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Wind Diesel Hybrid System with Pitch Angle Controller

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ABSTRACT- A wind diesel hybrid system is an autonomous electricity generating system using wind turbines with diesel generators to obtain a maximum contribution by the intermittent wind resource to the total power produced, while providing continuous high quality electric power. The main goal is to control load frequency and reduce fuel consumption enabling reduced system operating costs and environmental impacts. Frequency control in a power system is done to maintain an adequate balance between the consumed and generated active powers, so that the frequency remains within acceptable limits around the nominal frequency. Load–frequency control (LFC) is of importance in electric power system design and operation. The objective of the LFC in an interconnected power system is to maintain the frequency of each area within limits and to keep tie-line power flows within some pre-specified tolerances by adjusting the MW outputs of the generators so as to accommodate fluctuating load demands.

KEYWORDS – Energy, Hybrid System, Load Frequency Control, Wind Diesel System, Simulation

I. INTRODUCTION

Energy is a very important element in human life. Energy is essential for most activities of modern society. The global energy demand trend observes continuous progression, due to increase in population and also by economic and industrial growth of developing countries. Winds are only an intermittent source of energy. From past investigations and studies, intermittency of wind energy is no barrier to large-scale usage. The most basic and important application of wind is to generate electricity, with the wind turbines operating with utility grid systems or in parallel with diesel engines in remote locations. Grid systems havethe ability to accept about 20% or more from wind energy systems and more than 50% fuel savings from wind-diesel systems. The wind diesel hybrid system consists of wind turbine generator, a synchronous machine, the consumer load, dump load, a diesel engine governorand the discrete control system. In wind only mode the wind system provides the required power. When the load demand increases or wind output decreases the discrete control system in order to prevent the frequency collapse start the diesel engines which then meet the deficit energy demand and hence giving the name wind diesel mode.

II. LITERATURE REVIEW

H. Li Z. Chen in [1] showed an overview of different wind turbine concepts and possible generator types. The basic configurations and characteristics of various wind generator systems based on contemporary wind turbine concepts have been described with their advantages and disadvantages.

R.C. Bansal in [2] presented a comprehensive literature review on important aspects of SEIG such as the process of self-excitation and voltage buildup, modeling, steady-state andtransient analysis, reactive power/voltage control, and parallel operation. It is found that use of the SEIG in place of the synchronous generator can reduce the system cost considerably.

S. Sugiarto et al. in [3] presented a scheme to improve the power transfer capability of a WECS with fixed speed SCIG by the proper utilization of variable capacitor and OLTC transformer within the tolerable speed and voltage range of the SCIGs

Trinh Trong Chuong in [4] presented a method to study the relationship between the activepower and voltage (PV) at the load bus to identify the voltage stability limit. It is a foundation to build a permitted working operation region in complying with the voltage stability limit at the point of common coupling (PCC) connected wind farm.

Arulampalam et al. in [5] summarized the wind turbine technologies that are commonly used in large wind farms. For each wind turbine, the basic control concept and their performances have been discussed. Grid code requirements have been discussed for large scale integration of wind farms in terms of fault ride through, voltage control, reactive power control and frequency regulation.

The connected loads may be critical or non-critical. Critical loads require reliable source of energy and demand stringent power quality. These loads have a backup source of energythat is shown as G in the figure. Non-critical loads may be shed during emergency situationsand when required as set by the microgrid operating policies. The intermediate energy storage device is an inverter-interfaced battery bank, hydrogen storage, supercapacitors orflywheel [6].

Studies have shown that the integration of wind power into traditionally diesel-only remotearea power supply (RAPS) systems can significantly reduce the harmful emissions and life-cycle costs.Due to the very high costs of installing and maintaining transmission lines, islands and small villages located away from main grids often have their own power supply system. These standalone systems are typically powered by conventional diesel generators as they have high reliability, low capital cost and are easily deployable. In recent years however, there has been a trend towards renewable installations for both economic and environmental reasons. While the cost of renewable energy sources is dropping and the diesel fuel price is increasing and its supply diminishing, hybrid systems are already an attractive option [7].

