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Experimental Analysis of Hybrid Wind Diesel Energy System Software Module

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Abstract

The work deals with Hybrid wind diesel power system. The developed software predicts the optimum wind turbine characteristics like cutin speed, cutout speed and rated speed to suit the particular location. The developed module shows variation of power generation by the wind machine with respect to change in wind speed. The operations of different system components like windmill, diesel engine, load, Flow path of power and battery status are simulated. The various charts generated by module helps to predict the performance of hybrid system. The designed software can also be used for monitoring of existing hybrid wind diesel engine system. Visual basic- 6 software is used for writing the program to design wind mill of particular location and MATLAB codes are written to evaluate the amount of power generation by the windmill at a particular wind speed. The designed software results and MATLAB results are carried out followed with experimental data to validate the results. The comparison shows a close agreement between results obtained from developed software, MATLAB outputs and results obtained from experimental setup.

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Keywords: Power genertion, Wind speed, Cut in speed, Rated speed, Furling speed, Load, Kinetic Energy

1. Introduction

The quest for power is an integral part of human existence in the present day as it is closely interconnected to the standard of living of the populace [1]. There is an ever-increasing demand for power viewing the pace at which population and economy is growing.

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This demands for exploration of newer energy sources, which are cleaner and also reliable. Wind energy is an important contender in this respect but needs measures to make it reliable. The wind hybrid systems provide the necessary advantage to overcome the difficulties of wind standalone systems. A very important problem posed by fossil fuel energy conversion technologies is the inability of the systems to supply the electricity to places located far away from the generation point because either grid connection cannot reach or would be too costly. This deficiency can be removed if a decentralized power supply system is adopted. Here comes the impotents of renewable energy sources like solar, wind etc. Of the available renewable energy options wind with some backup system is the cheapest option for decentralized power supply & to reduce dependency on conventional energy sources. This new system also reduces the environmental hazards posed by thermal and nuclear power system. The earlier contribution towards hybrid system were by Iqbal M.T [2], A. N. Celik [3], M.A. Elhadidy [7] and Jamil et. al. [8]. Simulink is used for the dynamic simulation results of a small 500 W wind fuel cell hybrid energy system. Analysis of simulation results and limitations of a wind fuel cell hybrid energy system are discussed. Weibull probability distribution function to find out the wind energy density and other wind characteristics with the help of the statistical data of 50 days. The present work deals with the simulation results of various system constitutes of hybrid wind diesel power system using VB software and MATLAB codes then the results are validated with experimental.

2. Theoretical Analysis

2.1 Electrical power out put

Wind possesses energy by virtue of its motion. Any machine capable of slowing down the mass of moving air, like a sail or propeller, can extract part of the energy and convert it into useful work.[4] Three factors determine output from a wind energy converter: they are wind speed, Cross section of wind swept by rotor and Overall conversion efficiency of rotor, transmission system and generator or pump. No device, however well designed, can extract all of the wind's energy because the wind would have to be brought to a halt and this would prevent the passage of more air through the rotor. The power in the wind can be computed by using the concept of kinetics. The wind mill works on the principle of converting kinetic energy of the wind to mechanical energy. It is know that power is equal to energy per unit time. The energy available is the kinetic energy of the wind. The kinetic energy of any particle is equal to one half its mass and the square of its velocity, or ½ mv^2. The amount of air passing in unit time, through an area A, with velocity V, is AV, and its mass m is equal to its volume multiplied by its density ρ of air, or m=ρAV. Substituting this value of the mass in the expression of kinetic energy, It obtain the expression as follows

$$\text{Kinetic energy} = \tfrac{1}{2}\rho A V^3$$

The electrical power out put (P_e) is basically depends on the wind turbine characteristics like cut-in speed, rated speed and furling or cut-out speed.[3]

$$P_e = 0 \qquad (v < v_c)$$
$$P_e = a + bv^2 \qquad (v_c \le v \le v_R)$$
$$P_e = P_{eR} \qquad (v_R < v < v_F)$$
$$P_e = 0 \qquad (v > v_F)$$

Where the coefficients a and b are given by

$$a = \frac{P_{eR} v_c^{\,2}}{v_c^{\,2} - v_R^{\,2}} \qquad and \qquad b = \frac{P_{eR}}{v_R^{\,2} - v_c^{\,2}}$$

