Use of Wind Energy in Power Generation : Some Questions

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1. Abstract

The utilization of wind energy has many positive sides. Some negative effects of the same have also been reported in recent past. In this paper estimation and discussion have been done about the effect of use of wind energy on the cloud formation and formation of rain drop, if the wind energy be used in large scale.

2. Introduction

Use of Wind Energy for Electrical Power Generation is increasing day by day. Wind energy is one of those sources of energy, which are termed as non-conventional energy, renewable energy, clean energy etc.

The major arguments in favour of utilizing non-conventional energies including wind as a source of energy for power generation are:

a) Those have zero contribution to the atmospheric pollution.
b) Those have no green house effect.
c) Wind is commercially and operationally the most viable resource of energy.

Some recent studies have made it clear that wind mills have an adverse effect on the environment [1,2,3].

The type of hazards created by the wind mills as reported in the above said studies are:

a) Death of bats and birds including protected members in wind turbine blades in a significantly large number.
b) Creation or increase of geological hazards or soil erosion.
c) Localized generation of air borne dust.
d) Alternation and degradation of plant communities.

In spite of the above observations it should be remembered that some tolerable compromising factors must be there for the advancement of the civilization. Otherwise all the industries to be stopped and we have to go back in the era of lantern. The compromise must be done particularly if the proposed new technology replaces the major hazards of an on going technology. Therefore, except the death of natural elements we can compromise with the other hazards. In fact preventive measures can be taken to eliminate all the hazards including the death of birds.

The study did not include the effect of extraction of Kinetic Energy from wind upon the other natural processes like:

a) Transportation of various micro particles and pollutants (generated from industries and other sources) from one place to another for uniform distribution over a considerable area.

The observation of Jim Crawford (the TRACE-P deputy mission scientist at NASA Langley Research Center) may be relevant in this regard. He says "Larger concentrations of pollution are being transported away from Asia under the cover of clouds than we expected" [4].

Scientists also believe that Cold air masses or cold fronts flow eastward across Asia and lift the warm, polluted air mass in front of them. The lifting caused by cold fronts, which are dominant during the springtime in Asia, induce cloud formation in the warm air mass. Thus the mechanism for cloud formation and the export of pollution is the same, leading to a link between clouds and pollution [4].

b) Mixing of various locally generated gases (both useful and harmful) with the atmospheric air.

For example, Oxygen generated by the plant kingdom in forest and other green places are mixed with atmosphere by the wind blow. Thus, part of Oxygen thus generated is transported to the inhabitances of the places where numbers of plants are rare (e.g. deserts). Similarly, Carbon-di-oxide generated by the industries and through other processes are mixed with atmosphere by wind blow and part of it gradually goes to the green belt and forest side, which is converted to Oxygen through photosynthesis.

c) Moreover, the most vital area, it's effect on cloud movement and rain fall has not been studied.

The aim of this paper is to estimate the effect of use of wind energy on cloud movement and rain fall.

3. Approximate Velocity of wind stream after passing through wind turbine.

If a stream of wind with density (ρ) blows with a velocity (V) m/s through an area of A sq. m, then, the power of wind stream is given by:

$$P_{ws} = ½ \rho A V^3 \qquad (1)$$

The theoretical maximum power co-efficient (efficiency) of a wind stream is 0.5926 [5].

However, most of the practical wind turbines run with power co-efficient (efficiency) at the range of 40%. If, 10% of input energy is taken as loss, then after passing through the wind turbine the power of air becomes about 50% of the incoming stream.

Let

V_i = velocity of incoming stream,

ρ_i = density of air,

A_i = area through which the incoming air passes,

And

V_o, ρ_o and A_o are the same for outgoing stream of air after extraction of energy from it, Then

$$\frac{1}{2} \rho_o\ A_o V_o^{\ 3} = 0.5 \, . \, \frac{1}{2} \rho_i\ A_i V_i^{\ 3} \qquad (2)$$

Applying continuity equation between inlet and outlet of the turbine with assumption that the density of the air does not change considerably,

$$A_o V_o = A_i V_i$$

Or, $A_o = (A_i V_i) / V_o$

Putting this in Equn. (2) we get,

$$V_o = 0.707 V_i$$

Therefore, if we use a wind turbine in a field of air velocity of 10 m/s, after passing through wind turbine the velocity of air becomes 7m/s.

4. Mechanism of cloud formation

Clouds develop in any air mass that becomes saturated. Again, when air is cooled to it's dew point, saturation can occur. Any one or combination of the following natural processes can develop cloud.

a) Density Lifting

The temperature of stable air decreases with altitude at a rate of approximately 6^{o}C per 1000 m; this is termed the **Normal Lapse Rate**. When a mass of warm air (which is in contact of hot earth's surface) rises through the stable air, the pressure of the air mass decreases continuously, as it raises higher altitude. It does not exchange heat with the surrounding air. In other word, the hot air expands adiabatically. As a result, the temperature of the hot rising air decreases for adiabatic expansion. The rate at which the temperature of rising air mass goes down with altitude is termed as **Dry Adiabatic Lapse Rate (DALR). DARL** is greater than the Normal lapse rate. The air mass continues to rise until it cools to a temperature that is equal to the surrounding stable air. If it reaches the due point, the cloud is formed. If the cloud has enough energy to pass the freezing level, it may develop into rain and wind storm.

b) Orographic (topographic) Lifting

Orographic lifting occurs when air is forced to rise over an obstruction in the landscape, typically a mountain range. The air cools as a result of adiabatic expansion. If the lift and moisture content are adequate, condensation occurs and the cloud is formed.