The Ramea wind-diesel project is the first medium penetration wind installation integrated to a diesel generator-based power supply system in Canada. Integration of renewable energy (RE) sources into fossil-fuel based power generation systems for remote areas offers attractive economical and environmental merits including considerable fuel savings and carbon dioxide emission reductions. However, intermittent aspect of RE sources along withhighly variable nature of load demand for these applications may lead to significant degradation of RE utilization due to the excess RE losses [8].

Various optimization techniques, such as probabilistic approach, graphical construction method and iterative technique, have been recommended for renewable energy system designs. Besides these optimization techniques for designing solar and/or wind systems, some diesel generator control strategies have been reported for the design of power generation systems including diesel generators [9].

The optimization of a hydro-solar-wind-battery hybrid system in context of minimizing theexcess energy and cost of energy has been discussed in [10].The configuration of the hybrid system is derived based on a theoretical domestic load at aremote location. Reference [11] proposes an optimal design for a wind-PV-diesel-battery hybrid system. CO_2 emissions have been considered in this study, and the optimization has been done based on genetic algorithm.

III. MODELLING

The model of the hybrid power system under study and its implementation on the chosen simulation tool, MATLAB SIMULINK. The system elements are individually modelled and then combined to form the complete hybrid power system. The hybrid power system comprises a wind generator (WG), a diesel generator (DG), pitch angle controller(PAC) and a dump load (DL) shown in Fig 1

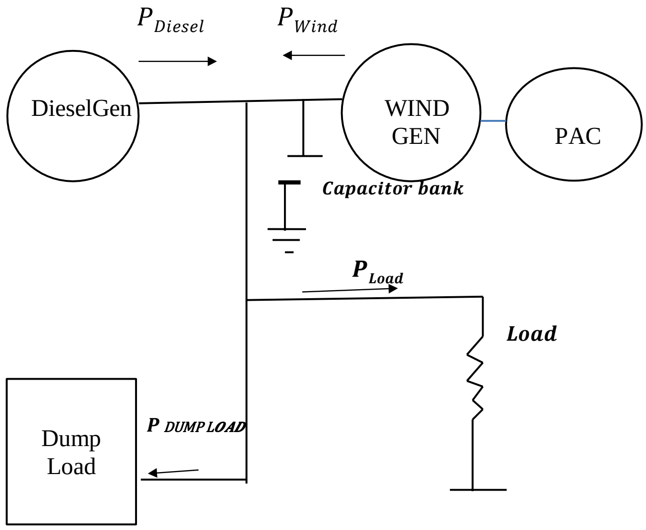

Figure 1: Hybrid Power system diagram

The system nominal voltage is 480 Vrms. Since all the elements are connected at the same voltage level, no transformers are required. The system's installed generation is 725 kW, that comprises: 300kW of DG nominal power, 275kW of WG nominal power

The maximum power absorption is 350kW and comprises: 200kW of DL nominal power and 150kW of BESS maximum instantaneous absorption. The DG has a power rating of 300 kVA and a nominal voltage of 480 Vrms. The excitation model implemented is the IEEE Standard DC1A Type Excitation System. SIMULINK provides a built in model in its SimPower Systems library. The excitation system model is as Fig. 2.

