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Hybrid Wind Diesel Energy System Using Matlab Simulation

T. Kranthi Kumar, Asha Tulasi, Smaranika Swain

Abstract -- In a Hybrid Wind Diesel energy system, the Wind turbines role is to reduce diesel consumption, and the Diesel generator's part is to compensate load changes and inadequate wind. Using the MATLAB SIMULINK design and simulation program, a low cost study of a Wind/Diesel/Battery system functions can be achieved. The main objective of the project was to Model the combined Wind/Diesel/Battery hybrid power system for a standalone unit in a remote location. The main objective of this project is to analyze and simulate a Hybrid Wind-Diesel power system. This paper presents the performance analysis of various control strategies used in the dispatch of stored wind energy in remote hybrid wind/diesel power system. The Fuzzy logic controller for various dispatch strategies were designed and analyzed. The analysis and simulation of the Wind/Diesel/Battery hybrid power system for a stand-alone unit in a remote location was achieved through modeling of the system using MATLAB SIMULINK software.

Index Terms—**Wind Turbine, Diesel generator, Lead acid battery, universal bridge inverter, fuzzy logic controller.**

I. INTRODUCTION

Wind is only an intermittent source of energy. In grid connected mode, wind power has proven extremely cost effective at good windy sites. The power in the wind is proportional to the cube of the speed and hence the presence of wind speed fluctuations (turbulence) and the frequent weather systems can lead to variable power availability.

A. WIND POWER

As shown in Figure 1, power production from a wind turbine is a function of wind speed. In general, most wind turbines begin to produce power at wind speeds of about 4 m/s (9 mph), achieve rated power at approximately 13 m/s (29 mph), and stop power production at 25 m/s (56 mph). Variability in the wind resource results in the turbine operating at continually changing power levels. At good wind sites, this variability results in the turbine operating at approximately 35% of its total capacity when averaged over a year.

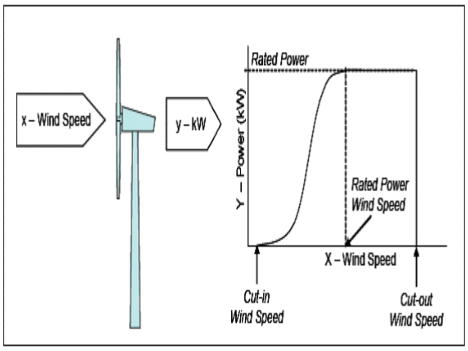

Fig 1 Relationship of Wind Speed to Power Production

B. Wind Turbines

Wind will vary from site to site mostly dependent on the general climate and the physical geography of the region. Locally, the surface conditions at the ground, such as buildings, trees and areas of water will affect the short time behavior of the wind and introduce fluctuations in the flow, turbulence. The effect of the ground roughness will then decrease as a function of height over the ground.

C. Power Developed from Wind Turbines

The actual power extracted by the rotor blades is the difference between the upstream and the downstream wind powers. That is, using equation .1:

$$P0 = \frac{1}{2} \text{ mass flow rate per second*}\{V2-V02\} \quad (1)$$

Where Po = mechanical power extracted by the rotor, i.e., the turbine output power

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V = upstream wind velocity at the entrance of the rotor blades

V_0 = downstream wind velocity at the exit of the rotor blades

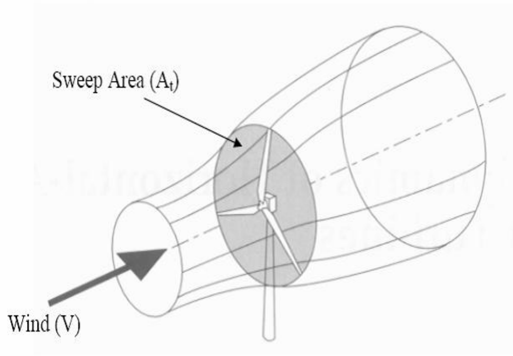

Fig 2.Energy Extracting Stream-Tube of a Wind Turbine

The air velocity is discontinuous from V to V_0 at the "Plane" of the rotor blades in the macroscopic sense. Multiplying the density with the average velocity therefore, derives the mass flow rate of air through the rotating blades. That is:

Mass flow rate= $\rho * A * \frac{(V + V_0)}{2}$

The mechanical power extracted by the rotor, which is driving the electrical generator, is therefore:

$$P_0 = \frac{1}{2}\left[\rho * A * \left(\frac{V + V_0}{2}\right)\right] * (V^2 - V_0^2)$$

