WIND ENERGY DEVELOPMENT IN THE PHILIPPINES

By

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Introduction

Windmill technology is perhaps the oldest of the nonconventional energy conversion methods. Even as far back as ancient Persia, writings exist mentioning windmills for pumping water from wells and also for grinding grains. In ancient China, we also find windmills of the sail type employed for similar purposes. For the isolated, independent farmers in the early American period, the old multi-bladed windmill is a common farm equipment which is used for pumping water. In Holland and the other low countries of Europe, as well, as at the earlier part of the twentieth century, the number of windmill machines used to proliferate in their countrysides. But oil was also beginning to appear at this time as an attractive source of energy. When the vast oil resources of the Middle East started large scale production, oil became cheap and easily available that everybody was converting to oil for fuel and heating. Wind energy technology could not compete in cost and reliability. Thus the technology was relegated to the background, employed only in highly selective sites where the internal combustion engines using oil fuel is impracticable.

The oil crisis in 1974 has changed all that. Not only is our dependence on oil threatened by politics and the unstable peace and order situation in the Middle East, which is the largest global source of oil, but the world's fossil fuel resources are expected to get exhausted in maybe fifty years. Furthermore, there are other uses of oil which are more useful than burning it for heat and fuel. In particular, petrochemical industries will be competing soon for oil as raw materials. Aggravated further by the growing demand for energy by a burgeoning global population, one can clearly see the imperatives for developing indigenous alternative energy resources, like solar energy.

In the industrial countries in America, Europe and Australia, the development of windmill technology has been very fast in the past few

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years. New concepts and more efficient windmills are now being field-tested in order to optimize system designs and bring down cost, as well as eliminating features objectionable to the nearby populace. For small capacity units, say from 50 watts to 50 KW, intended for small, independent users, the present state of the technology can offer a prospective buyer a rich variety of makes and designs. There is no question that within this range, the technology is not only ready but its commercialization is in full swing as well.

In the higher range having a capacity of a few hundred kilowatts up to few megawatts, the technology is still in the piloting stage. In America, as in Europe, there are now aeroturbines of the megawatt capacity which are actually generating electricity and feeding the energy to the existing grid. An increasing number of private utilities in the United States are acquiring large wind energy generators to be fully operational before the end of the decade. A representative of Bendix Corporation visited Manila last month and offered to install large wind generating plants for anyone interested. The Bendix 3-megawatt aeroturbine located near Los Angeles, U.S.A., which is now the largest so far, has been operational. The plant cost $1,000,000.00, so that the cost per watt of rating is 33 cents. This may be cost effective now in a site with sufficient wind resource.

Switching now to our local setting, one can easily see a large gap in the application and development of the technology. We have not evolved from the water pumping stage. The number of local private companies now manufacturing this type of windmills are proliferating. Of course, it may be added that with our abundant wind resources, we are still far from fully utilizing windmills for pumping water for household, commercial and agricultural purposes. The wind dispersal project of the government now being implemented has installed a number of windmill powered pumps around to generate interest in this application and open the way towards extensive utilization of wind energy. However, what is needed is a comprehensive program to transfer the technology here and lay the ground work for its commercialization. This must be our course of action if we expect to benefit from this renewable source of energy as soon as possible. In a few more years, the large capacity aeroturbines will come of age. We must have ready manpower and local expertise to manage and operate them.

Fundamentals of Wind Energy Conversion

The windmill is the device that extracts energy from the wind and converts this to mechanical or electrical power. The basic transfer of energy takes place at the rotor blades. In Fig. 1, we have a cross section