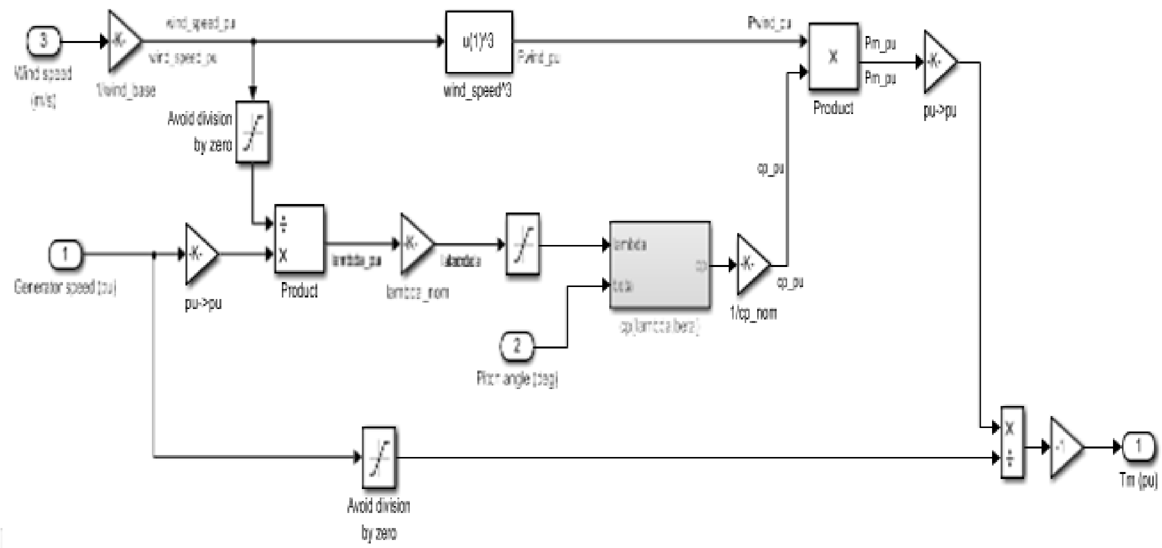

Figure 2: Simulink built-in model

IV. SIMULATION MODEL

The simulation of IG, wind turbine, synchronous generator, resistive main load, controlled external load have been carried out with MATLAB 2015Ra / simulink technical computing software. Based on the models obtained, system is simulated in a wide range of operation where the wind speedand the load can be varied below and above rated values. The components used in simulink model are asynchronous machine, 3- pahse V-I