The above expression can be algebraically rearranged:

$$P_0 = \frac{1}{2} * \rho * A * V^3 \frac{\left[\left[1 + \frac{V_0}{V}\right] * \left[1 - \left(\frac{V_0}{V}\right)^2\right]\right]}{2}$$

The power extracted by the blades is customarily expressed as a fraction of the upstream wind power as follows

$$P_0 = \frac{1}{2} * \rho * A * V^3 * C_p$$

Where $C_p = \frac{\left(1 + \frac{V_0}{V}\right) * \left[1 - \left(\frac{V_0}{V}\right)^2\right]}{2}$ is the Betzlimit

Here Cp is the fraction of the upstream wind power, which is captured by the rotor blades. The remaining power is discharged or wasted in the downstream wind. The factor Cp is called the power coefficient of the rotor or the rotor efficiency. For a given upstream wind speed, the value of Cp depends on the ratio of the downstream to the upstream wind speeds, that is (V0/V). It has the maximum value of 0.59 when the (Vo/V) is one-third. The

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maximum power is extracted from the wind at that speed ratio, when the downstream wind speed equals one-third of the upstream speed. Under this condition:
In practical designs, the maximum achievable Cp is below 0.5 for high speed, two blade turbines, and between 0.2 and 0.4 for slow speed turbines with more blades. The following Fig. shows the comparison between the theoretical and actual power curves obtained from the wind Turbine

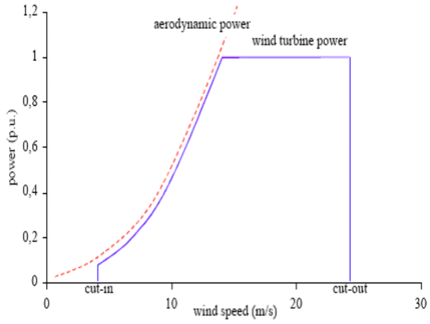

Fig 3 Power Curve of a Wind Turbine corresponding to wind speed .

At wind speeds from 12m/s to 25m/s the power is limited to the rated power by means of different wind turbines control mechanisam.The wind speed at which wind turbines are stopped is called the Cut-out wind speed.i.e.20-25m/s

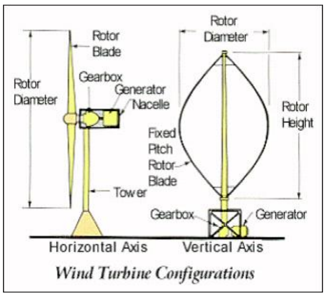

Fig 4 Basic Wind Turbine Configurations

Figure 4 illustrates the two types of turbines and typical sub-systems for an electricity generation application. Vertical axis designs have an advantage of rotational symmetry that obviates any need for a yaw system.

D. Wind Turbine Generators

Most of the wind turbine generators directly connected to the grid. This configuration of connection is used due to its cost effectiveness and robust solution for the wind turbine owners. The main drawback of this configuration is that the wind turbine generators consume reactive power for the excitation of the rotors. In order to compensate the reactive power consumption, the wind turbine uses capacitor bank. The capacitor banks are typically designed only to compensate for the generator no load consumption of reactive power. The capacitor bank for no load compensation is connected to the grid in steps to limit the transients during switching.

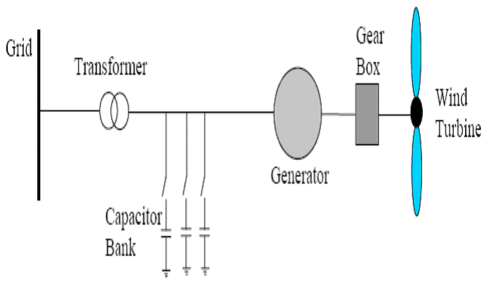

Fig 5: Single line diagram for typical wind turbine generator configuration

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E. Dynamic Performance of Wind Turbine-Induction Generator

The problem of using wind as an input source of power generation is that wind varies from time to time. The use of staticVAR compensator to regulate voltage produced from gusts wind generator system became an alternative solution to overcome the problem of input variation. To achieve stability of the system, a state and output PI controller is proposed to control the static VAR controller and the mechanical input power to the generator. From software simulation results, the proposed controller shows good damping performance for the wind generation system under severe wind gust and large electrical system disturbances. In a wind generation system, unbalanced loading at the point of common coupling (PCC) will result in unbalanced voltage at PCC. This unbalanced voltage will cause large negative sequence currents due to low negative sequence impedance of induction generator. Eventually these large currents will cause unbalanced heating (hot spot) in the machine windings that can eventually lead to machine failure. Also the unbalanced voltage operation will create a pulsating torque which produces speed pulsation, mechanical vibration and acoustic noise