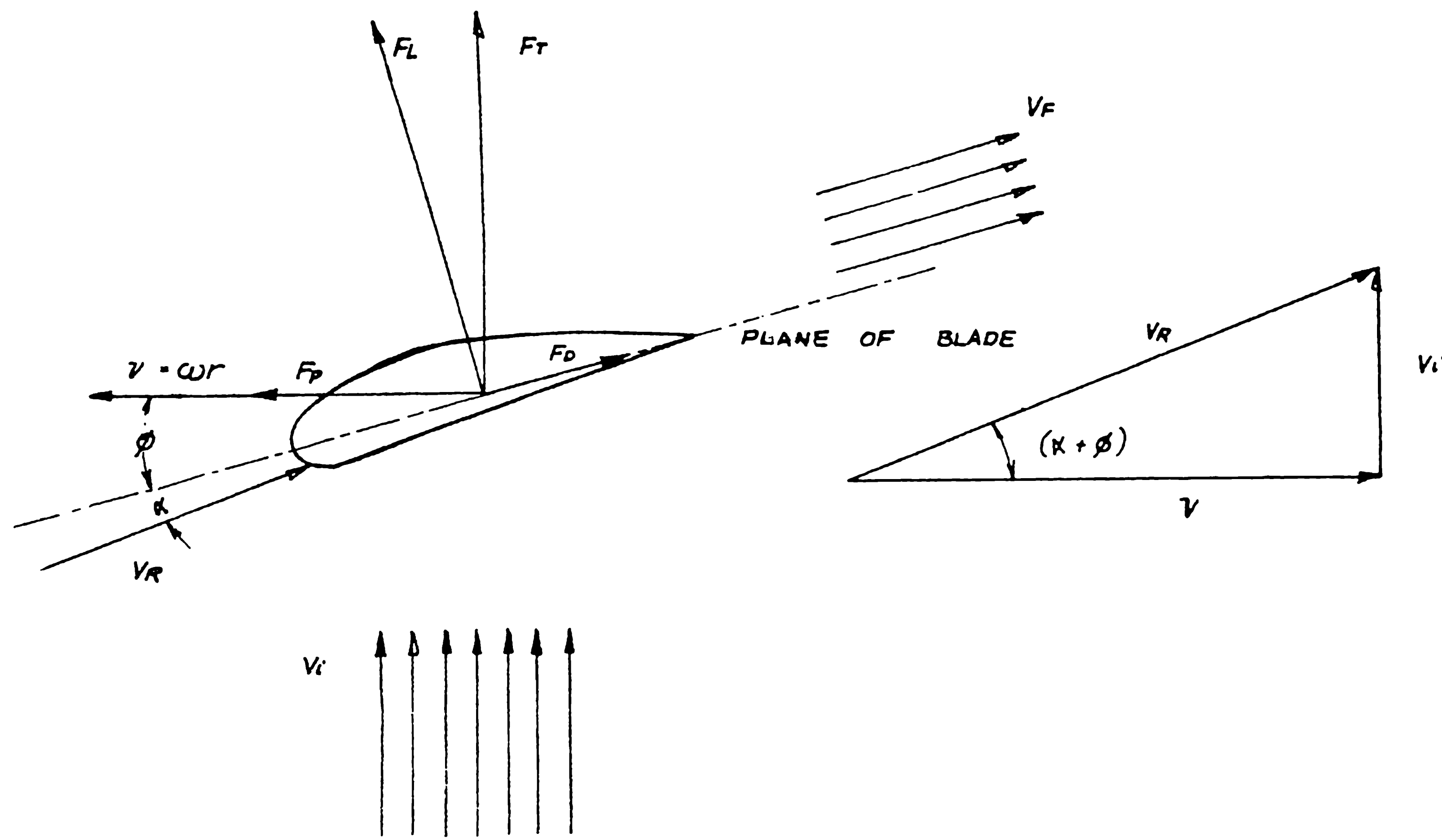

Figure 1. The mechanics of wind energy transfer.

of an element of the blade, with thickness Δr and at a distance r from the center of rotation. The incident wind speed is V_i, the outgoing V_f. The energy of a cylindrical air mass before and after it has swept past the windmill are respectively, E_i and E_f. Obviously, we must have $E_i > E_f$ if our energy converter is effective. Thus the energy rate E_i available can be written as

(1)
$$E_i = 1/2\,(\rho \text{Vol}) V_i^2$$
$$= 1/2\,(\rho A V_i) V_i^2$$

where vol is the volume of the air cylinder that sweeps past the windmill per unit time, ρ is the air density and A is the cross-sectional area.

Our converter can only extract a small fraction of E_i. Indeed, if the machine were ideal, it can only convert at most about 60%. If we now lump all the other sources of losses into the system, the power output P_a of the windmill is usually expressed as

(2)
$$P_a = C_p E_i$$

where C_p is now defined as the power coefficient. For making estimates, Equs (1) and (2) can be written as

$$P_a \cong 0.2\, A V_i^3 \text{ in watts}$$

The area A and speed V_i must be in MKS units.

