FREQUENCY CONTROL OF STAND-ALONE WIND-DIESEL HYBRID SYSTEM

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Abstract: *Modelling of a stand-alone wind-diesel hybrid system is done to operate under various wind speed and load conditions on MATLAB Simulik platform. The quality of the power is improved by controlling the system frequency to the rated value. The models of the generation units, power controller, frequency regulator and load are developed and simulation studies have been performed under various conditions using MATLAB Simulink. The simulation results of the proposed hybrid system are presented to demonstrate its effectiveness in meeting change in load demands along with change in wind speed. It has been demonstrated that this system can provide reliable and good quality power to the customers in the system.*

Key Words: *Wind-Diesel, Generator, Speed, Power, MATLAB.*

1. INTRODUCTION:

The hybrid system presented in this paper comprises of a wind turbine generator system acting as the renewable energy source and a diesel generator system acting as the conventional energy source. In this paper, the frequency is controlled and the diesel generator is start/stop automatically depending on the balance between the supply and the load. Under low wind speed conditions, i.e. the wind turbine generator cannot provide the required load power; the diesel generator starts to provide the required power. The diesel generator stops when the wind turbine generator can generate enough power. Under high wind speeds, the secondary load absorbs the excess power to regulate the system frequency. This methodology can reduce the fuel cost and power consumption of the hybrid system.

2.WIND DIESEL GENERATION SYSTEM:

A hybrid generation system consisting of a wind turbine generation system and a diesel generator system along with the power electronic interfacing is presented in this section. The system voltage is 400 V and the system frequency is 50 Hz. The squirrel cage induction generator is used in wind turbine generation system with rating of 275 KVA. The synchronous machine of 300 KVA rating is used in diesel generation system. Two types of loads are used: fixed load of 200 KW and variable secondary load of the range from 0 to 500 KW.

At low wind speeds, both the induction generator and the diesel-driven synchronous generator are required to feed the load. When the wind power exceeds the load demand, it is possible to shut down the diesel generator. A secondary load bank is used to regulate the system frequency by absorbing the excess wind power produced. The block diagram of the proposed system is shown in Fig 3.1.

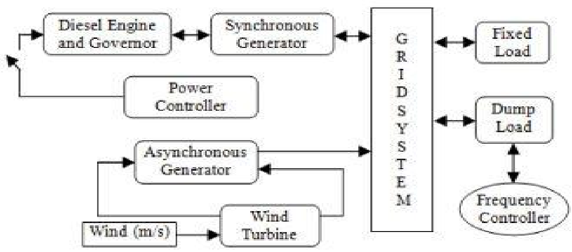

Fig 2.1 Block diagram of wind-diesel hybrid system

3. MODELLING OF WIND-DIESEL HYBRID SYSTEM:

3.1 Wind Generation System

The wind turbine model is based on the steady-state power characteristics of the turbine. The stiffness of the drive train is infinite and the friction factor and the inertia of the turbine must be combined with those of the generator coupled to the turbine. The output power of the turbine is given by the following equation.

$$P_m = \frac{1}{2} C_p(\lambda,\beta)\rho A v^3 \quad (3.1)$$

Where P_m is the output power of the turbine, C_p is the power coefficient, λ is tip speed ratio, β is blade pitch angle, ρ is air density, A is wind swept area and v is the wind velocity.

$$\lambda = \frac{\omega_r R}{v} \qquad (3.2)$$

3.2 Diesel Generator System

A diesel engine consists of a governor, and engine. The differential equations describing the diesel engine and speed regulation are shown as follows.

$$\frac{dP_C}{dt} = -\frac{K_1}{\omega_{ref}}\Delta\omega \qquad (3.3)$$

$$\frac{dm_B}{dt} = \frac{1}{\tau_2}\left(K_2 P_C - \frac{K_2}{\omega_{ref} R}\Delta\omega - m_B\right) \qquad (3.4)$$

Where, m_B is the diesel engine fuel consumption rate (kg/sec); K_1 is the governor summing loop amplification factor, R is the diesel engine permanent speed droop.