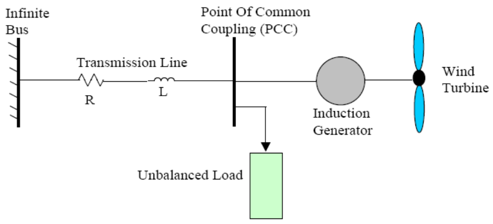

Fig 6 Connection of wind energy system

Using steady state and dynamic analysis and simulation on the impact of unbalanced voltages on the three-phase induction generator, solutions to improve the unbalanced conditions are deduced which are to increase the power capability of transmission lines, redistribute load periodically to equalize any unbalanced load and to use power converter with wind turbine on the utility side.

F. Types of Power Conversion Systems

Two main types of generators used for Variable-speed wind turbine can either be the synchronous or the induction generator. The synchronous generator (SG) Produces reactive power, hence it can be connected to a load-commutated rectifier, i.e., a diode rectifier or a Thyristor rectifier. The induction generator (IG) requires reactive power to operate. Consequently, the IG often uses the voltage source converter (VSC), which produces reactive power. The Inverter of the system is connected to the grid. Here, the grid-commutated inverter, also called the Thyristor inverter, and the VSC can be used. VSC can act both as a rectifier and as an inverter: the controller sets the power direction.

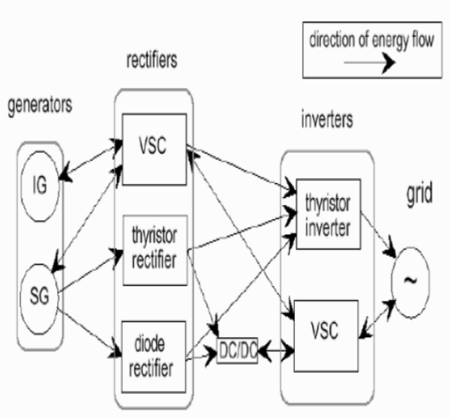

Fig 7: Different Electrical System Alternatives for Variable-Speed Operations

G. Hybrid System Control

The power output from wind turbines varies during the day according to the variations in wind speed. In a large grid these variations and fluctuations in wind power are absorbed by the strong grid, thus controlling frequency and voltage. In a small and isolated grid the power balance between production and consumption has to be

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maintained in order to keep frequency and voltage within predefined limits. As the wind power does not supply constantly, the power balance between the consumption, the fluctuating wind power and the diesel power must be maintained by regulating the power output of the diesel generator or regulating the load by means of a dump load or load bank. There are mainly two controls to ensure the quality of supply from hybrid system.

H. Frequency Control

Control of the grid frequency is maintained by the fast control of the power balance between the fluctuating wind power, the dump load/load bank (electrical heating elements) and the consumer load. frequency is controlled by absorbing the surplus wind energy in a dynamic variable dump load or load bank.

I. Voltage Control

Control of the grid voltage is maintained by the Automatic Voltage Regulator (AVR) of the synchronous generator also supplying reactive power for energizing the induction generators in the wind turbines.

J. Control Strategy There are two distinct levels in the control of a hybrid power system:

- Dynamic control, which deals with control of the frequency and magnitude of the output voltage of the system, and
- Dispatch control, which deals with the flow of energy in the system from the various sources to the load. The dispatch control problem is concerned with controlling the flow of energy, on a time scale of minutes to hours, in such a way as to optimize system performance in terms of operating costs.

K. Discharge Strategy

The goal of the discharge strategies that is presented in this paper is to minimize the operating cost of the system. The operating cost of the system is assumed to be the sum of the hourly fuel costs and battery wear costs.

L. Fuzzy Discharge Strategy

The goal of fuzzy discharge strategy is to design a practical discharge controller that can perform better in terms of reducing operating cost. There are two factors that are to be considered in implementing an improved discharge strategy: the current state of charge of the storage batteries and future wind predictions. In general, as the SOC (state of charge) of the batteries decreases, the threshold of net loads to be met by storage also decreases. In this implementation current battery SOC is defined in terms of the three fuzzy sets: Low, Medium, and High. The definition of what range of SOC constitutes each of these fuzzy sets is illustrated in Figure 8.