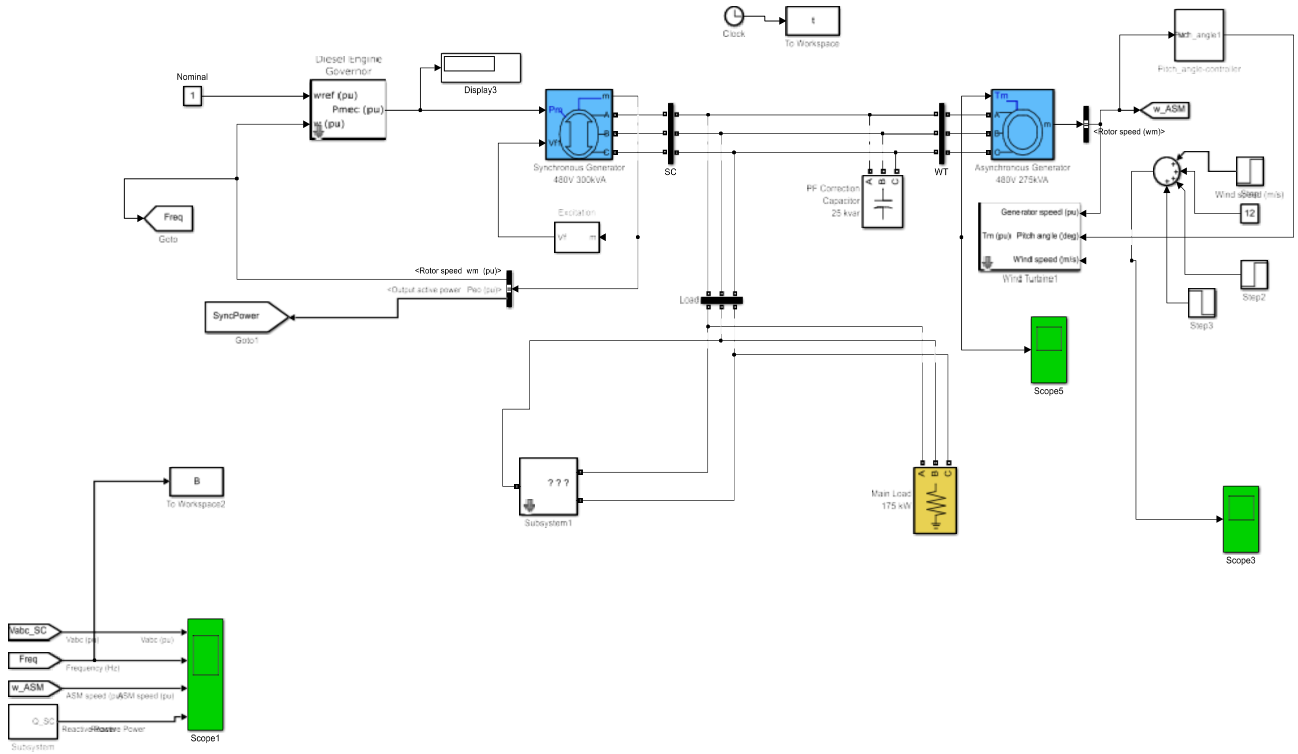

Figure 3: Simulink model of the system

measurement blocks, main load, externally controlled load (which have three resistive load in parallel with three three-phase breaker between them), wind turbine, three-phase PI section line.

A wind farm consisting of 110 KW wind turbine is connected to an induction generator of275 KVA, 480 Volts using a pitch angle controller which changes the pitch of the turbine blades depending on the velocity of the air or availability of the air using a sensing mechanism attached with the rotor. The stator winding is connected directly to the load through transmission line and therotor is driven by a fixed speed wind turbine. A simple model of the induction generator driven by uncontrolled wind turbine has been constructed using MATLAB given in Fig.3. The simulation has been carried out in order to observe the performance of the system

V. RESULTS AND DISCUSSIONS

A. *Simulation results for change in wind speed and time*

The effect of variation in the wind speed by changing the pitch angle of the turbine according to the speed of the wind. Here in this simulation result the base speed of the wind turbine is set 12m/s and after the 5 second of the simulation a step increase of 2m/s is increase in the base speed after 10 seconds of the simulation 1 step increase made in the speed.

