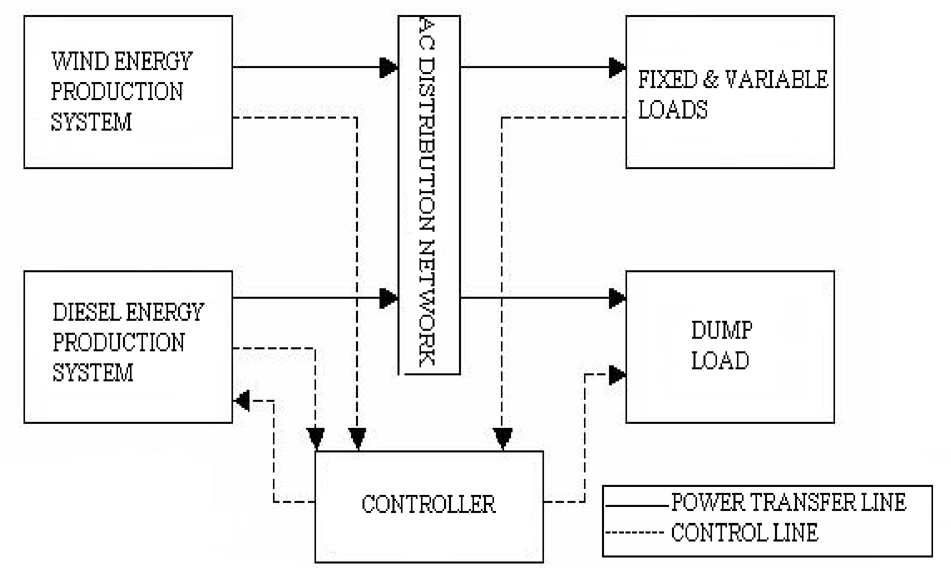

Figure 1. A simple block diagram of the wind-diesel power generation system

The energy cost in small, powerfully isolated networks is rather higher than the unit price of electric energy produced at main networks. Because, in small powered networks, diesel generators are used in generation of the electric energy. To provide the energy in the most economical manner, the unit energy cost is tried to be decreased by benefiting from the power generation systems in optimum manner. The biggest disadvantage of the renewable energy resources is the irregularity in their generation power.

Using of the wind-diesel power generation systems in housing units far from the main distribution networks and in places with high renewable energy potential has a great importance in respect to productive and optimal usage of the energy.

3. Modeling of Hybrid Power Generation System

In this study, dynamic modeling of the hybrid power system consists of the combination of 250kW WPGS and 200kW DPGS was realized by using the Matlab-Simulink, SimPowerSystems program as shown in Figure 2. Then, by considering that voltages and frequencies of the WPGS and DPGS are different, their frequency and voltage values must be equalized in order to prevent any problem when these two power generation systems are interconnected.

The sub-components of the wind and diesel power generation systems that form the hybrid power generation system given in Figure 2 are given separately in a single block. The basic components of the WPGS are the variable speed wind turbine, asynchronous generator, diesel machine and speed regulator. Modules of the components that belong to these two power generation systems in SimPowerSystems of Matlab-Simulink program were used. Interconnection was made according to the energy flow in each generation system and operated in a computer medium in conformity to its actual behavior in the real system. Each of the wind and diesel power generation systems was operated separately and their frequency and voltage values were equalized. Then, these two power generation systems were interconnected in parallel and a hybrid power generation system was established.

The hybrid power generation system established in the Matlab-Simulink program was loaded with different consumer loads and changes in the electrical output magnitudes of the system (power, voltage and frequency) were simulated. The power quality in all the power generation systems is very important. For this reason, the operation voltage and frequency must be in desired value interval.