And the rated electrical power output at rated wind speed is expressed as

$$P_{eR} = \frac{1}{2} C_p \, \eta \, \rho \, A \, v_R^3 \quad Watt$$

Where

$$C_p \text{ is power coeff} \quad = \frac{\text{power extracted by windmill}}{\text{power available in wind stream}}$$

2.2 Relation between V_c, V_R and V_F

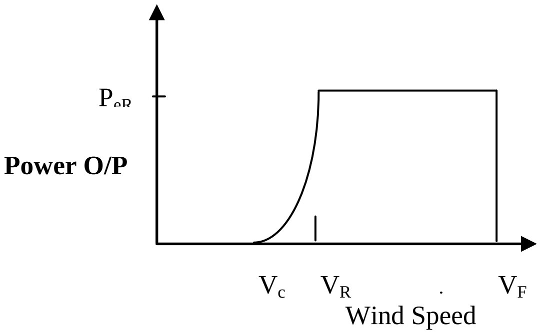

Fig. 1. Wind turbine power v/s wind speed

Cut-in speed (V_c): is minimum wind speed at which turbine starts generating power.
Rated speed (V_R): speed at which turbine will generate designed or rated power. At wind speeds between cut-in speed and rated speed, power output from turbine increases with wind speed and output of machine levels off above rated speed.
Furling speed (V_F): Corresponds to high wind speeds during which the turbine ceases to generate power and is shut down. It is also known as cutout speed.

Relation Between V_c , And V_R : $V_c = 0.31V_R$
Relation Between V_F , And V_R : $V_F = 2V_R$
Relation Between V_R And V_{avg} : $V_R = 2V_{avg}$ Where V_{avg} is mean wind speed

2.3 Status of battery in Amp. hours

Energy = power x time (1)
But power is the product of voltage and current i.e
Power= voltage x current (2)
Substitute eq. (2) into eq. (1) we get
Energy =Voltage * current *time

$$current * time = \frac{Energy}{Voltage} \quad \text{Ahr}$$

3. Experimental setup

The experimental work is carried out at Energy Systems Engineering Department. BVB College of Engineering, Hubli, Karnataka, India, where a Hybrid wind diesel power system is installed to meet power demand of department[2]. The different electrical appliances which are being used are lights, fans and computers. The site is having high wind energy potential, with maximum wind velocity at about 38 kmph and minimum about an average of 15 kmph. The average wind velocity of the place is around 22 kmph on yearly basis. The line diagram of experimental setup is shown in Fig 2.

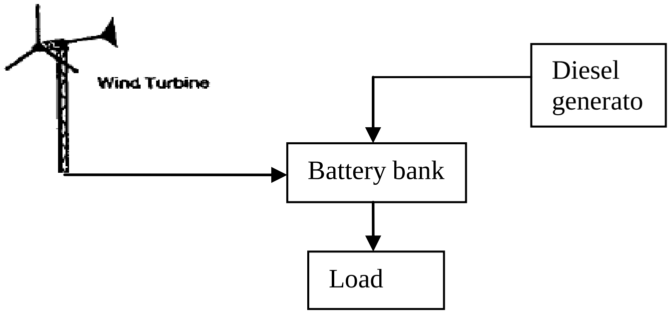

Fig. 2. Experimental Setup

The system has 1 kW windmill and 7.35kW diesel genset to generate electricity. A battery bank of capacity 48 V is attached with system, which stores energy generated by wind mill and supplies back to load. An inverter of 1 kVA is used to interface between AC load and DC battery storage. It also has controller to monitor battery status and a dump load to prevent overcharging of batteries.

3.1 Wind turbine specifications

Wind mill of capacity 1 kW is manufactured and supplied by United Energy systems private limited, Pune. The detail specification is as fallows

- Type : Up-wind, permanent magnet
- Modal : Whisper 1000
- Rotor : 3 blade, fiber glass
- Rated power : 1000 watts.
- Rated wind speed : 11 m/s
- Cut-in speed : 3 m/s
- Cut-out speed : 25 m/s
- Poles/50 Hz rpm :10/600
- Propeller diameter : 2.7 m
- Blade tip to tower centre : 33 cm

3.2 Test procedure

The Hybrid wind-diesel system is ready for performing the experiment, All connections and proper functioning of measuring instruments were ensured by inspection and found satisfactory before start of the experiments. The wind power generation and load requirement during month of June is shown in Table 1. General procedure is as follows

- Specific gravity of each cell of the battery is noted before and after the test.
- The different parametric readings are noted down a interval of 10 min each between the experimental hrs.
- The experiments are repeated for 3 or 4 days to know the precise behaviour of the system and to reduce the errors involved if any.

