INDUSTRIAL EXHAUST FANS AS SOURCE OF POWER

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Abstract: The energy demand of the world has become unbridled in the past years and is augmenting by leaps and bounds. With increase in energy demand, the conventional sources of energy(fossil fuels, nuclear) are encumbered with monumental pressure and hence, the unremitting use of it, leads to dearth of fossil fuels. This has provoked an extensive research into the area of non-conventional energy sources like hydro, wind, thermal energy, etc. Out of these, the wind energy is being discussed in this paper. Wind energy has a lot of potential and advantages but its utilization is restricted due to its irregularity, geographical conditions and its availability. Our primary goal is to suggest an idea that can surmount these conundrums and utilize the wind energy to its maximum extent. This paper deals with the wind energy that can be derived from the wasted wind energy from industrial exhaust fans. The wind force from an exhaust fan can drive a small windmill and the energy generated from it will be stored in energy storage unit. The power stored in the battery can be transmuted into ac with the help of an inverter and then it can be supplied to the load and hence, this wasted power from exhaust fan can be utilized to meet the growing energy demand.

Keywords: Wind power, exhaust fan, wind turbine, storage.

I. INTRODUCTION

The rapid depletion of natural resources and fossil fuels has led to the development of alternative sources of energy. The conventional sources of energy are non-renewable, cause pollution, not sufficient to meet the growing energy demand. Due to these reasons, it is imperative that we must start exploring and developing methods to utilize the non-conventional energy sources to reduce too much of dependence on conventional sources.

One of the most arresting forms of non-conventional energy is wind energy. But due to some of its limitations, the wind energy cannot be utilized fully to produce electricity. This limitation can be surmounted with idea of using the wind from exhaust fan of big industries as a source of power.

II. WIND FORMATION

The air movement across the surface of Earth engenders wind and it is influenced by the areas of high and low pressure [1]. Sun unevenly heats the surface of the Earth. Huge bodies of water, such as the oceans are slower than land in terms of heating up and cooling down. At the Earth's surface, the heat energy is absorbed which is transmitted to the air which is just above it and, as cooler air is denser than warmer air, the warmer air rises above the cooler air to create high pressure areas and thus this causes pressure differentials. When the Earth rotates, the atmosphere is dragged around with it engendering turbulence. These effects will add up together causing a continuously varying wind patterns across the Earth's surface.
Sources of wind are discussed below [2]:

- Local winds: These winds are caused by unequal heating and cooling of ground and ocean/lake surfaces during day and night.
- Planetary winds (Global winds):These winds are engendered by daily rotation of earth around its polar axis and unequal temperature between polar regions and equatorial regions.

III. WIND POWER

The metamorphosis of energy of wind into a usable form of energy is the wind power (e.g. generating electrical power using wind turbines, mechanical power from windmills, for water pumping or for drainage, wind pumps are used.
Merits of wind energy:

- It is renewable source of energy.
- It emits no greenhouse gases and hence non-polluting.
- It uses very little land
- Fuel transportations are not required in wind energy conversion system.

Demerits of wind energy:

- Owing to its irregularity, the wind energy needs storage.
- Availability of energy is fluctuating in nature.
- Wind energy conversion is noisy in operation.
- Low energy density
- Maintenance is required.
- Wind turbines design, manufacture and installation have proved to be most complex due to several variables and extreme stresses.
- Its implementation is limited due to geographical locations.

IV. WORKING PRINCIPLE

The exhaust fan in big industries can play a seminal role in producing electrical energy which can surmount the energy demand to certain extent. The wind force from the exhaust fan can be directed towards a small windmill in front of it. The wind thrust from the exhaust fan can drive wind turbine and these wind turbines produce electricity which can be stored in storage unit.

The storage unit may vary according to the production of electricity from the wind turbines. Then inverter will convert the stored dc energy into ac. This ac energy can be supplied to the load and grid.

This mechanism begets several advantages:

- Wasted wind force from the exhaust fan can be utilized to generated electrical power.
- It will surmount the present day problems of wind energy conversion, that is, it can provide a constant source of wind and the wind fluctuations can be surmounted.
- It will not be affected by geographical locations and hence can be implemented in many big industries.
- It will be plentiful, renewable and eco-friendly source of energy.
- The stored energy can be used when main supply is cut off. Hence, can be used as an emergency unit.