The engine is a combustion system which is presented by a gain K_2 and a dead time τ_1. The dead time can be expressed as

$$\tau_2 = \frac{60 s_t}{2Nn} + \frac{60}{4N} \qquad (3.5)$$

The mechanical power, the mechanical torque, the electrical rotor angle and the mechanical motion equation are given as follow.

$$P_m = C_1 m_B \varepsilon \qquad (3.6)$$

$$T_{Dm} = \frac{P_m}{\omega_m T_b} = C_2 P_k \qquad (3.7)$$

$$\frac{d\delta}{dt} = \omega - \omega_0 = \Delta\omega \qquad (3.8)$$

$$\frac{d\omega}{dt} = \frac{\omega_0}{2H}\left(T_{Dm} - T_{De} - \frac{D}{\omega_0}\Delta\omega\right) \qquad (3.9)$$

Where, s_t is number of strokes, N is the speed in rpm, n is the number of cylinders, C_1 is proportionality constant, ε is efficiency, T_b is the base torque, C_2 is the proportional constant, T_{De} is the electrical torque, D is the load dumping coefficient and $D = \frac{\partial P_L}{\partial f}$, H is the inertia constant of the generator, P_m is engine mechanical power, T_{Dm} is mechanical torque and δ is electrical rotor angle.

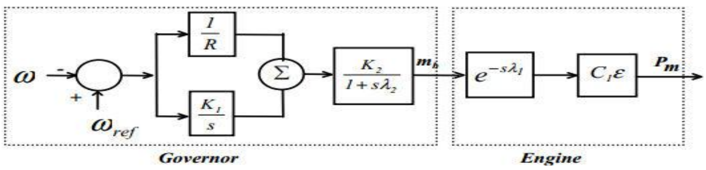

Fig. 3.1 Basic model of diesel engine and governor

3.3 Load

In this paper two types of loads are used; fixed or village load and secondary or dump load. A secondary resistive load bank is used to regulate the system frequency by maintaining a balance of real (purely resistive) power, effectively absorbing any excess wind power above consumer demand. The Secondary Load block consists of eight sets of three-phase resistors connected in series with GTO (Gate Turn Off) thyristor switches. The nominal power of each set follows a binary progression so that the load can be varied from 0 to 446.25 kW by steps of 1.75kW.

The power controller is connected to diesel engine and governor through a switch. This controller compares the load power and wind power and produces an error. The error is negative value or positive/zero value. This error can start or stop the Diesel generator.

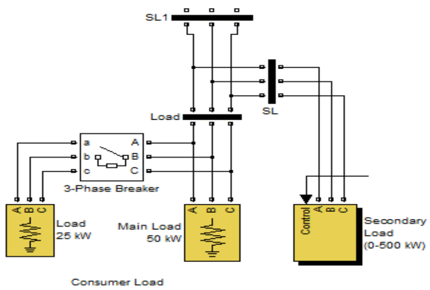

Fig. 3.2 Basic model of fixed and secondary load

This strategy can reduce the running cost and fuel consumption by diesel generator, so this controller is best for economical point of view.

3.4 Frequency regulator

Basic model of frequency regulator is shown in Fig. 3.3.

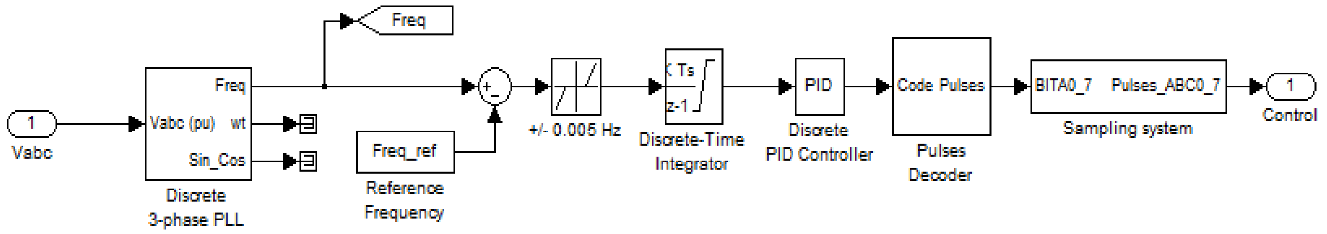

Fig. 3.3 Basic model of a frequency regulator

The frequency output from phase lock loop is compared with the reference frequency. The error signal passes through discrete time integrator and discrete PID controller. The output control signals are sent to the secondary load.