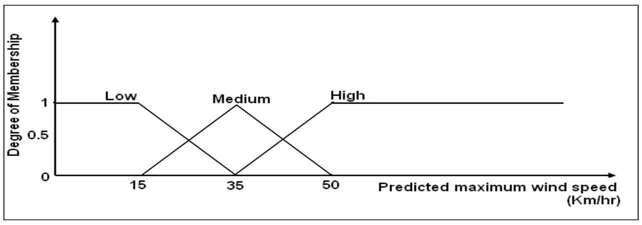

Fig 8: Membership function of SOC

M. Battery Lead-Acid Model

The Battery block implements a generic dynamic model parameterized to represent most popular types of rechargeable batteries.

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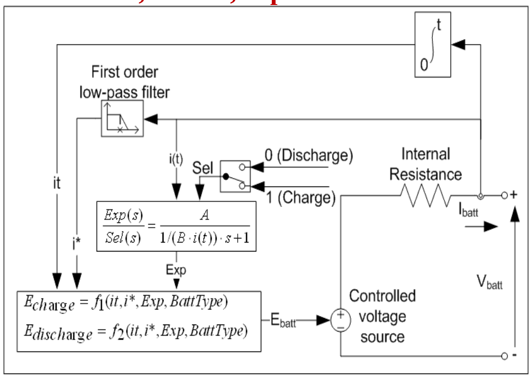

Fig 9: Lead-Acid Model

The parameters of the equivalent circuit can be modified to represent a particular battery type, based on its discharge characteristics as shown below.

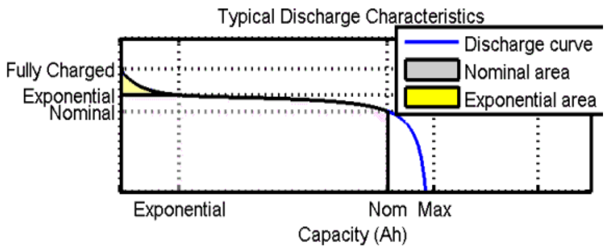

Fig 10: Typical Discharge Strategy

The first section represents the exponential voltage drop when the battery is charged. Depending on the battery type, this area is more or less wide. The second section represents the charge that can be extracted from the battery until the voltage drops below the battery nominal voltage. Finally, the third section represents the total discharge of the battery, when the voltage drops rapidly.

N. Simulink model of Fuzzy discharge strategy

The Universal Bridge block allows simulation of converters using both naturally commutated (and line-commutated) power electronic devices (diodes or thyristors) and forced-commutated devices (GTO, IGBT, and MOSFET).