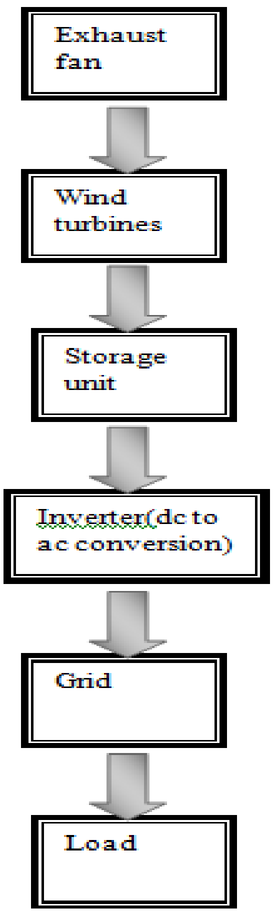

Fig 1.Flow chart of the process of using exhaust fan as a source of power

Wind power and energy

The kinetic energy of air is nothing but the wind energy. Total wind energy passing through A (i.e. an imaginary area) during the given time (t) is given by the eq(1) [3]:

$$E = \frac{1}{2}mv^2 = \frac{1}{2}(Avt\rho)v^2 = \frac{1}{2}At\rho v^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where v is called as the wind speed ; ρ is defined as the air density ; Avt is defined as the volume of air flowing through an area A.

The energy per unit time is defined as the power, so the wind incident on area (i.e. equal to the rotor area of a wind turbine) is given by the eq(2):

$$P = \frac{E}{t} = \frac{1}{2}A\rho v^3 \quad \ldots\ldots\ldots\ldots(2)$$

Thus, with the increase in wind speed, the wind power increases. When speed of wind becomes double, then the available wind power will be increased by eightfold.

Calculation of power generated from wind turbine from wind speed of industrial exhaust fans:

Table1: specification of exhaust fans used in Rourkela Steel Plant

Plant	Diameter(m)	Speed(rpm)	Gas density(kg/m³)	Motor (MW)	Temperature (degree Celsius)	Wind speed(m/s) approximately
Sinter plant 1	3	1000		6		16.4
Sinter plant 2	3.695	990	0.7	5.7	160	15.5
Sinter plant 3	3.5	1000	0.6359	8	170	16.2

The wind speed suitable for viable wind turbine generating system is 5m/s or more. Air normally has a density of approximately 1.2 kg/m^3(at sea level and at 15°C), as per the International Standard Atmosphere (ISA).But in the calculation, gas density of 0.7 kg/m^3 is taken into account.

The speed of wind coming out of exhaust fan is very high and when such high wind force strike the wind turbines, it can generate electricity either an equal amount or 1.5-2 times more than the power generated from atmospheric wind and this generation of power varies depending upon the speed of wind from the exhaust fan. This has been proved in the following calculation.

V. CONSIDERATION OF POWER COEFFICIENT

Albert Betz (German physicist) concluded that a wind turbine cannot transmute more than 59.3% of the wind kinetic energy into useful mechanical energy [4]. This is called as Betz Limit or Betz' Law. The maximum power efficiency(theoretical) of any wind turbine design is 0.59(i.e. more than 59% of the wind energy cannot be extracted through wind turbine).This limit is known as "power coefficient" and is defined as: C_{Pmax}= 0.59.Even at this maximum limit, the wind turbines cannot be operated . The value of C_P is unique to each kind of turbine and depends upon the wind speed that the wind turbine is designed to operate in. The common value of power coefficient of multifarious wind turbine designs lies within 0.35-0.45 range[4].

Hence, the power equation becomes

Power generated = $\frac{1}{2}A\rho C_P v^3$ ……(4)

The diameters of modern wind turbines lie in the range 40 to 90 metres (130 to 300 ft) and these turbines are normally rated in the range 500 kW to 2 MW. These values are being tabulated below and the power that can be generated using the wind from the exhaust fan(taking the exhaust fan specification of sinter plant 2) is calculated. Power generated is calculated using eq(4) (taking C_P=0.4).