EXAMPLE: For a wind speed V_i of 10 mph and blade diameter of 10 ft., a good approximation of the power output would be:

$$P_a = (2.0)\left(\frac{\pi}{4}\right)\left(\frac{100}{10.8}\right)(4.4)^3 \quad = \quad = 268 \text{ watts}$$

Referring now to Fig. 1, let us analyze the forces acting on the surface of the blade. The lift and drag forces can be written in terms of the air pressure as

(3)
:
$$F_L = C_L \cdot 1/2\,\rho A V_r^2$$
$$F_D = C_D \cdot 1/2\,\rho A V_r^2$$

where we have introduced the lift and drag coefficients as C_L and C_D, respectively. The ratio $F_L/F_D = C_L/C_D = K$ is the lift/drag ratio, an important parameter in airfoil designs. High speed rotors are usually fitted with airfoils having K with values between 50 to 100. This property is essential in electric power generation because the resting high tip-speed ratio

$$\lambda \;\; 8(\;\; \lambda \left(= \frac{WR}{V_i}\right)$$

eliminates much of the gearing up mechanism. The relationship among the po coefficient C_p, the lift-drag ratio K and the tip speed ratio λ for the cases of 2-bladed and 3-bladed rotors.

The thrust F_T experienced by the rotor propeller, as well as the propelling force F_p, can be expressed in terms of F_L and F_D and the angular parameter a and ϕ:

$$F_T = F_L \cos\phi + F_D \sin\phi$$

(4)

$$F_P = F_L \sin\phi - F_D \cos\phi$$

The power p generated by the blade element is then

$$p = F_p \quad v$$

(5)

$$= (F_L \sin\phi - F_D \cos\phi) \qquad \text{(or)}$$

Since V_r depends on the angles ϕ and α (see velocity triangle in Fig. 1), we can see how they also affect the stresses in the blade and the power output of the motor.

The Wind Data

The most basic element in the design of an aerogenerator is the wind data. All analyses whether technical or economic must begin with a reliable and accurate measurement of the wind structure and characteristics at the site.

The PAGASA data, which is quite extensive in points of time and space, are not suitable for purposes of windmill design. The wind speed, as well as the direction, are taken at the various PAGASA stations once every three (3) hours. What is given to us is the average over the month for each year of observation. This procedure, therefore, gives an average value that is much lower than the actual wind speed, inasmuch as high speed winds cannot be expected to blow much longer than 10 hours in a day. Thus a PAGASA average speed of 10 knots is a good wind resource. An hourly average would surely yield a more accurate picture of the wind structure.

A detailed measurement would employ a chart that will conti-nuously record the wind speed at a site. From such raw data, one can then proceed to construct the velocity duration curve, the power duration curve, and the velocity frequency curve. Furthermore, the time of the day when the good winds occur is also important as these times maybe different from the peak demand. Provision for storage will be decided from the data. No such measurement has ever been taken at a site in the Philippines. In Fig. 2, 3 and 4, I have taken the corresponding curves from Golding and Harris* for the 3 sites indicated in the curves.

A detailed analysis can now be made as to the energy potential of the wind resource at the site. Of course, only a small fraction of such resource will be ultimately converted by our machine. In addition to the determination of annual energy output, we can now set for our design the cut-in and cut-off speeds, as well as the speed at full power output. Again, this is shown in Fig. 5.

Wind Resources in the Philippines

The country is in the path of two prevailing winds. During the summer in continental Asia, the heated air masses there rises up, creating a low-pressure area into which the heavier air masses from the South China Sea and the Pacific rush in. These on-rushing winds hit the Philippines from the southwest. The southwest monsoon wind starts in the latter part of May, lasting up to early September. Likwise, during these period, the western coasts of the country experience the rainy season. During the other part of the year, from late September up to perhaps the month of March when it is winter in the Asian mainland, we experience the northeast monsoon. At this period, the cold winter winds descend toward the equatorial zone. The eastern coasts have their rainfall season at this time.

These two prevailing winds are our principal wind resources, inasmuch as we do not have large desert areas inland. Thus we expect good sites at our eastern and western coasts. In the central areas, except some places of high altitude, the northeast and southeast winds maybe blocked by mountain ranges that run along the islands.

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*Golding & Harris, *the Generation of Electricity by Wind Power*, John Waley & Sons, 1978, London.