Table 1 Wind generated power and load requirement on 2nd June

Time IST	Wind velocity m/s	Wind current in amps	Wind voltage in Volts	Power in Watts	Load in Watts
7.00	6.3	8	35	252	120
7.10	5.4	6	30	162	240
7.20	4.7	4	30	108	360
7.30	8.1	12	40	432	440
7.40	5.3	5	35	157.5	600
7.50	4	2	30	54	400
8.00	4.6	4	30	108	280
8.10	5.3	6	30	162	200
8.20	6.7	10	30	270	80

4. Results and discussion

The input parameters required to run the software are Wind speed in m/s, Time in minute, and Load in watt.

4.1 Output of the Software

- Simulate operation of different system constituents
- Wind turbine Characteristics includes cutin, cutout and rated speed
- Various charts viz.
  - Power output in Watt vs speed
  - Battery status in Ahr vs Time
  - Load in Watt vs Time
- Current total power generated by wind mill in Watts
- Battery status after every interval (10min) in Ahs
- Diameter of the turbine in meter
- Total run time of diesel engine
- Finally produces brief report

The main window of Hybrid wind diesel power system software module is shown in Figure 2. It contains different constituents like windmill, diesel engine and battery with three text boxes in the top row of the main window where in the requisite input data needs to be fed, like wind speed in m/s, Time in min or hr and required load in watt of that particular time. After entering the input data of any locality, run the software. The software compiles and gives different design parameters of system as shown in Figure 3.

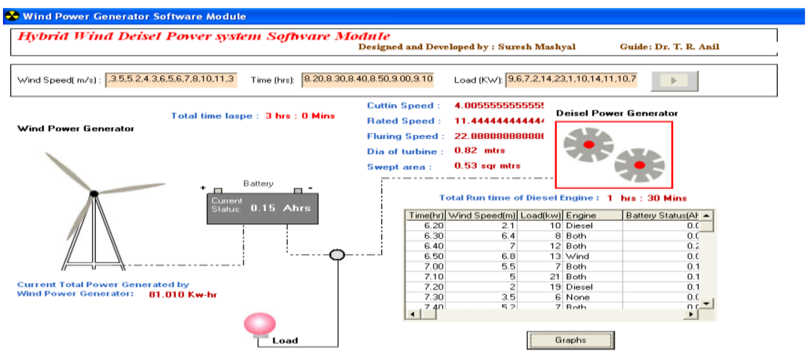

Fig. 3. Main window indicating results of software

The main application of the software is once the input data of particular locality like wind speed, time and load is entered. The software not only simulate the different constituents of the system but also before installing the actual hybrid wind diesel system the software gives optimum wind diesel characteristics like cut-in, rated and furling speed of the wind mill required. Power produced by wind turbine on the basis of cut-in, rated and furling speed of designed wind mill, and total run time of the diesel engine by this value we can predict the total consumption diesel to fulfil the remaining load. Another main application of the software that is developed, it can be used to monitor exiting hybrid system continuously.

4.2 Various charts obtained from software

The various charts obtained from software after giving the input parameters are as follows,