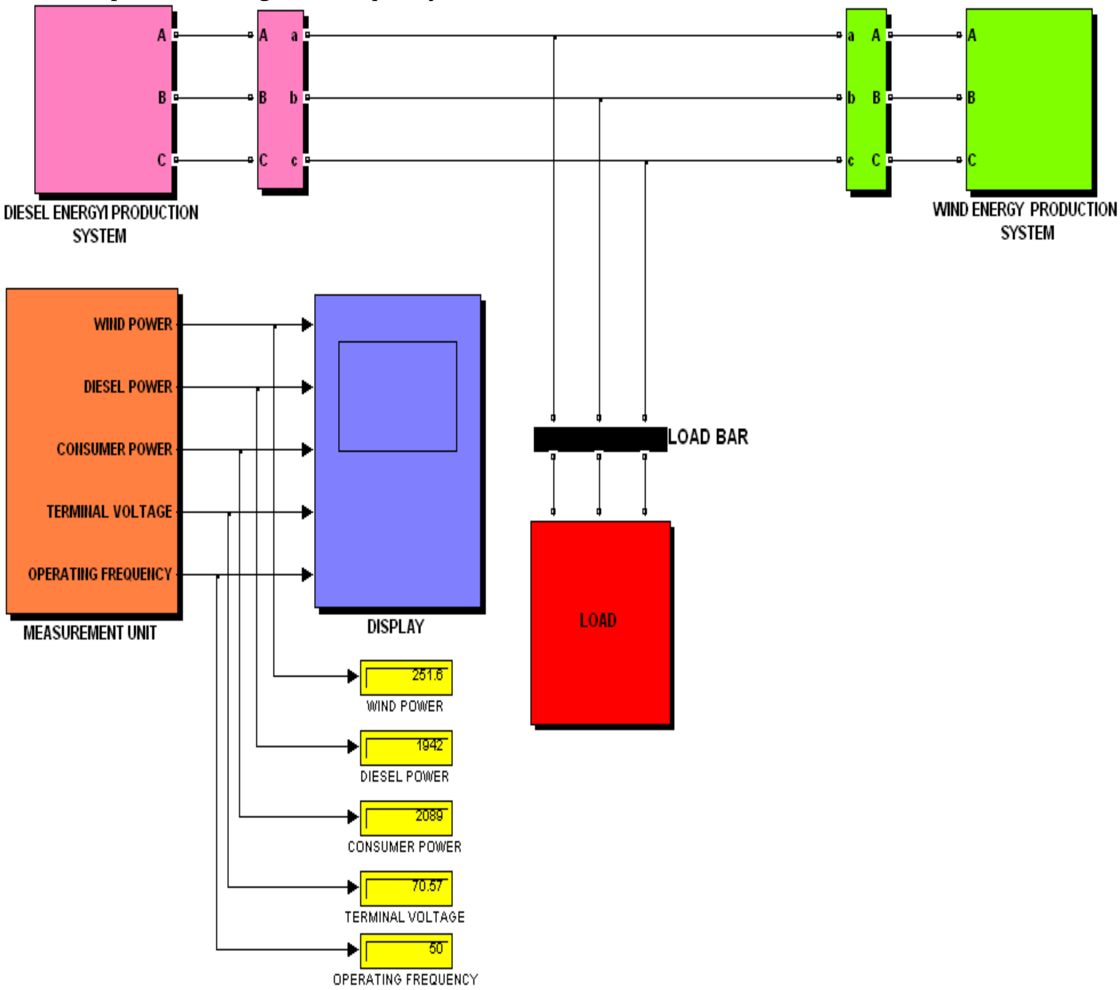

Figure 2. The simulation block diagram of the hybrid wind-diesel power generation system in the Matlab/Simulink program

4. Voltage and Frequency control in Hybrid Power Generation System

In wind tribunes, the power output varies depending on the changes in wind speed. In big and powerful networks, these changes and fluctuations in wind power are absorbed by the powerful network. For this reason, through frequency and voltage control, the balance between the generation and consumption must be established in a small, powerful and isolated network. The balance between the generation and consumption power is ensured by keeping the frequency and voltage values between the upper and lower limit values previously determined. As continuity of the wind power cannot be ensured, the power balance between the wind speed and diesel power must be ensured by regulating the output power of diesel generator or the excessive wind power with dump loads or additional loads [12]-[13].

The established powers of energy generation systems in isolated networks are generally consisted of small powerful systems. These small generation systems generally ensure the flexibility in regulation of output power. For instance, the diesel generator may be operated, synchronized and connected to a network in a period less than 2 seconds. Besides, during operation of the speedy automatic controller of diesel generator, it reacts to changes in frequency and voltage of the network, so fluctuations can be neglected.

