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Wind generated electricity from exhaust mine ventilation fans – a conceptual approach

1.0 Introduction

The wind power converts kinetic energy in wind to generate electricity. This is done by using wind turbines. The exhaust air driven out to atmosphere by the mine ventilation fan has the potential to drive the wind turbines. The wind turbines will subsequently generate electricity which can be used to lighten the lights of streets, office complex, pumping water etc. The paper deleneates the concept followed by experimental investigations.

2.0 Mine ventilation fans

Ventilation fans provide flow of fresh air to different working areas of underground mines in sufficient quantity to dilute and remove dust and noxious gases and regulate the temperature of mine atmosphere. They are either centrifugal or axial flow type. Booster fans are installed inside the mine to ventilate remote working areas. The main mine ventilation fan is installed at surface. Centrifugal fans deliver low quantity of air at higher heads whereas axial flow fans deliver large quantity of air at lower heads.

The exhaust air energy from mine ventilation fans installed at surface can be used to drive wind turbines to generate electricity. The conceptual scheme is illustrated in Fig.1. The wind energy from ventilation fan is certain unlike natural wind where uncertainty of wind energy is the main problem in matching the demand.

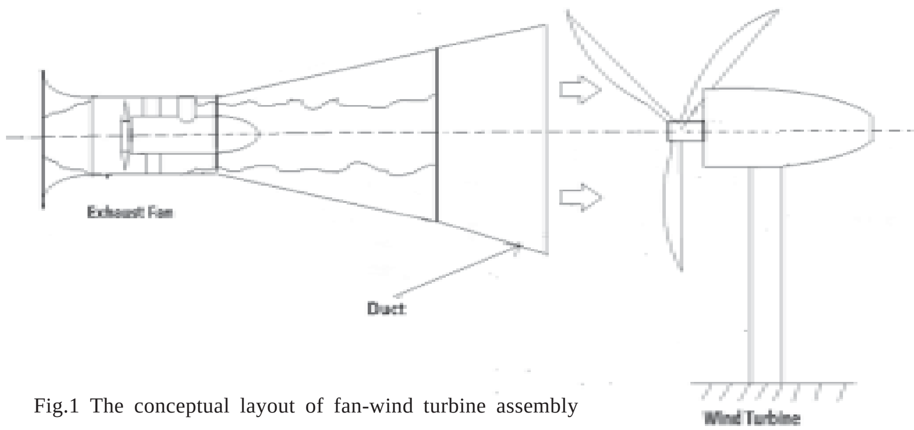

Fig.1 The conceptual layout of fan-wind turbine assembly

The operation of wind power from ventilation fan is not susceptible to change like the systems depending on natural wind where change in wind pattern result from climate change. Thus the available wind source can be classified into natural wind and man made wind. The consistent and predictable wind produced by the ventilation fan will be suitable for generating electrical energy.

3.0 Wind turbines

A wind turbine consists of airfoil shaped blades which drives a generator through coupling and gearbox. The purpose of the blades is to convert the linear motion of the wind into rotational motion of the drive system to drive the generator. Most of the wind turbines built today is of two or three bladed type.

Two types of wind turbines are found - vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT). In VAWT, the main rotor shaft driving the generator is put in tranverse direction of wind flow. The generator and gearbox are located at the base of the turbine. In HWAT, the shaft driving the gearbox and generator is parallel to the wind stream and are kept at the top of the turbine. The wind turbines utilize the advantage of the air stream for energy recovery.