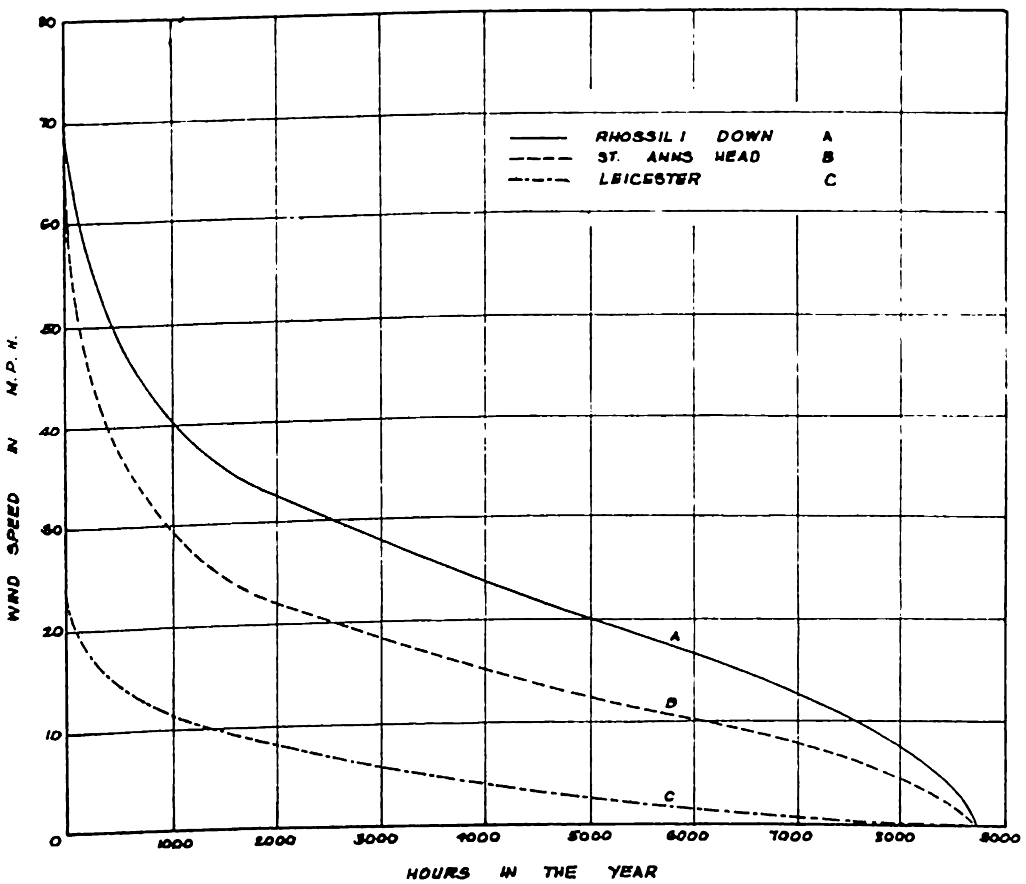


Figure 2. VELOCITY DURATION CURVE

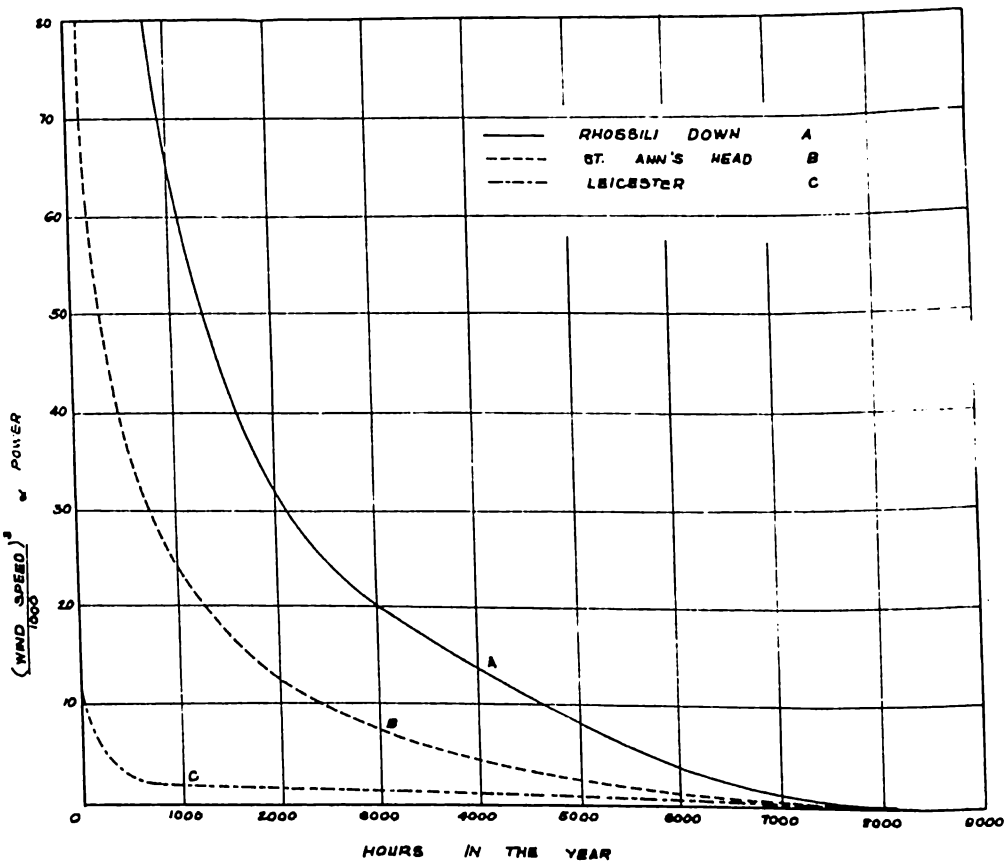


