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WIND POWER

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1. Introduction :

The increasing demand for electric power for industrial, commercial, agricultural, and domestic purposes together with the high cost of coal has focussed considerable attention upon the comprehensive and competent development of other sources of nature's power potential. The inherent disadvantages of coal with its high cost of transportability and storage forced the thermal stations to flourish only at the pit heads of coal-mines with considerable economy. The ever increasing demand for electricity with its shifting load-centres necessitated the search of some other sources of power to duplicate the existing thermal and hydel stations. Some of the solutions put forward envisage the harnessing of wind, tidal, solar and nuecliar powers. Wind is one of the long term sources of power apart from solar power that can satisfy world's enormous and growing needs. Atomic energy, a power for advanced and wealthy nations, is still too expensive and complex for world's underdeveloped countries where there is an urgent need for power to raise the general standard of living.

It has been universally accepted that most of the nature's power sources like coal, oil etc , owe their origin to solar power. The atmosphere enclosing this earth is a rotating, regenerative thermal cycle stocked by the radiant energy from the Sun. It is this cycle that causes the gentle breeze, pleasant wind, stormy gale, and dreadful typhoon ! So the study of wind power is only a chapter in the volume of Solar power.

2. **Historical :-** The primitive man realised the power in Wind. He invented sails to drive his boat. Wind mills appeared first in Greek and Roman literature. Persia, China, and Middle East also claim to be the beginners of wind mill construction, but there are no authentic details except "The Pneumatics" of Hero of Alexandria." Hero's wind mill appeared in 200 B.C. with a horizontal axis. Persians then introduced the vertical axis type, and as late as in 12 century the first wind mill appeared on the soils of western Europe.

In 1759 Andrew Meikle, Edmund Lee, Stephen Hooper, Sir William Cubit and John Smeaton designed and submitted a paper "on the construction and effect of wind mill sails" before the Royal Society. The main feature of this design was the automatic operation of the wind mill as soon as the wind was sufficiently strong. Further in high winds the rotational speed was controlled by the opening of slats with which the rotor blades were fitted. The slats operate automatically with the pressure of wind. The steering of the wind wheel face towards the direction of wind was achieved by means

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of a fan tail. This type became so popular for grinding corn and pumping water, that at one time as many as 10,000 wind mills existed in Britain.

3. **Developments:-** The next step in the development was to convert the power in wind into a more convenient form a of energy-the electrical energy. In 1890 Prof. P. Lacour of Danish state testing station at Askov, designed and constructed gigantic wind mills with bevelled gearing and (was) connected for the first time to a dynamo. By 1910 hundreds of wind mills. with 2 to 25 kw. generators at 110 or 220 V sprang up.

In World War II, Germany, the mother of Wartime inventions, constructed sail and propeller type of wind mills each about 70 Kw. capacity and generated more than 18,000 M.Wts. of power for local supply net works. Further attempts were made in U.S., U S.S.R. and Germany to produce wind driven generators of 7500 Kw. But before we make an attempt let us try to have an idea about the available power in Wind.

4. **Available Power :-** Let us derive an expression for the amount of electrical energy available from a Wind stream of definite dimensions.

Let A = Projected area swept by windmill blades in Sq. Ft.

V = Velocity of wind stream in m p.h.

P = Density of wind in wind stream at a barometric pressure of 1000 millibars and 290° k.

K. E. of wind stream $= \frac{1}{2} MV^2 = \frac{1}{2} PAV. V^2 = \frac{1}{2} PAV^3$

A non-dimensional proportionality constant K is introduced into the equation to make the energy output into kilowatts.

Here $K = 2.14 \times 10^{-3}$

$P = 2.33 \times 10^{-3}$ slugs/c.ft. or 1201 g/m3

$$\therefore \text{Power} = \frac{2.14 \times 2.33}{10^6} \times AV^3 = \frac{5}{10^6} AV^3 \text{ Kw.}$$

for an average wind velocity of 30 mph. and 50 feet motor diameter.

$$\text{Power} = \frac{5}{10^6} \times \frac{22}{7} \times \frac{50 \times 50}{4} \times 30^3 = 265 \text{ Kw.}$$

But Bentz, Göttengen suggests to consider an overall power coefficient of 0·4

So Available power from Wind $= 0.4 \times 265$

$= 104$ Kw.