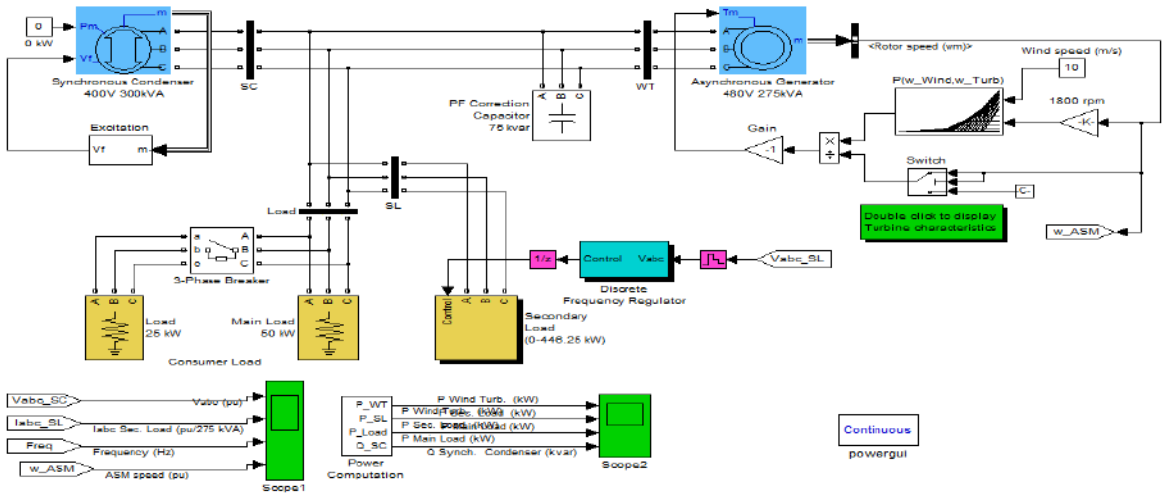

Fig. 3.4 Complete simulink model of the proposed system

4. PERFORMANCE AND SIMULATIONS:

In this study, the performance of WDHS with power controller at different wind speed and load is shown by using MATLAB/SIMULINK. Here diesel generator component would control the voltage and frequency by means of the exciter and governor. The diesel generator automatically start or stop when wind turbine generator have enough power (*Pwind*) supplied to load demand (*Pload*). The performance of WDIS is performed with frequency and power controller, without frequency controller, and without power controller. In with frequency and power controller, a controller is designed for the dump load to consume excess power output from the wind turbine when the diesel powered generation is at minimum. Thus power to be absorbed by the dump load is,

$$P_{Dump\ Load}=P_{Diesel}+P_{wind}-P_{load} \qquad (4.1)$$

In without frequency controller, i.e. frequency controller and dump load part is disconnected from the system. Only the fixed load is connected to hybrid system. Thus the power to be generated by diesel generator is:

$$P_{diesel}=P_{load}-P_{wind} \qquad (4.2)$$

In without Power controller, i.e. Power controller part is disconnected from the system and frequency controller is connected to dump load system. Thus the power to be generated by diesel generator is:

$$Pdiesel=Pload+Pdump\ load-Pwind \qquad (4.3)$$

The performance of isolated diesel wind turbine generation can be divided in two sub cases:

CASE - I: When the Wind power is less than load

In this case a wind speed is 8 m/s is applied to the wind turbine and fixed load of 150kW is connected to the system including consumer load of 25kW. At this wind speed, wind turbine produces the negative electromagnetic torque to induction generator which generates the wind power of 35kW. The power consumption by load is 75 kW which is greater than wind power generation. The automatic power controller start the diesel generator that supplies the power to complete the extra load power needed. The power generated by diesel generator is .40 kW and no power consumption by secondary load.

The frequency is controlled to 50 Hz by frequency regulator. The simulation results for case I are shown in Fig4.1 and 4.2 respectively.