4.0 The experimental set-up

An integrated experimental set-up is developed consisting of a three bladed fan, which is the source of air stream and a three bladed turbine in front of it. The turbine is fixed at a distance from the fan. They have been assumed as the exhaust mine ventilation fan and a HAWT of real life. The turbine across the exhaust air is installed to harness the discharged air for electric power generation. Fig.2 shows the

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TABLE 1: EXPERIMENTAL DATA

	Fan rpm	Turbine rpm	% of slip between fan and turbine rpm	Measured voltage in wind turbine generator (V)	Measured current in wind turbine generator (mA)	Wind speed (m/s)	Density of air (ρ) (kg/m^3) (assumed)	Cp (assumed)	Turbine rotor area (A) (m^2)	Wind power (W) $P = 1/2(C_p \rho A v^3)$	Electric power (W) P = (V.I)	Brightness of the LED (lux)
1	2845	1470	48.33	3.35	0.90	2.459				0.036	0.003	90
2	2965	1620	45.36	3.45	2.02	2.513				0.039	0.007	150
3	3070	1730	43.65	3.52	2.55	2.610				0.043	0.009	190
4	3160	1790	43.55	3.68	2.99	2.733				0.050	0.011	235
5	3335	1905	42.87	3.93	8.65	2.903	1.00	0.40	0.0122	0.060	0.034	280
6	3455	1990	42.40	4.04	14.60	3.065				0.070	0.059	340
7	3590	2045	43.04	4.23	19.58	3.283				0.086	0.084	440
8	3747	2095	44.09	4.37	21.50	3.488				0.104	0.092	510
9	4023	2140	46.81	4.45	29.43	3.737				0.127	0.131	605
10	4180	2185	47.71	4.54	41.19	4.062				0.163	0.187	680

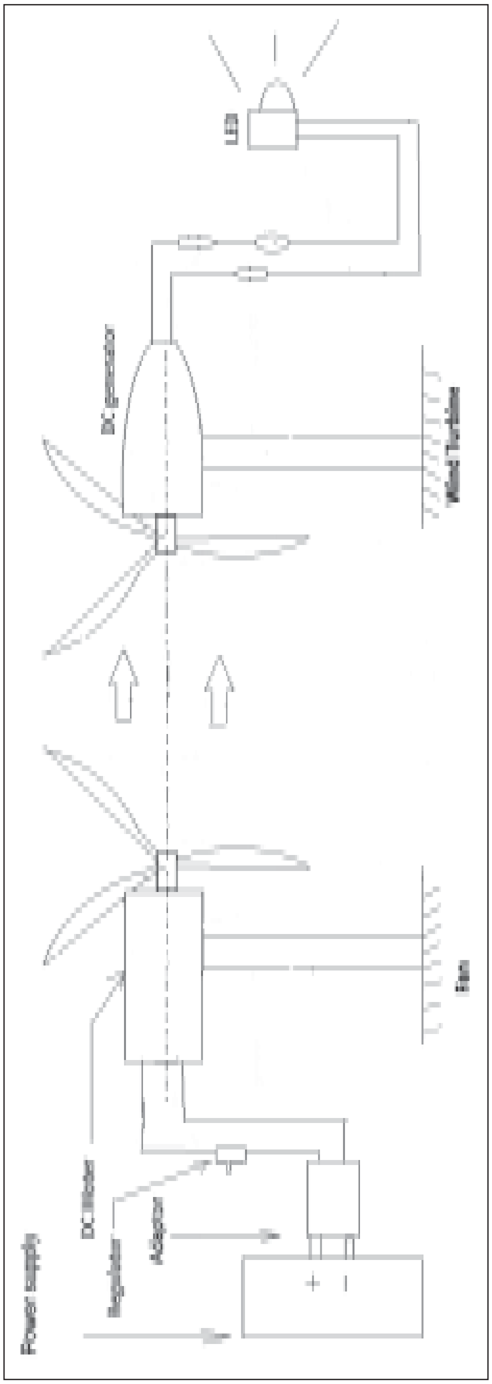

Fig.2 The layout of the experimental set-up

layout of the energy recovery system consisting of the fan and the wind turbine. The bench top experimental set up developed is shown in Fig.3.

The fan and the turbine are not real ones but resembling the actual types for the purpose of elucidation. The fan rpm is varied using a regulator. With the change in rpm of the fan, the wind speed varies. The change in wind speed causes change in power generation and illumination in LED. Illumination is measured by a luxmeter.