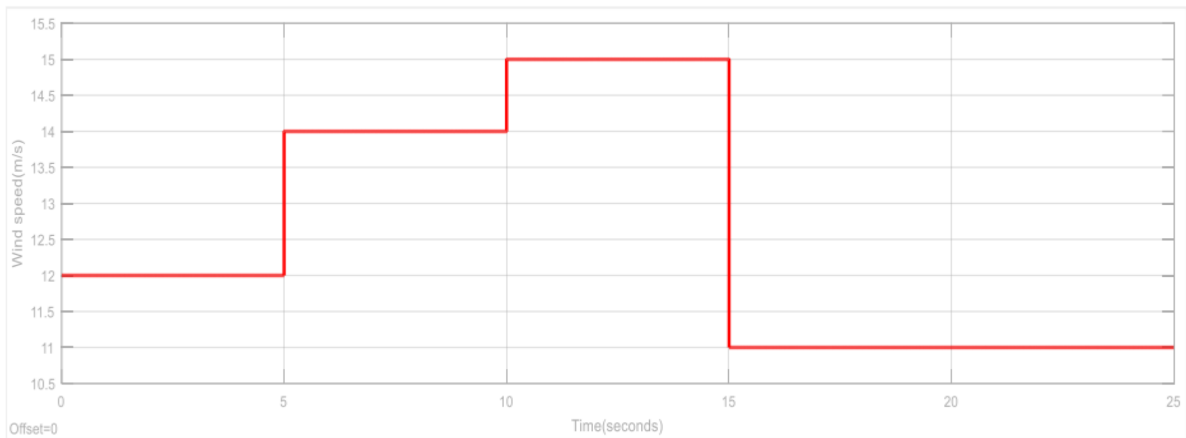

Figure 4: Simulation results for change in wind speed and time

B. Simulation results for change in Torque vs time according to change in the load

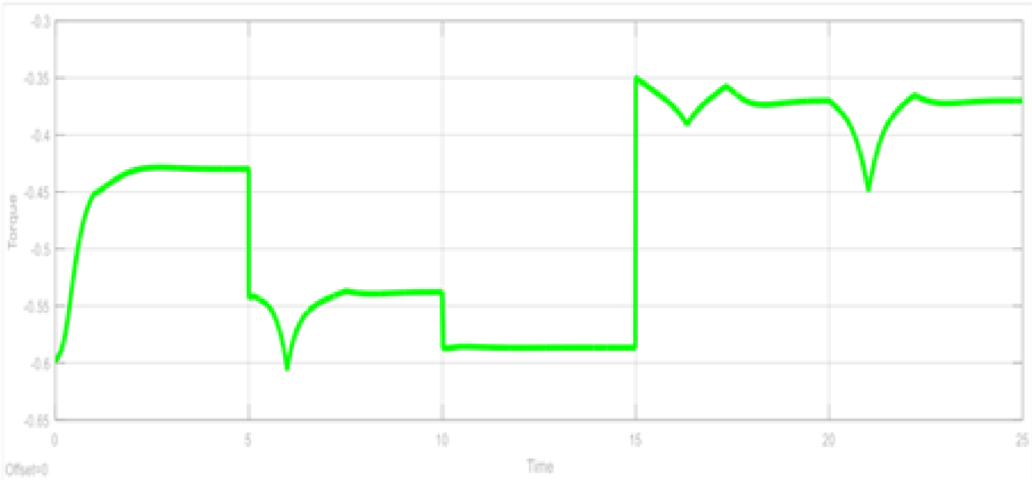

Figure 5: Simulation results for change in Torque vs time according to change in the load. The effect of variation in the load on the torque of the asynchronous generator is shown infigure 5.2. Here a load of 125 kw is added after 5 seconds of the simulation and when t=15 of seconds another load of 125kw is added and when t=20 seconds another load 125kw the variable load is added. Accordingly to the load the variation in electromagnetic torque of the asynchronous generator is shown.

C. Simulation results for change in wind turbine output vs time according to the total requirement of the load

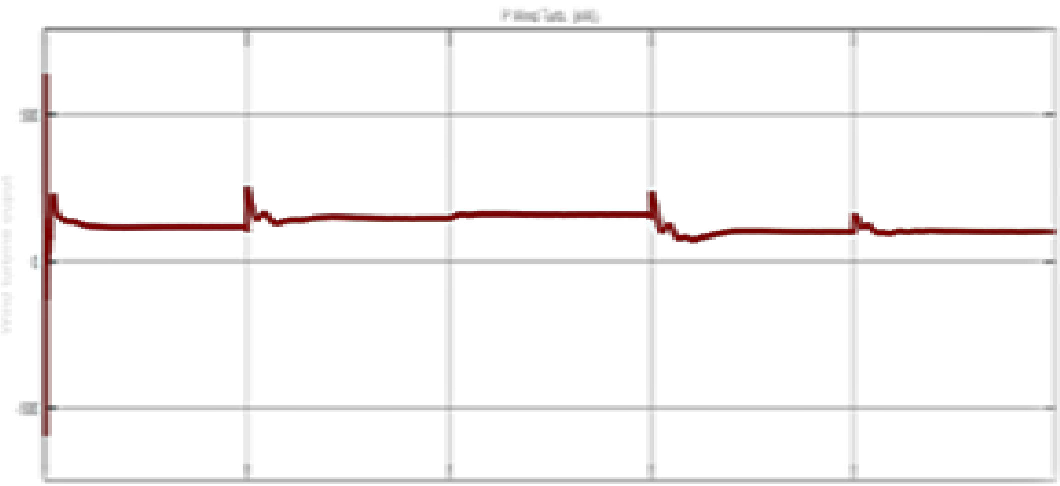

Figure 6: Simulation results for change in wind turbine output vs time according to the total requirement of the load

The simulation result shows the variation in the total output power delivered by the wind turbine to the load as per the change in the load requirement and when the load demand not fulfilled completely by the power of thewind turbine than the power by the synchronous generator increased at that particular time.