In times of sufficient wind power, the electric network is only fed from the wind power generation system. The diesel power generation system is separated from the generation bar. In such operation situation, the diesel power generation system does not consume any fuel. During this process, diesel fuel may be saved.

4.1 Frequency Control

Controlling of the network frequency is continued with speedy control of the power balance between the fluctuating wind power, dump load/additional loads (electrical heating elements) and consumer load. In periods the diesel machine runs, the frequency is controlled by means of the diesel machine controller. In periods the WPPS is 100% active, the frequency is controlled by consuming the excessive wind energy at dump load (switching load) and additional loads.

4.2 Voltage Control

The network voltage control is ensured with the automatic voltage regulator of the synchronous generator that ensures reactive power to realize the power generation of asynchronous generator actuated by means of the wind tribune. In increasing load and decreasing wind power situation, the wind power cannot meet all the consumption. DPPS that supports its RPPS is automatically put into use to supply the increasing power demand and so, the voltage is regulated.

5. Simulation Results

In the simulation study, a traditional PID controller was used to ensure the electrical output magnitudes of the hybrid wind-diesel power generation system to be in desired value and quality. With the traditional PID controller, speed control was ensured for both power generation systems. When we consider it in part of consumers, the rotating area machines that operate in high frequency and voltage are damaged. In the simulation study, the power generation and consumption was realized without exceeding the tolerance limit values permitted by the operational place in respect to voltage and frequency.

In the simulation study, in situations the hybrid –diesel power generation system meets the load demands of the consumer between 0kW and 2250kW, the output magnitudes can be obtained individually in graphics. In this study, the simulation results obtained for three different loading situations are shown. The total generation power of the wind and diesel power generation systems must be equal to the least consumption power. The results obtained as a result of the simulation study clearly indicate that situation. With the equations given below, relations between the generation and consumption powers are expressed.

$$P_{generation} \geq P_{consumption} \tag{1}$$

$$P_{wind} + P_{diesel} \geq P_{consumption} + P_{synch\_con} + P_{loss} \tag{2}$$

When the output electrical magnitudes of the hybrid power generation system were examined, it was determined that the operational frequency reached to the desired 50Hz± %1·$f_{operating}$ value between 1 seconds and 1.5 seconds. The acceptable operational frequency for Turkey is ($f_{operating}$) 50 Hz. The voltage value obtained in the simulation study is the maximum (peak) value. Nominal voltage value is 400 Volt. The maximum value of that voltage was obtained during the simulation study as

$$U_{max} = U \cdot \sqrt{2} = 400 x \sqrt{2} = 565 \text{ Volt.}$$

The simulation results obtained with the hybrid wind-diesel power generation system are shown in Figure 3, Figure 4 and Figure 5. In Figure 3, the consumer power is 225kW. In this loading situation, all the 225 kW power is met from the WPGS. In Figure 4, the total consumer power is 600kW. 200kW of that power is met from the WPGS and 400kW of it from the DPGS. In Figure 5, the total consumer power is 2100kW. 1940kW of that power is met from the DPGS and remaining of it from the WPGS. Consequently, until the power value demanded by the consumer becomes equal to the generation power of the WPGS, no power consumption is made by the DPGS. If the consumer power is above the generation power of the WPGS, power consumption is made by the DPGS. As a result of the simulation study made on the hybrid power generation system, this situation can be clearly seen.