5.0 Experimental results and discussions

The velocity of air flow changes with the change in rpm of the fan. This causes the wind turbine to rotate at different rpm and generates different amount of electric power. The rpm of the fan and wind turbine blades have been measured by non-contact tachometer. The generated voltage and current is measured with the help of multimeter. Electric power is calculated by multiplying voltage and current. The velocity of air is measured by anemometer. Brightness of the LED improves with the increase in turbine blade rpm and measured by a luxmeter.The wind power is calculated from the relationship $P = 1/2(C_p \rho A v^3)$, where A is the area through which the wind energy is passing, ρ is the density of air , C_p is the capacity factor and v is the wind speed. C_p is a constant and used to estimate average energy production from a wind turbine as a percentage of its maximum capacity which is approximately 59%. Turbines located at good wind sites can achieve the maximum capacity factor. The common values of C_p lie in between 0.35 and 0.45. In this study the value of C_p is assumed as 0.40. The air density

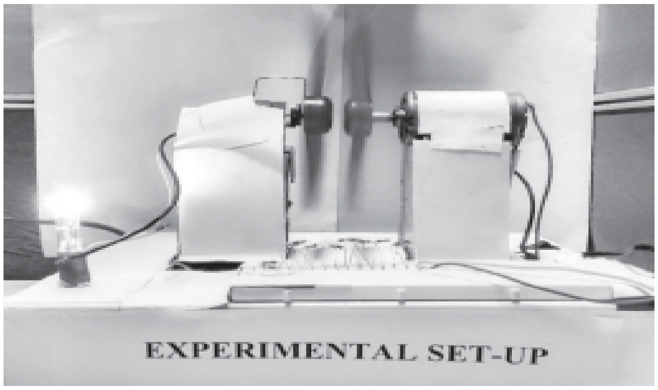

Fig.3 The bench top experimental set-up

is assumed as 1.0 kg/m^3. At mean sea level and at 15ºC, air density is 1.2 kg/m^3 as per the International Standards Atmosphere (ISA).

The experimental data are presented in Table 1. It is observed that as the fan rpm increases, rpm of turbine blades, wind speed and wind power also increase. At lower rpm of the fan, the difference between electric power and wind power is significant. At higher rpm of the fan, the turbine generates wind power nearly equal amount of the electric power. The voltage, current, wind speed and illumination increase with the increase of fan rpm. All the measurements are taken within the limiting values of the developed set-up. The experimental data shown in Table 1 are graphically presented in Fig.4(a) to (f).