D. Simulation results for change in Load vs time

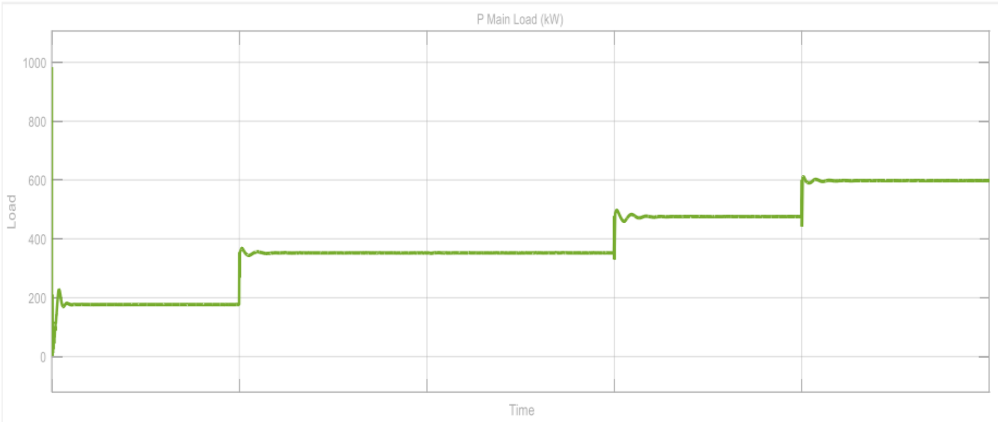

Figure 7: Simulation results for change in Load vs time

The change in the total load The effect of variation in the load vs time. When here a load of 125 kw is added after 5 seconds of the simulation and t=15seconds another load of 125kw is added and when t=20 seconds another load of 125kw a variable load is added.

E. Simulation results for change in Synchronous Generator Power vs time as per the requirement of the load

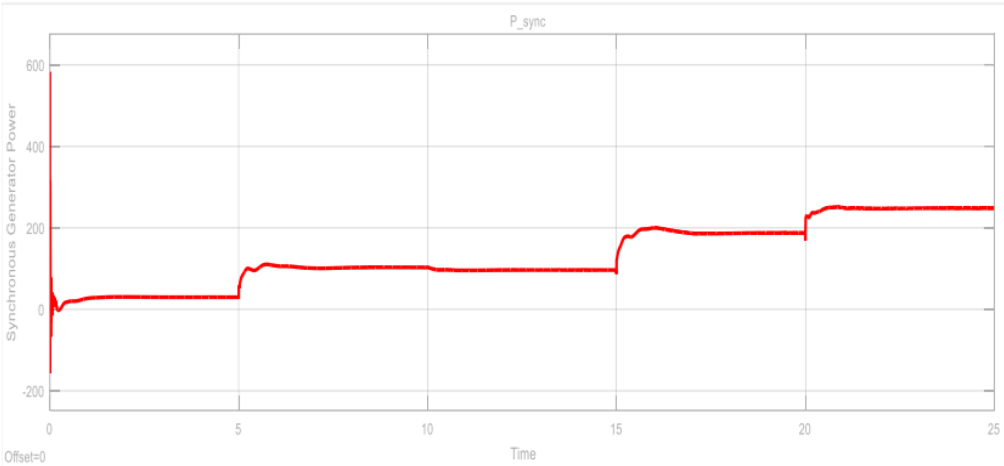

Figure 8: Simulation results for change in Synchronous Generator Power vs time as per the requirement of the load

The effect of the change in the load on the total output power of the Synchronous Generator. At time t=5 second when a load increase the total output power of the Synchronous generator is also increased or when the demand of the load not fulfilled by the total output power of the wind turbine than the Synchronous generator increase its power and fulfil the demand of the load.