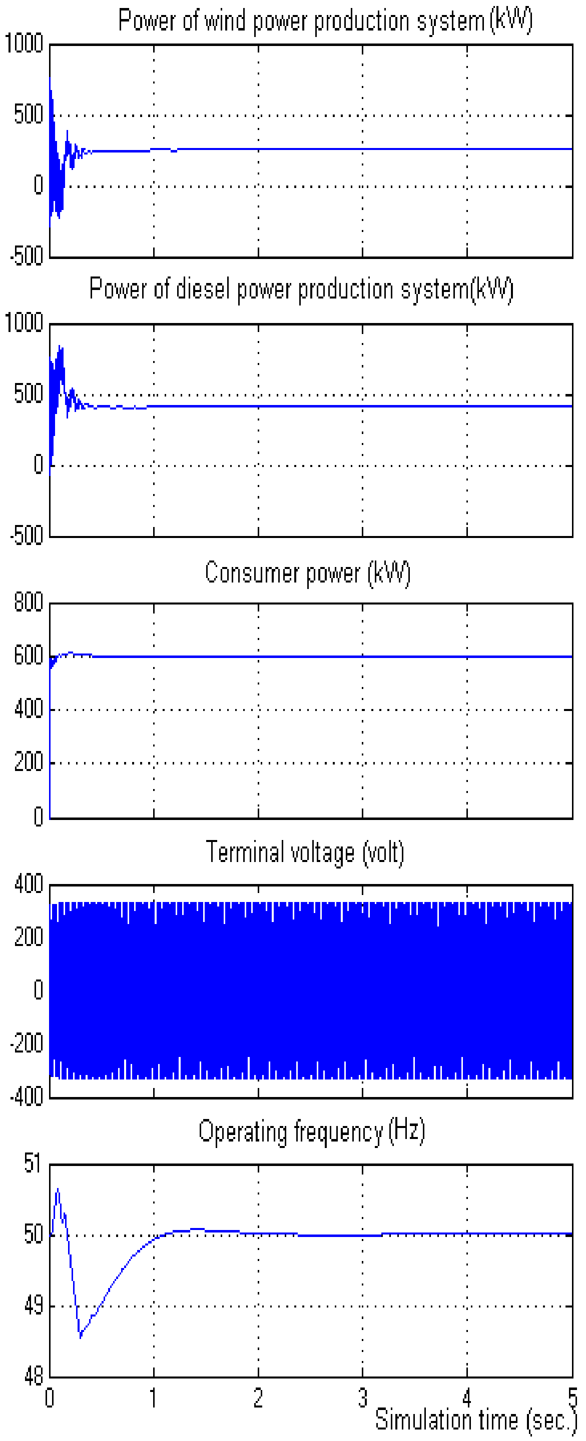

Figure 3. Curves for changes in power, voltage and frequency in case of the hybrid power generation system is loaded with 600kW consumer load

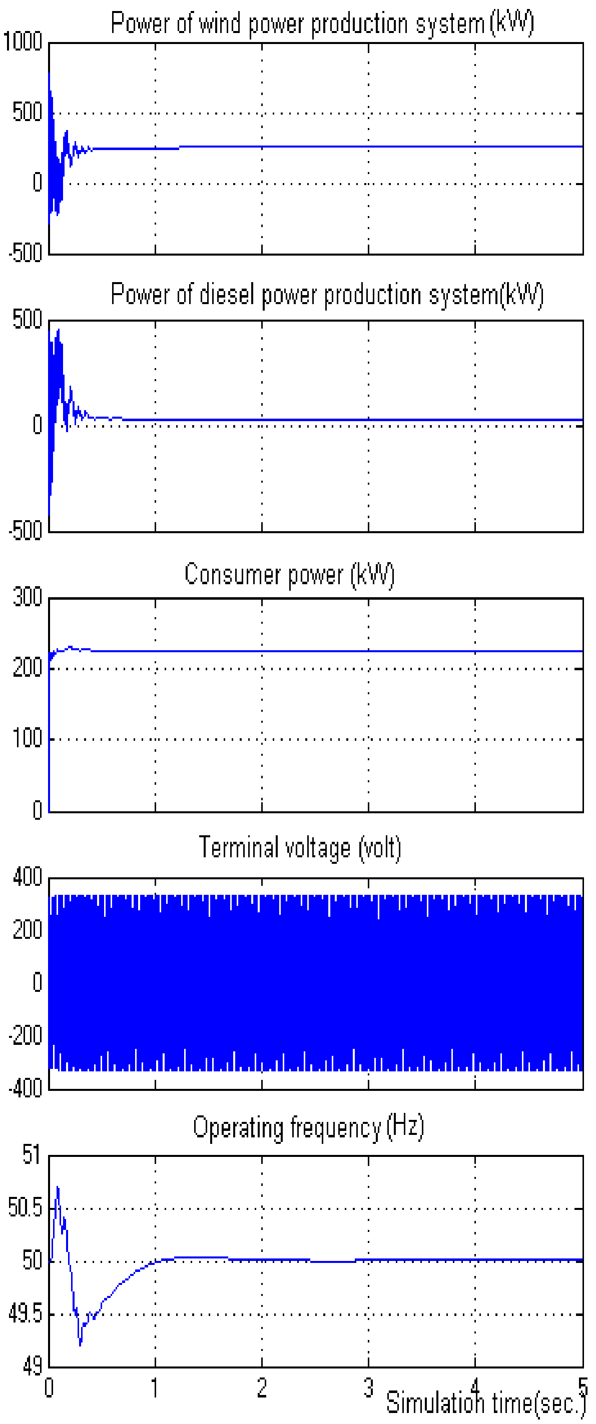

Figure 4. Curves for changes in power, voltage and frequency in case of the hybrid power generation system is loaded with 225kW consumer load