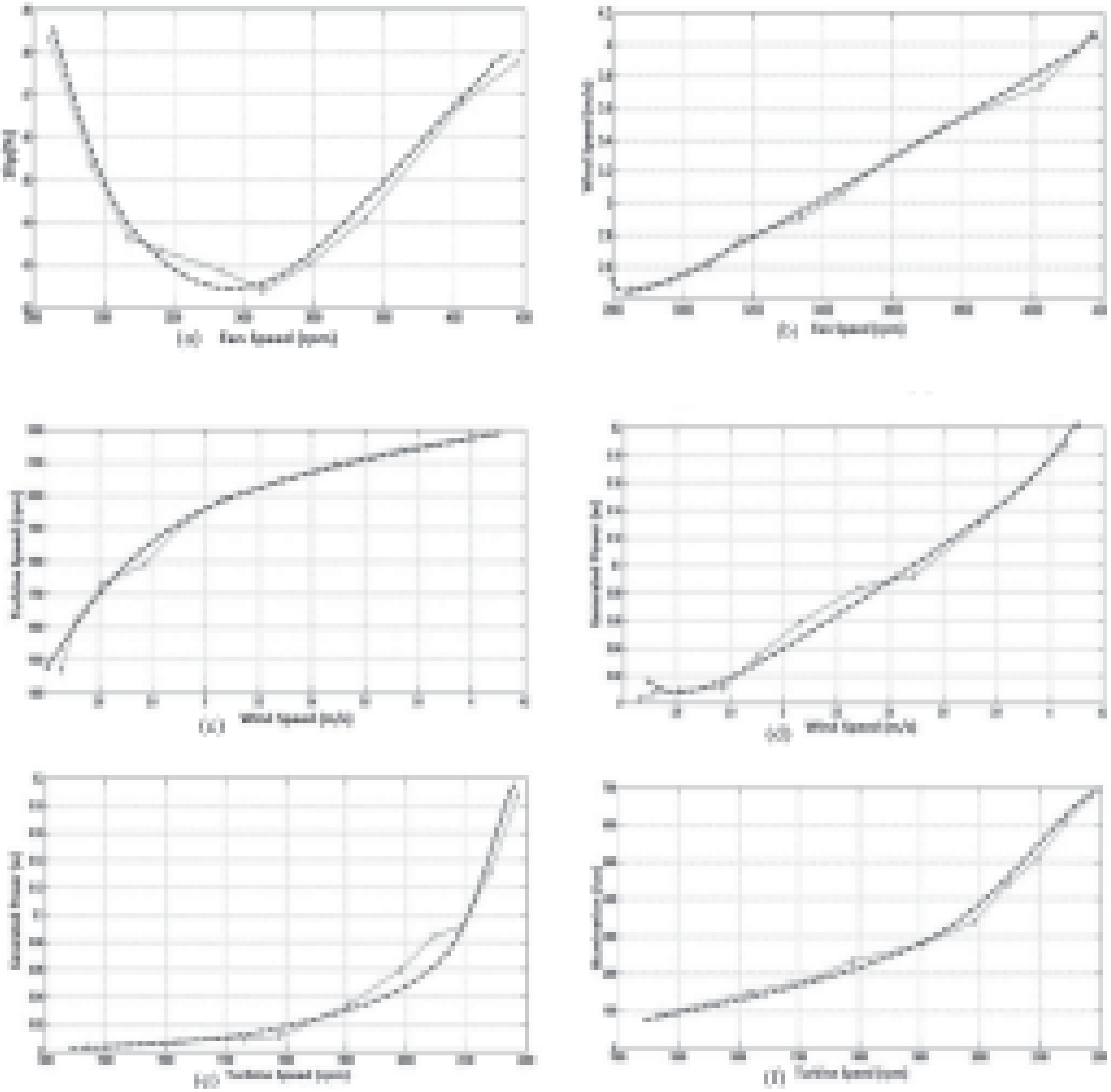

Fig.4 Graphical represtation of experimental results

6.0 Conclusion

With the increase in energy demand, exploring non-conventional energy resources have become imperative to supplement the conventional source of energy. This will be clear with an example of the estimated annual energy production of a wind turbine with rated capacity of 10 kW located at a site with a capacity factor of 40%, is 10 (kW)×0.40(CF)×8760 (hrs/yr), equal to 35,040 kWh/year.

The concept deriving electric energy from exhaust mine ventilation fan has been discussed in this paper. Wind characteristics are function of geographical location, wind speed, climatic conditions etc. The characteristics of mine exhaust air remain unaffected from these functions. So, the operation of wind power from ventilation fan is not susceptible to change like the systems depending on natural wind. This will ensure delivery of consistent and predictable electric energy.

The bench top experimental set-up developed in this study was not covered by a ducting arrangement. The absence of duct causes disruption in the wind speed, their directions of travel, uniform wind pressure etc. A ducting arrangement would ensure better performance of the assembly.

Excessive wind speed will damage the wind turbine. So, a particular wind turbine will have a cut-out speed. Above this cut-out speed the wind turbine will shut down to protect it from damage. The wind turbines also have cut-in wind speed, typically 12-15 kmph, when they will produce electricity. Below the cut-in speed, there will be not enough wind energy to produce electricity.

The electricity generated in this process can be stored in storage systems, like using batteries. The generated voltage can be improved using transformers.

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