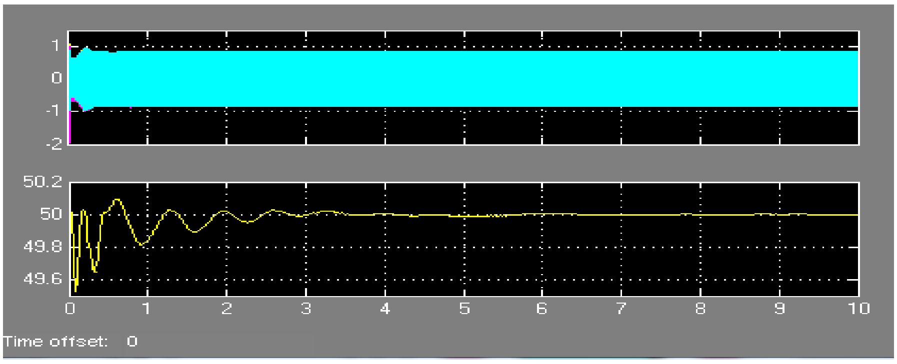

Fig. 4.1 Variation of V_{abc} and frequency for Case I

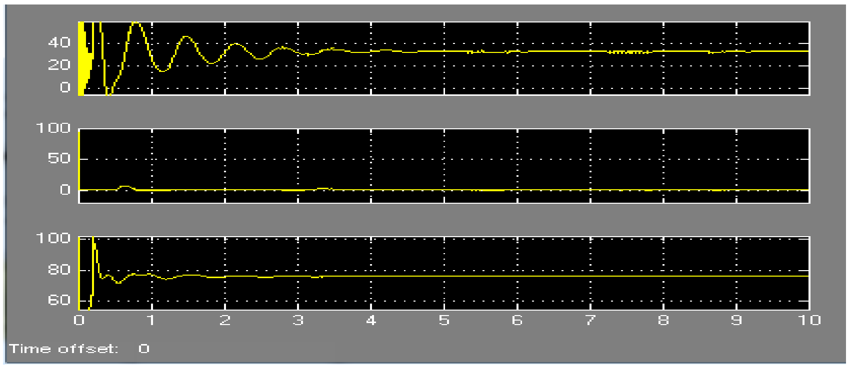

Fig. 4.2 Variation of P_{wind}, $P_{secondary}$ and P_{main} for Case I

CASE - II: When the Wind power is more than load

When the wind power is greater than load power: In this case a wind speed = 12 m/s is applied to the wind turbine and fixed load of 200 kW is connected to the system including consumer load of 25 kW. At this wind speed, wind turbine produces the negative electromagnetic torque to induction generator which generates the wind power of 200 kW. The power consumption by load is 150.2 kW which is less than wind power generation, thus no need to generate the extra power. The automatic power controller stops the diesel generator. Now the diesel generator system consume the power (-1.52 kW) and power consumption by secondary load is 125kW. The frequency is controlled to 50 Hz by frequency regulator. Simulation results for Case II are shown in Fig. 4.3 and 4.4 respectively.

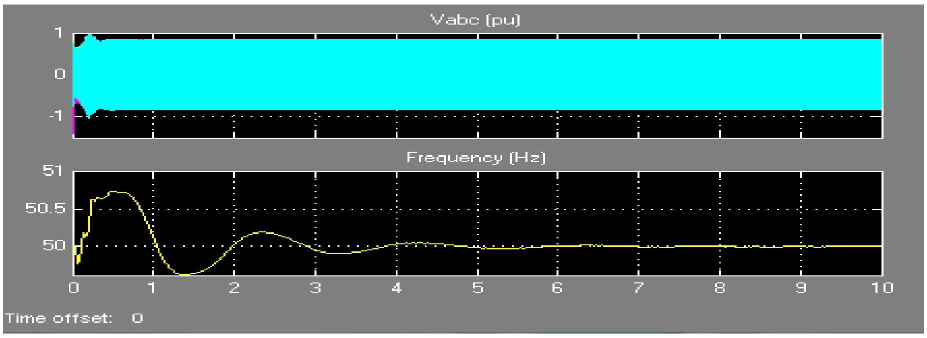

Fig. 4.3 Variation of V_{abc} and frequency for Case II

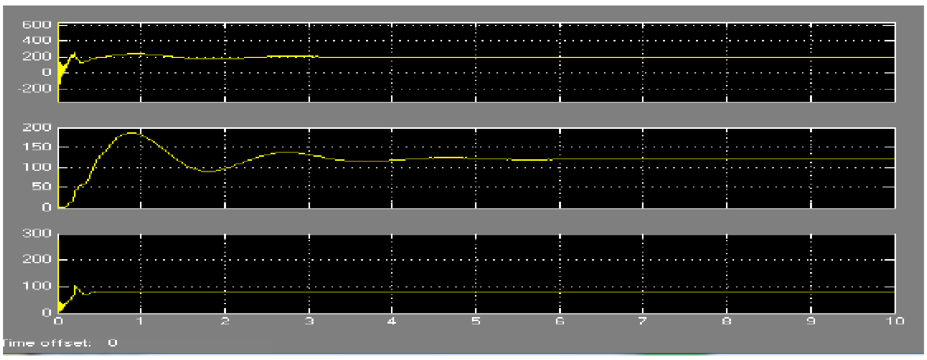

Fig. 4.4 Variation of P_{wind}, $P_{secondary}$ and P_{main} for Case II

5. CONCLUSION:

A detailed model of load flow control and performance of isolated diesel wind turbine generation system is developed and implemented by using MATLAB / SIMULINK. The system is simulated for different cases involving variation in wind speed and connected to the system. As the wind turbine output depends on wind speed which varies time to time, a diesel generator with automatic power controller is coupled to the system to make the power output of the hybrid system more reliable. The power controller is designed to operate the diesel generator in an economical way to reduce the fuel consumption and total cost of the generation, which can be observed from the simulation results. From the study it is revealed that an efficient power sharing among the energy source is successfully demonstrated for different wind speed and load condition.

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