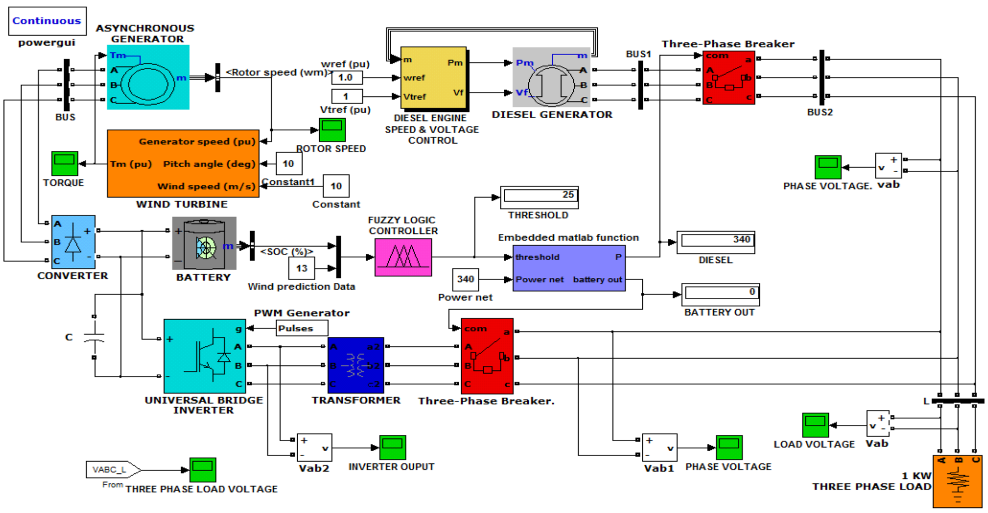

Fig 11 Simulink model of Fuzzy discharge strategy

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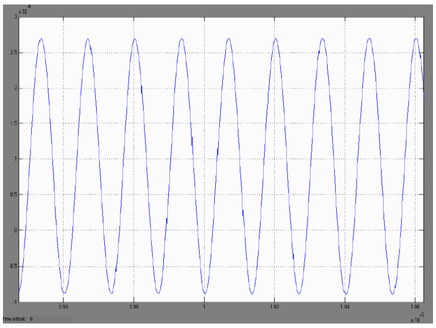
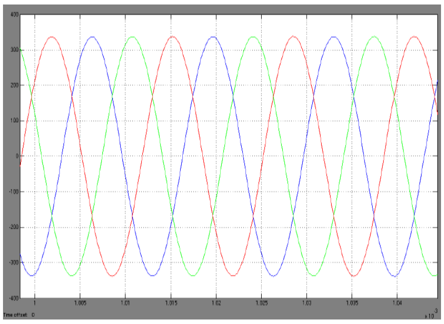
II.RESULTS AND DISCUSSION

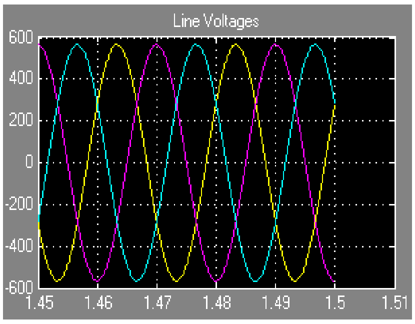
Simulation results of Proposed Hybrid Power System



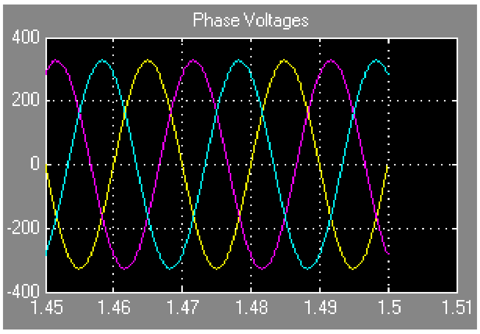
Output during battery operating (single phase)



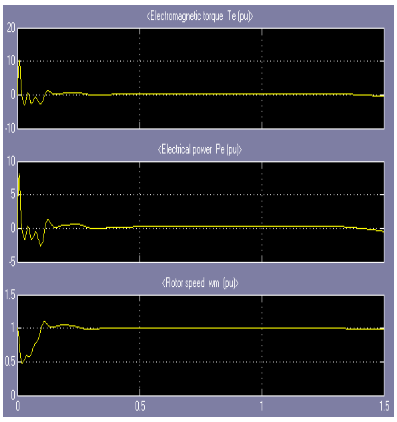
Three Phase Voltage of the load when diesel generator operating



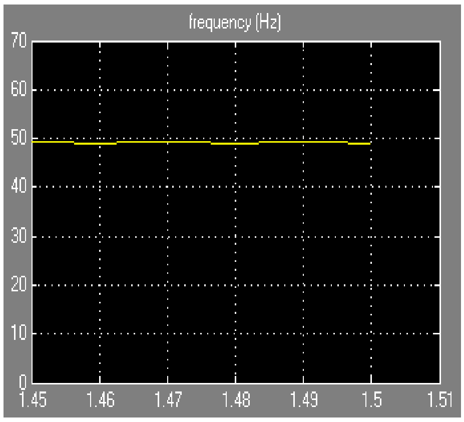
Three Phase load (line) voltages



Three Phase load (phase) voltages



Torque, Power and Speed in p.u. system



Frequency of the Grid

III. CONCLUSIONS AND SCOPE FOR FURTHER WORK

The theoretical Ideal Discharge Strategy showed the potential of increasing savings in operating costs through the judicious dispatch of stored energy. Two practical methods of implementing such improved discharge schemes are the Optimal Fixed-Threshold Discharge Strategy and the Fuzzy Discharge Controller. The Fuzzy Discharge Controller uses a more sophisticated method to achieve further reductions in operating cost. The implementation of this strategy requires incorporating long-term wind speed prediction in the controller structure. Fuzzy discharge controller operates according to the state of charge and the expected wind condition.

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If wind prediction is more accurate means then fuzzy threshold controller performs accurately and thus reduces the operating cost by reducing the start/ stop of the diesel generator. This model can be extended with the method of using DC Motor-Alternator setup instead of using static Inverter. DC Motor is coupled to Diesel engine, especially when PV, Wind, FC power also considered, which facilitates improvement in power quality, and ensures continuity of supply to load.