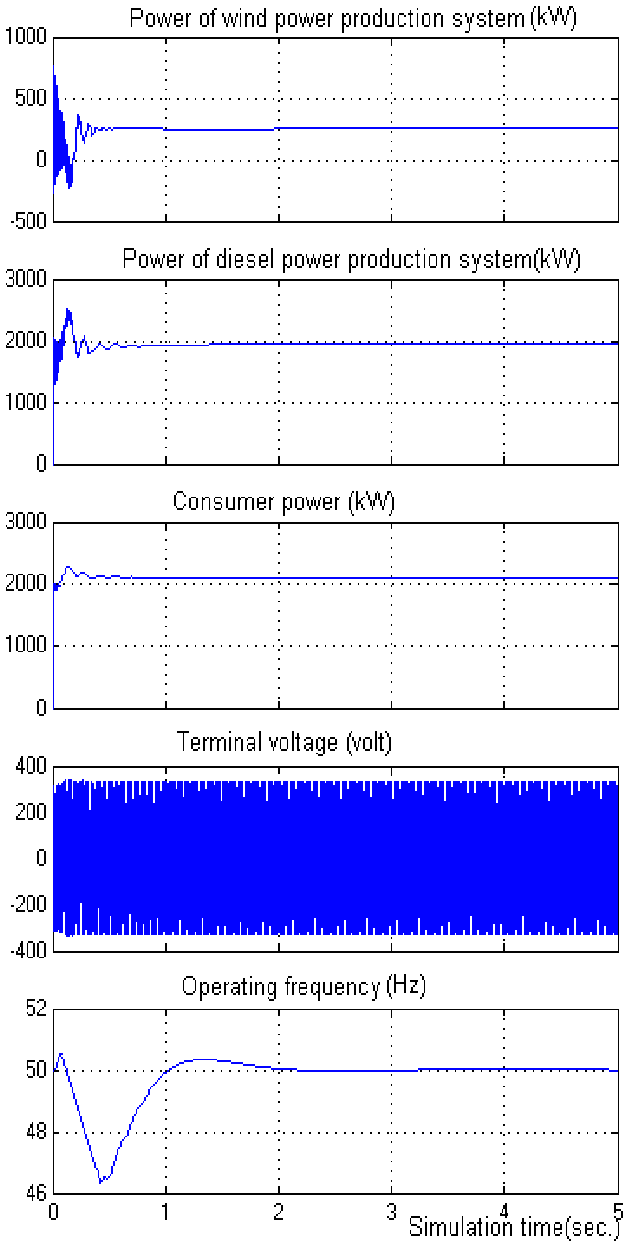

Figure 5. Curves for changes in power, voltage and frequency in case of the hybrid power generation system is loaded with 2100kW consumer load

6. Conclusion

In the realized study, the dynamic behavior of the hybrid power generation system consisted of 250kW WPGS and 2000kW DPGS was examined with the simulation study. In the simulation study established in the Matlab-Simulink program, electrical output magnitudes similar to the dynamic behavior of the wind-diesel generation units in the real operational place were observed. The realized simulation study will assist in developing of different control strategies in the hybrid wind-diesel power generation systems. Meanwhile, power flow analysis, frequency and voltage control can be easily made.

All the electrical output magnitude values of the hybrid power generation system were settled in the operational desired values in a time interval of 1.5-2 seconds. Maximum value of the phase-neutral voltage obtained from the hybrid power generation system was about 326 Volt and in sinusoidal form. The operational frequency was realized within permitted tolerance limits (50Hz ±%1·f_{opr}). Terminal voltage and operational frequency in desired value expresses the quality of power.

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