C) Frontal or Convergence lifting

Frontal or Convergence lifting occurs when two large air masses of different temperature, density and moisture content collide. The boundary between the air masses is termed as front and may be 10-150 km across and hundreds of kilometers in length. A warm front forms when a warm air mass advances over a cold air mass. The warm air rises above the colder air. Warm air is also forced upward when cold air approaches a warm air mass along a cold front. The lifting causes the warm air mass to cool due to expansion resulting in saturation. This cloud formation mechanism is common at mid latitudes, where cyclones form along the polar front and near the equator, where the trade winds meet at the inter-tropical convergence zone.

Convergence lifting also occurs when two air masses of nearly same temperature, density and moisture content collide, forcing some air upward as both air masses can not occupy the same space. This happens regularly over Florida where air moves westward from the Atlantic Ocean and eastward from the Gulf of Mexico to collide over the Florida peninsula.

D) Frictional turbulence

Air stream flowing over ground or water produces a turbulent layer, up to 150 m deep in light winds. It may go above 900m in strong winds. The vertical eddies within this friction layer or boundary layer transport air from the upper level to the surface. This air is warmed due to adiabatic compression to a higher pressure at ground level. Thus, the temperature of this compressed air goes above that of the surface air. Similarly surface air is transported to the upper level and cooled due to adiabatic expansion to temperatures below that of the upper level. The turbulent mixing continues until the temperature lapse rate through the layer equals the Dry Adiabatic Lapse Rate and the layer is in neutral stability, providing the air remains unsaturated.

The deep turbulent mixing also has the effect of evening out the moisture content through out the layer and if the humidity mixing ratio is high enough a mixing condensation level will be reached within the friction layer. If the lapse rate of the layer above the friction layer is stable then layer cloud will form. The thickness of the cloud layer will vary from very thin to possibly 900m.

Cloud produced by frictional turbulence is not usually associated with precipitation except perhaps for drizzle from dense layers.

5. Effect of lowering velocity of wind on cloud formation:

The wind turbines are installed at the places where wind velocity is considerably high (10 m/s to 15 m/s).

From the discussion about the processes of cloud formation it is clear that the hot air must have sufficient kinetic energy to form cloud. If the kinetic energy is lowered as a result of extracting energy from the wind, It may not reach at the desirable stage of cloud formation.

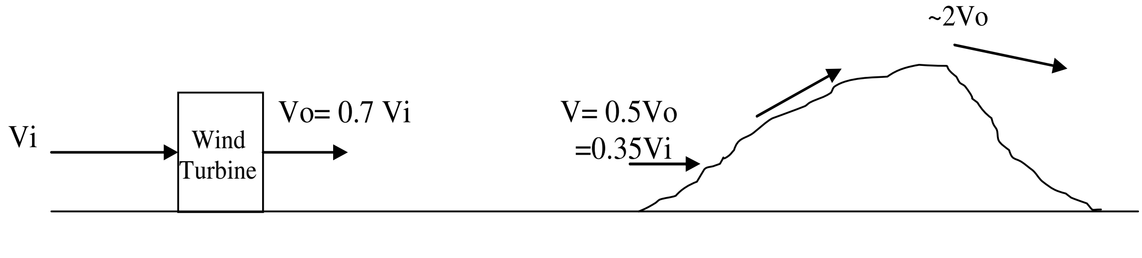

Fig. 1 Effect on Orographic Lifting

As an example, let us find out the effect of placing wind turbines with power co-efficient (efficiency) of about 40% (with 10% loss) near a mountain range.
With reference to Fig. 1.

Let,

Vi = Free stream velocity far from the hill

Then,

Vo = 0.7Vi = Velocity of wind after passing through turbine (as deduced earlier)

The velocity of wind at the foot of the hill becomes about 50% of the free stream velocity (which is 'Vo' in this case) [6]

Therefore,

velocity of wind at the foot of the hill = 0.5Vo = 0.35 Vi (approx.)

and

Kinetic Energy of the wind at the foot of the hill = 0.1225 times of the Kinetic energy of free stream (approx).

. This will further reduced by friction of ascending wind with the surface of the hill.

This may affect the cloud formation process through "Orographic Lifting", as, the velocity and the Kinetic Energy are considerably low.

Though with ascending towards the top of the hill the wind velocity increases to double, but this depends upon the velocity of wind at the foot and can be found in the hills of gradual slop of a long ridge. Thus, The wind may not get sufficient energy for cloud formation.

Similarly, the wind mills at the sea shore will affect the cloud formation process "Frontal or Convergence Lifting", as, the air mass will collide with only 70% of the free stream velocity or with 50% of the kinetic energy. This may not supply the sufficient energy to lift the air mass to the desirable height.

The "Frictional Turbulent Process" will also be affected, as, turbulence depends upon Renold's Number [$R_e = (\rho VL)/\mu$; when μ is absolute viscosity and L is dimension of length ρ and V have usual notation], which is again a function of velocity of fluid. If R_e becomes less, the mixing process and hence the cloud formation process will suffer.

It may be remembered that cloud formation does not confirm the formation of rain drops. After formation of cloud, high velocity air at high altitude accumulates the fine water particles to form the rain drops. If the considerable amount of Kinetic Energy from air is drawn, the formation of rain drop and the transportation of the rain will be affected.

6. Conclusion:

Wind is being used as a source of energy form a long past. But the use was very limited with respect to the total potential of the wind energy and hence no negative effect was reported. The object of this paper is not to draw any final conclusion against the use of wind power available from nature, but to draw the attention of the Engineering and Scientific community towards the harmful effect of the same and to either use it upto a certain limit or to think about some alternative to the wind power.

7. References:

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