This amount of power is not steady but varies with wind velocity. The graph (fig. 1) shows the variation of a generator output with wind velocity. So a study about the wind velocity, its behaviour etc., is quite essential.

WIND POWER

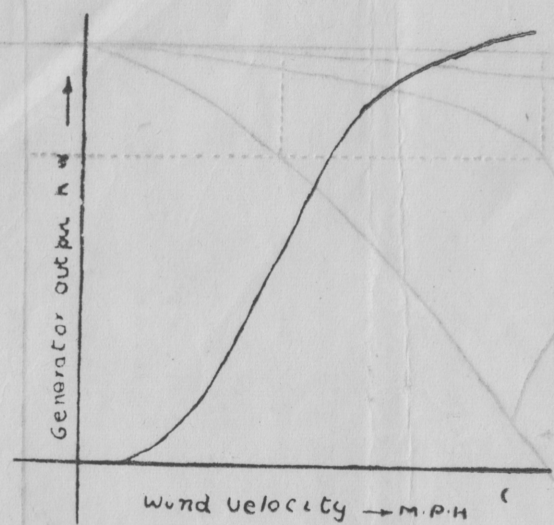

FIG 1

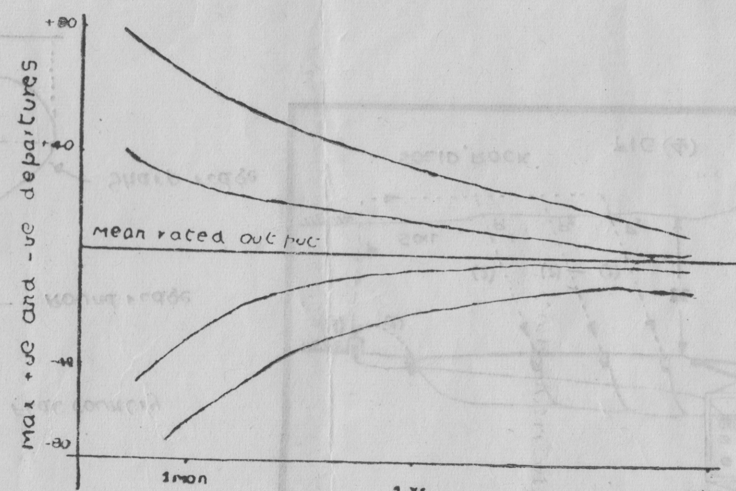

FIG 2

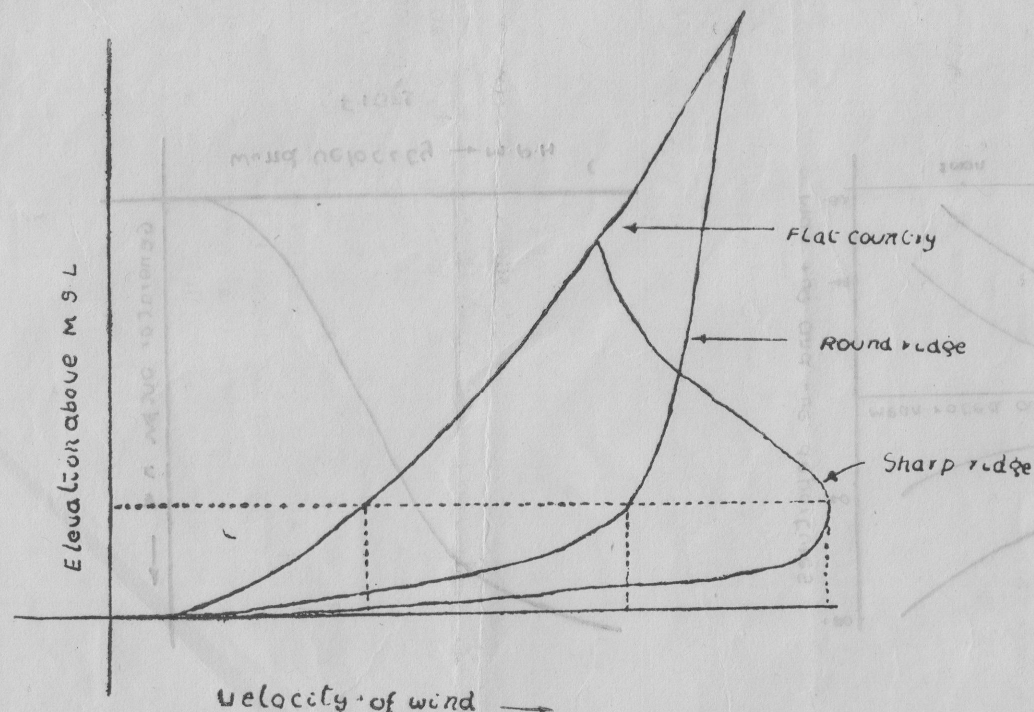
Flat country
Round ridge
Sharp ridge
Elevation above M S L
Velocity of wind