F. Simulation results for Voltage waveform

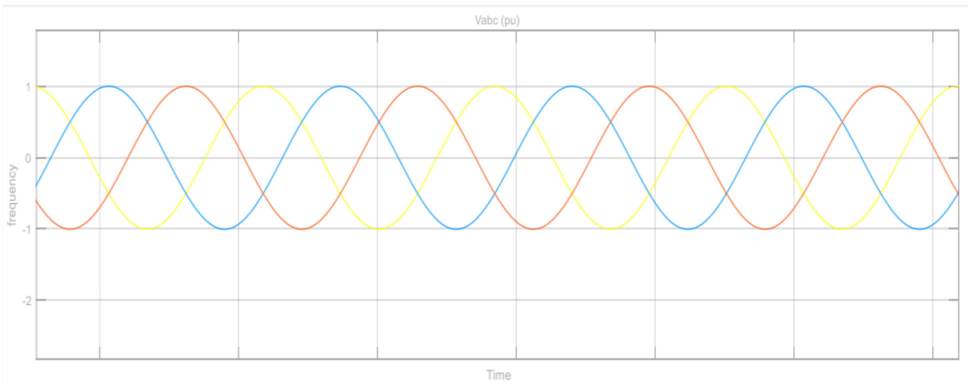

Figure 9: Simulation results for Voltage waveform

G. Simulation results for change in Frequency vs time with pitch angle control

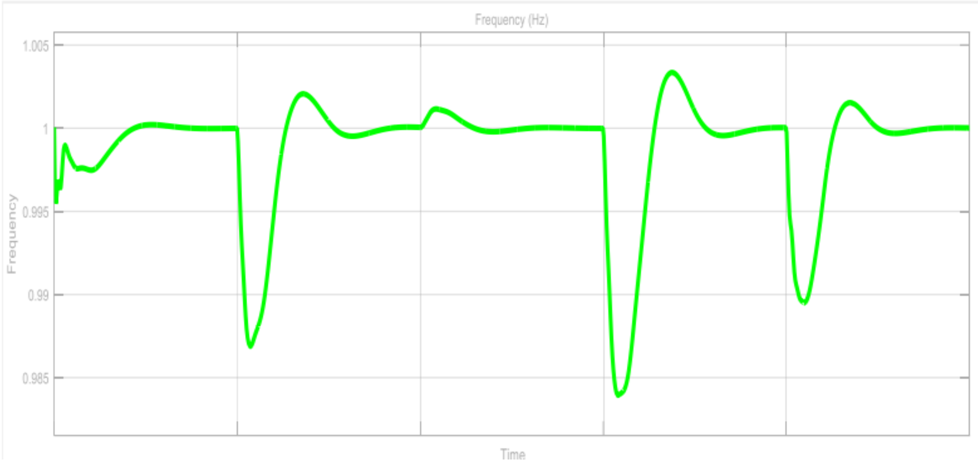

Figure 10: Simulation results for change in Frequency vs time with pitch angle control

H. Simulation results for comparison between Frequency vs time with pitch angle control & without pitch angle control

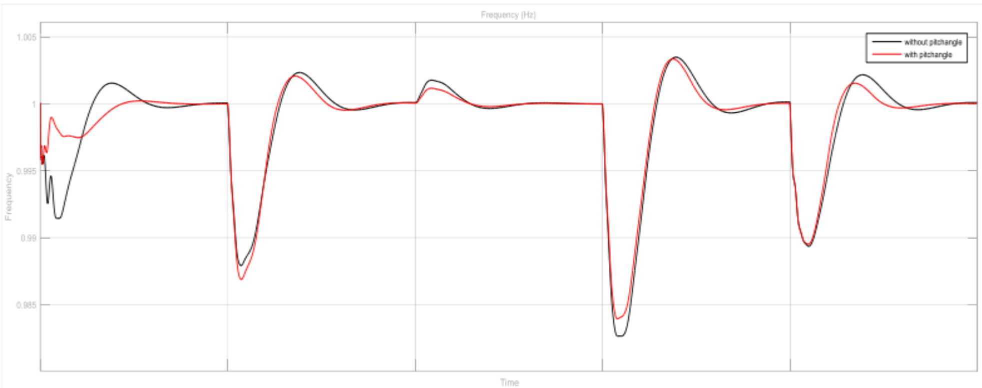

Figure 11: Simulation results for comparison between Frequency vs time with pitch angle control & without pitch angle control