Table 2: Power generated on normal wind turbines using exhaust fan wind

Turbine diameter, D(m)	Area swept by blades=$(\pi/4)\times D^2$	V=speed(m/s)	ρ = gas density(kg/m^3)	Power generated(MW)
40	1256.637	15.5	0.7	0.655
90	6361.725	15.5	0.7	3.317

Specifications of common industrial wind turbines are also taken into consideration for the calculation of generated power using the wind thrust out of exhaust fan.

Generally General Electric (GE) and Vestas are the famous producers of industrial wind turbines in the U.S and specification of some of its models are in below table 3.The following power generated calculation is made taking wind speed(15.5 m/s) of sinter plant 2 exhaust fan.

Table 3:Calculated power generation with wind speed of 15.5m/s using different wind turbines.

Model	Blade length(m)	Area swept by blades(m^2)	Rated wind speed(m/s)	Capacity(MW)	Power generated (MW)with wind speed (15.5m/s)
GE 1.5s	32..25	3,904	12	1.5	2.035
GE 1.5sle	38.5	4,657	14	1.5	2.428
Vestas V82	41	5,281	13	1.65	2.753
Vestas V90	45	6,362	11	1.8	3.317

Design considerations for wind turbine:

As it is observed that the wind speed and the power that can be generated from wind turbines using wind force from industrial exhaust fan are higher than the rated speed and the capacity of the normal wind turbines respectively. This makes the design of wind turbine a matter of overriding importance.

Wind turbine design should obey the following criteria:

- It should be small in size.
- The efficiency should be good.
- Insensitive to turbulence.
- Should be suitable for mass production at low price.

Wind power generation in India

The wind power development in India has been traced since 1999 and has shown tremendous rise in the past few years. The 5th biggest installed wind power generation capacity in the world is in India.

In 31 Jan 2013, the installed capacity of wind power generation in India was about 19564.95 MW[6]. Various states wind power generation installed capacity are: Tamil Nadu has 7154 MW capacity, Gujarat has 3,093 MW capacity, Maharashtra with 2976 MW capacity, Karnataka with 2113 MW capacity, Rajasthan 2355 MW capacity, Madhya Pradesh with 386 MW capacity, Andhra Pradesh has 435 MW capacity, Kerala has 35.1 MW capacity, Orissa has 2 MW of capacity, West Bengal with 1.1 MW capacity and other states have 3.20 MW capacity. It is estimated that in India by the end of 2014 an additional wind power generation capacity of 6,000 MW will be installed. 8.5% of India's total installed power capacity is formed by wind power and this wind power produces nearly 1.6% of the country's total power [6].

Energy storage

The storage of electrical energy generated from the windmills is of overriding concern. Depending upon the wind penetration level, the type of energy storage varies. Low penetration level needs daily storage of power and high penetration level warrants both long and short term storage.

Supercapacitors can store electrical energy. They are much more efficient and advantageous than other kind of batteries/capacitors. They have higher power density, shorter charging times, and higher cycle efficiency (95% or more) and higher specific power than conventional capacitors.

But taking the cost factor into consideration, supercapacitors are not economical and also their energy density is very low as compared to batteries.

The problems that might occur in adopting this idea:

The process should be examined from every conceivable angle before its execution. This mechanism will provide plethora of advantages but there are few conundrums that the system may face and these conundrums are listed below:

- The wind turbines should be strong enough to withstand high wind force from exhaust fan and hence, the design of wind turbines might become complex and costly.
- Wind from the exhaust fan, after travelling some distance, may get dispersed and when the wind spreads over a large area, the wind speed might get decreased and the expected power

generation(as calculated above) may not take place.

- The amount of power generated from such system may require large electrical storage system and cost of the storage unit may affect the overall cost of the system.

CONCLUSION

It is observed that the wind from the exhaust can work as a very good source of electricity. The wind speed is sometimes more than the natural air speed and hence can generate even more electrical power than what is produced from natural air. As it is discussed earlier that wind from exhaust fan may get dispersed after some time, there should be some kind of directors/connectors that will guide the wind from the exhaust fan directly to wind turbines without getting the average speed of the wind decreased as the velocity of the wind is most important factor in the system.

The wasted wind from exhaust fan can be efficaciously utilized to generate power if proper implementations are done.

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