FIG 3

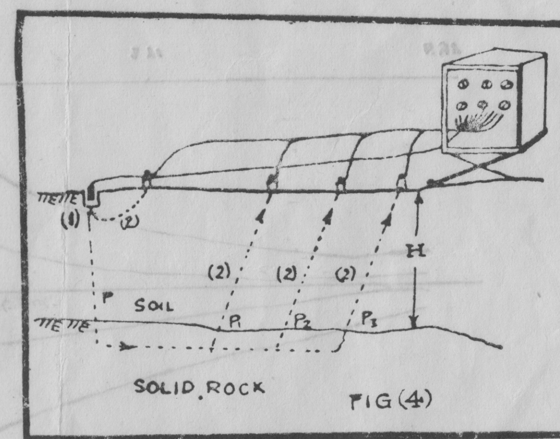
(1)
(2)
(2)
(2)
(2)
H
P
SOIL
P1
P2
P3
SOLID ROCK

FIG (4)

5. Behaviour of Wind: The annual average wind speed does not, exceed in general 10% of the long term mean. So wind is a dependable source of energy but not a reliable source of power as there is every possibility for calm spells or terrific hurricanes. In gusty winds and hurricanes the instantaneous speeds change from 50 to 100% within a matter of 0.5 seconds. So the most dependable source of information can be sought from the annual average wind speed which may vary from 2 to 50 m.p.h. Also it is quite essential tohave an idea about daily, monthly and yearly fluctuations from the mean. In northern hemisphere, in general, January is the windiest while July and August the least windy. But in India the effect of monsoons causes a pronounced variation of wind speeds from August to October.

Further the diurnal variations of wind speed and direction depend on the convection currents caused by the UN-equal absorption and radiation capacities of land and sea. These land and sea breezes vary from 10 to 60 mph. from temporate to tropical regions. The records of the coastal meteorological stations of India show higher wind speeds during noon to evening and less at midnight. Under such varied conditions, so many diverse factors should be considered with the aid of experimental and statistical data.

6. Reliability :- In view of the aforesaid behaviour of wind, how far its power can be relied upon is a matter for serious consideration? The graph (Fig. 2) roughly corresponds to the maximum departures of power expressed as a percentage of the mean rated out-put of the Grandpha's wind station at Mt. Washington in U. S. A. In order to cope up with the short term fluctuations of power, as indicated by the graph, it is quite essential to run the wind driven generators in parallel with some other source of power. A storage battery of sufficient capacity may be allowed to operate in parallel to cater to the needs in calm spells.

7. Survey and Location of Site : As the power from wind varies as the cube of wind velocity it is quite obvious that the site should be so chosen as to fulfil this condition. In general the windy places of the world lie between 25° to 60° parallels and are generally mountainous. The ridges of hills act like air-foils which can conveniently be used to speed up wind by about 20%. Further the frictional forces decrease as we go up, hence high isolated mountain ridges will be the best places for the location of a wind mill. In India the windy places are the Himalayas, the mountain ranges of Deccan and the Andamans. The last two places are highly suitable for Indian requirements. In Deccans where there are isolated and remote mountain ranges, the power potential of wind can justifiably be used to supply power to local networks for electrification, lift irrigation for some dry crops where seasonal wetting of crops is not quite essential. The same is the case with the Andamans where there is no other source of power except the wind, tidal and Solar.

8. **Extraction :—** After a complete survey, the next step is to extract the power in an efficient manner. For this two main types of wind mill propellers–the solid type and the screw type were developed. In the solid type, the effective surfaces of the motor will move in the direction of wind while in the screw type, the Vanes will be mounted helically on the shaft and as the shaft rotates it presents the shape of a screw.