I. Simulation results for change in Asynchronous machine speed vs time

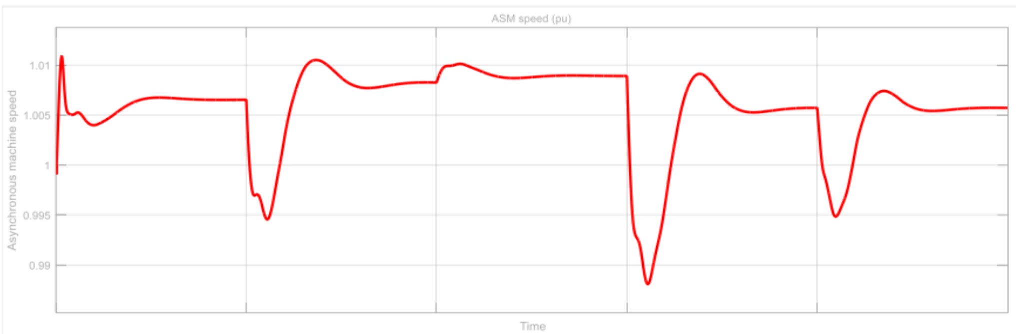

Figure 12: Simulation results for change in Asynchronous machine speed vs time

The effect of the increased load on the asynchronous machine speed is shown in Change in load occurred at t=5 sec and the change in load occurred at t-15 sec. With the increase in load, the Asynchronous machine speed momentary oscillates and has beendecreased. Variation in load has effect on machine speed.

J. Simulation results for change in Reactive power supply vs time

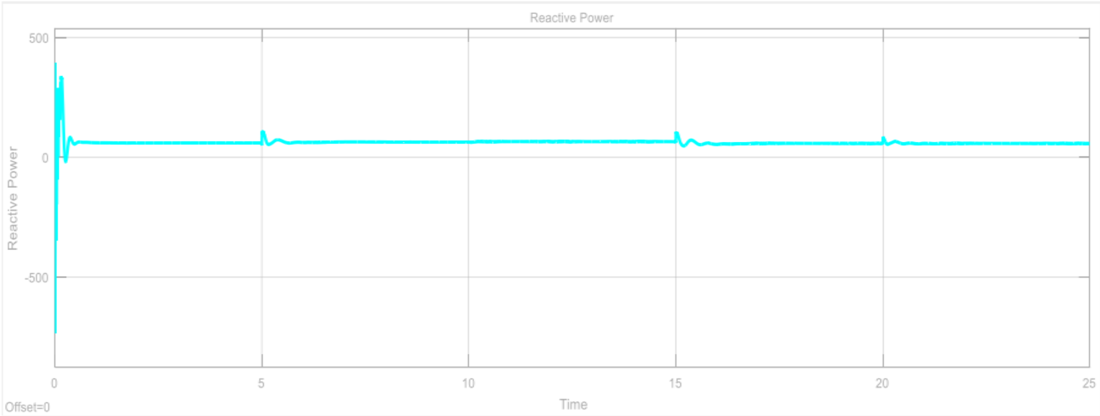

Figure 13: Simulation results for change in Reactive power supply vs time

The reactive power for maintaining the voltage level of the line so that active power can flow to do useful work and this is why we compensate reactive power by external means.Itis done by a capacitor bank to supply reactive power is connected in parallel to the transmission line.In the figure 5.9 the supply of the reactive power by capacitor accordingto load increased or dip the frequency waveform. At time t=5 sec.t=15sec.,t=20sec the loadincrease and their is a dip in the frequency accordingly the reactive power is supplied to compensate.

VI. CONCLUSION & FUTURE WORK

In this work wind-diesel hybrid system is modelled. As the wind speed and load is varied,there is frequency deviation occurs, the same can be observed in the chapter five. For the purpose of load frequency control 'Pitch-angle controller' is designed and modelled.

The wind-diesel hybrid system is subjected to different perturbations like variations in windspeed and variations in load. Then system performances are analysed with and without application of pitch angle controller. From the simulation results it is found that when the pitch angle controller is applied the deviations in the frequency reduced quit considerably.Also the number of oscillations, overshoot and undershoot reduces. The frequency settled to normal value more quickly as compared to when no pitch angle controller is used.

Also a diesel governor system and voltage regulator for the synchronous generator is proposed. These components help in regulating the voltage as per the normal value and minimum use of diesel engine when ample amount of wind speed is available. These can be seen in the waveforms of power generated by diesel engine driven synchronous generator and wind generator versus wind speed.The wind-diesel hybrid system proposed gives satisfactory results under different perturbations, but there is some scope of modifications. These are as:

- The hybrid system can be integrated with different energy storage systems like battery, flywheel etc. So that excess energy can be stored in these ESS and can be used when generation falls due to lower wind speed.
- The gain of the pitch-angle controller can be adjusted by using artificial intelligencemethod like fuzzy, ANN etc.
- The system performance can also be examined by connecting the hybrid system with grid, solar system or any other renewable energy source.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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