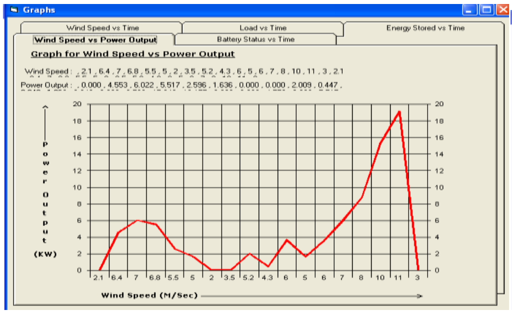

Fig.4 Power output v/s Wind speed

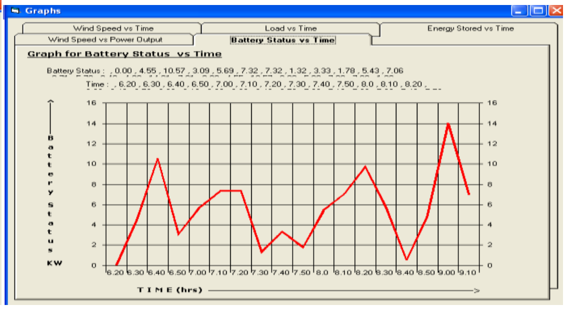

Fig.5 Battery Status v/s Time

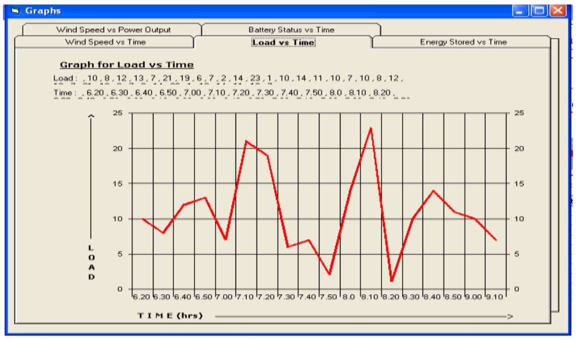

Fig.6. Load v/s Time

4.3 Graph and results of MATLAB

The MATLAB codes have been written for obtaining wind turbine characteristics value. Figure 7 shows the results of all parameters of wind turbine and figure shows the graph where vertical axis is power generated and horizontal axis is wind speed.

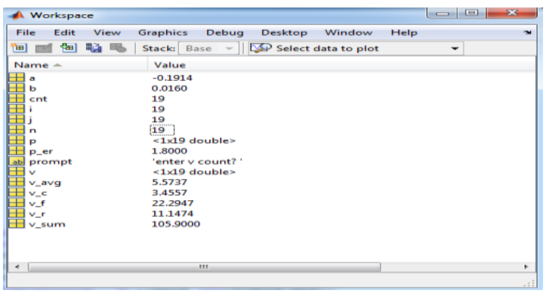

Fig. 7 MATLAB results

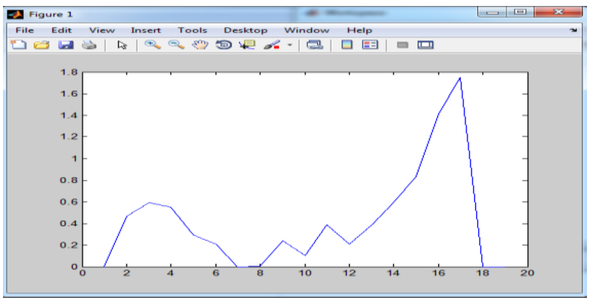

Fig. 8 Power vs Wind Speed

Hence from Table 2 we can conclude that there is good agreement, between the software and experimental result of wind turbine characteristics, which is thought to be quite acceptable. The error occurs due to variable wind speed and quality of bearing and aerofoil structure of blades.

Table 2 Comparison of Software and Experimental results of wind turbine characteristics

	Software	MAT LAB	Expt
Cut in speed (m/s)	4	3.4	3.5
Rated speed (m/s)	11.8	11.14	11
Furling speed (m/s)	22.88	22.29	25

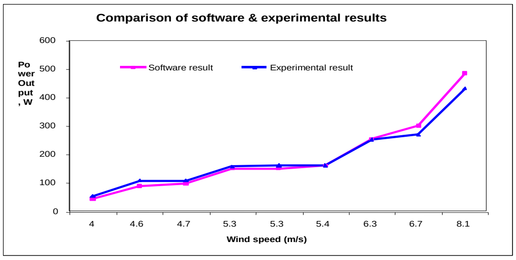

Fig. 9 Comparison of Software and Experimental power output

The Figure 9 shows the graph of comparison of software and experimental obtained result. The comparison shows a close agreement with in 5 % error, which is thought to be quite acceptable.

5. Conclusion

- The software developed simulates operation of Wind diesel hybrid system with respect to the constituents like wind mill, Diesel engine, load and battery.
- It can be efficiently used for the monitoring of existing system.
- The software aids in design and analysis of hybrid wind diesel system and predicts wind turbine characteristics and other features like power generation, battery status, total run time of diesel engine, wind turbine power before actual installation of system on site.

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