In the solid type all vanes are not subjected to the same pressure as the air leaving advancing Vanes retards the incoming wind causing back pressure. So the power co-efficient of a solid type propeller is as low as 0.33 when compared to that of screw type (0.593). Also as the rotational speed falls with the increase of diameter, the latter being essential for the increase of output, we have to provide expensive gearing if high speed generators are to be driven. So the solid type is not highly feasible to generate electrical energy.

The Screw type : In the previous case the wind strikes the Vanes perpendicularly. Therefore the relative velocity, is equal to the wind velocity minus the Motor velocity. But in this case a small angle is made, the angle of attack, between wind direction and motor face avoiding back-pressure and higher motor speeds can be attained. The optimum power coefficient for this occurs at the value of "tip speed ratio", μ

$$\text{Where } \mu = \frac{\text{peripheral speed of blade tip}}{\text{Wind speed}}$$

= 1, for slow running multispeed machines used for pumping water.

= 2.5 for four blade wind mills.

= 6 for aerogenerators.

While running A. C. generators, the motor should run at a constant synchronous speed. Therefore μ should vary along with wind speed. In order to achieve this we have to vary the blade pitch. The depression principle developed by M. Andrew in France was used in Enfield Andreau Alternator in Algeria. Here the pitch of the propeller blades can be varied. As the blades rotate, wind discharges through tip outlets by centrifugal force. The depression thus generated causes the air to be drawn up into the blades through an air turbine located near the base of the wind mill tower which drives the alternator, Thus there was no mechanical connection between the alternator and propeller.

DESIGN PROBLEMS : From the designers point of view we have to consider installed and running costs, propelling area, volume and weight of structure per k.w. of output cost per kw. as compared to thermal and hydel powers and types of drives etc. As the density and average velocity of air are less as compared to other propelling fluids, the knitic energy per Unit volume of propelling structure is less. As such a greater propelling area is required per kw. of output. So a very big structure is required to install and mount these apparatus which means an increase in capital cost.

The low density and viscosity of wind are further draw backs along with its inconsistancy. There is no question of increasing the density by methods like super-charging but the velocity can be increased taking advantages of the fact that the ridges of hills act like airfoils. Graphs (3), (4), and (5) clearly show the effect of altitude and type of contour on wind velocity.

The type and size of structure to mount the apparatus depends on the capacity of the generator to be driven. For small scale exploitation of wind power with generator capacities not exceeding 10 to 15 kw, the propeller blades may be of well seasoned wood. But for high ratings it is always better to use non-corrosive metals like stainless steel or Aluminium. To achieve optimum results the blades should taper with a slight twist. The structure should be of steel, painted well to withstand rough weathers.

The generator to be driven may be kept at the ground level with a bevelled gear drive or may be kept aloft. In most of the practical cases the latter was found to be more economical. Induction or synchronous generator may be used with a centrifugal speed governer in the primemover. In view of the variable speed of the wind-mill another possibility is to use A.C. Commutator generator running at a variable speed, yet supplying constant frequency. The Induction generator is quite robust and stable in automatic operation. But Putnam, an American Engineer, successfully used synchronous generators for Grandpa's knob aerogenerator.

The ultimate aim of a designer is to achieve a steady and maximum amount of power output (called firm power) throughout the span of the year by avoiding short term fluctuations. As wind cannot be stored as water in reservoirs there is no question of storage and pondage to regulate the flow of air. So firm power may be obtained through the effect of diversity if wind generators are connected through an extensive net-work (ie., on infinite bus bars). Also it is true that the out-put from a number of interconnected stations is steadier than from an isolated machine. The inter-connection of Wind stations with thermal and hydel stations appears to be a promising method of stabilizing the power supplies on a large scale.

UTILISATION : Wind power can be used in the best manner for lift and sprinkler irrigation of the high grounds along the banks of canals and rivers and vast areas can be brought under cultivation without trouble of water-logging and salting Mountain crops like rabi etc., can be grown easily at dry places as they do not require continuous supply of water. In places with a continuous supply of wind, a large scale mill with about 1500 kw. generator can supply sufficient power for illuminating and heating. At places where there are intermittent winds power can be extracted with a generator 10-100 kw. and a storage battery of 200 to 300 AH. This type is best suited for communities which cannot be supplied otherwise.

So within reason, however, we can expect a time to come in the persuit of such an elusive quarry of power, as wind, to feed the myriads of our scattered Villages with all requirements of power.

References:

(1) POWER FROM WIND BY PUTNAM

(2) "ELECTRICAL ENGINEERING"—Journal.