REFERENCES

[1] C. Kathirvel, Dr. K. Porkumaran 'Analysis and Design of Hybrid Wind/Diesel System with Energy Storage for Rural Application' IEEE transactions 978-1-4244-7398-4/10/2010.

[2] I. Hsum Li, Wei-Yen Wang (2007) 'A merged fuzzy neural network and its applications in battery state of charge estimation', IEEE Transactions on energy conversion Vol 22, No 3, PP 697-708.

[3] Bossanyi, E. A. (1985) 'Short-term wind prediction using Kalman filters', journal of Wind Engineering, PP. 1-8.

[4] Baring- Gould, E.1. (1998) 'Hybrid2 the Hybrid System Simulation Model', Users Manual. National Renewable Energy Laboratory.

[5] Chin H. Lo, Max. D. Anderson 'Economic dispatch and optimal sizing in battery energy storage systems in utility load leveling operations' (1999) IEEE Transactions on energy conversion Vol 14, PP 824-829.

[6] Vincenzo Galdi, Antonio Picolo (2008)"Designing an adaptive fuzzy controller for maximum power extraction", IEEE Transactions on energy conversion Vol 23, No 2, PP 559-569.

[7] Davies, T. S., Jefferson, C. M., & Mayer, R. M. (1988) 'Use of flywheel storage for wind diesel systems', Journal of Wind Engineering and Industrial Aerodynamics, pp.157-165.

[8] Contaxis,G. C., & Kabouris, J. (1991) 'Short term scheduling in a wind diesel autonomous energy system', IEEE Transactions on Power Systems, PP.1161-1167.

[9] Lee, C. C. (1990) 'Fuzzy logic in control systems: fuzzy Logic controller - Part 1', IEEE Transactions on Power Systems, PP.404-418.

[10] Lipman, N. H. (1984) 'An analysis of the integration problem for Wind power inputs into small grid systems', Wind Engineering, PP.9-18.

[11] T.J.Ross (2002) "Fuzzy Logic with Engineering Applications" Tata McGraw Hill publications.

[12] MATLAB/Simulink SimPower Systems Documentation. Available http://www.mathworks.com .

[13] Mukund. R. Patel, Wind Power Systems, CRC Press, 1999.

[14] Tony Burton, David sharpe, Nick Jenkins and Ervin Bossanyi, "Wind Energy handbook", John Wiley& Sons, 2001.

[15] Danish Wind Energy Association manual, "Guided Tour on Wind Energy" Available: http://www.WINDPOWER.org.

[16] Sharaf, A.M., Abdin, E.S,"A digital simulation model for wind-diesel conversion scheme" System Theory Proceedings, 1989, Page(s): 160 – 166 .

[17] Eduard Muljadi and C. P. Butterfield, "Pitch-controlled variable-speed wind turbine generation," IEEE Transactions on Industry Applications, vol. 37, no. 1, pp. 240-246, Jan/Feb 2001.

[18] Tomas Petru, "Modeling of wind turbines for power system studies" PhD. thesis, Department of Electric Power Engineering Chalmers University of Technology Goteborg, Sweden 2003.

[19] J. G. Slootweg, S.W.H. de Haan, H. Polinder and W.L. Kling, "General model for representing variable speed wind turbines in power system dynamic simulations," IEEE Transactions on Power Systems, vol. 18, no. 1, pp. 144-151, Feb. 2003.

[20] R. M. Hilloowala and A. M. Sharaf "A utility interactive wind energy conversion scheme with an asynchronous DC link using a supplementary control loop", IEEE Trans. on Energy Conversion, Vol-9, No.-3, Sept. 1994.

[21] Udaykumar R.Y, Atul S.Kini, "Modeling and Performance Analysis of Wind/Diesel Hybrid Power System'', IEEE Proceedings 2006, pp 1215-1221.

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AUTHOR BIOGRAPHY

T.Kranthi Kumar: He is working as assistant Professor in G.I.E.T, Gunupur, and Odisha has completed M.TECH from JNTU. He published many papers in National & International level. He is a member of SESI. .

Asha Tulasi : She is working as assistant Professor in G.I.E.T , Gunupur , Odisha has completed M.TECH from JNTU. She published many papers in National & International level. She is a member of SESI. ..

Smaranika Swain: She is working as lecturer in G.I.E.T, Gunupur, and Odisha has completed M.TECH from BPTU. She is a member of SESI.

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