Figure 3. POWER DURATION CURVES

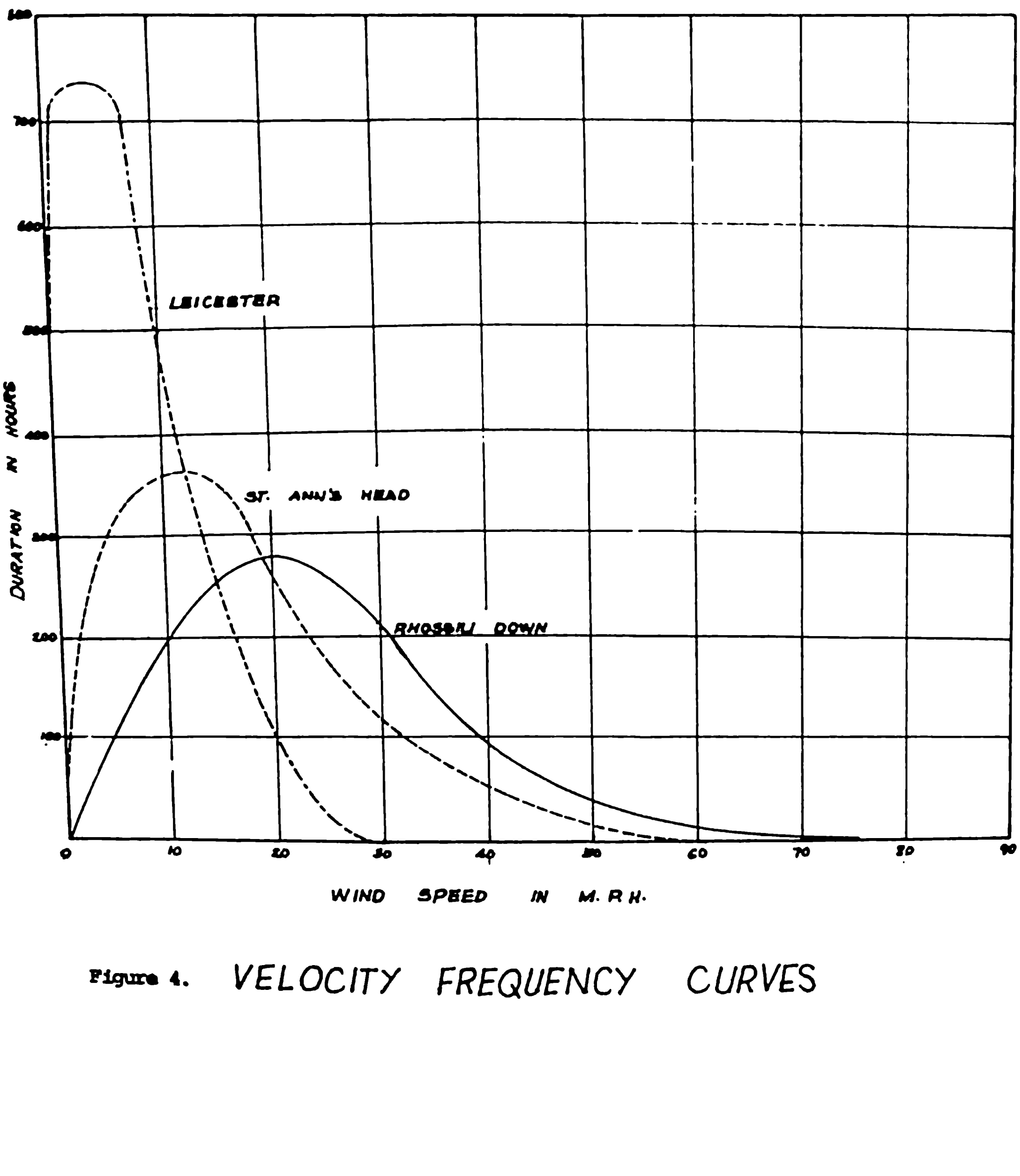


Figure 4. VELOCITY FREQUENCY CURVES

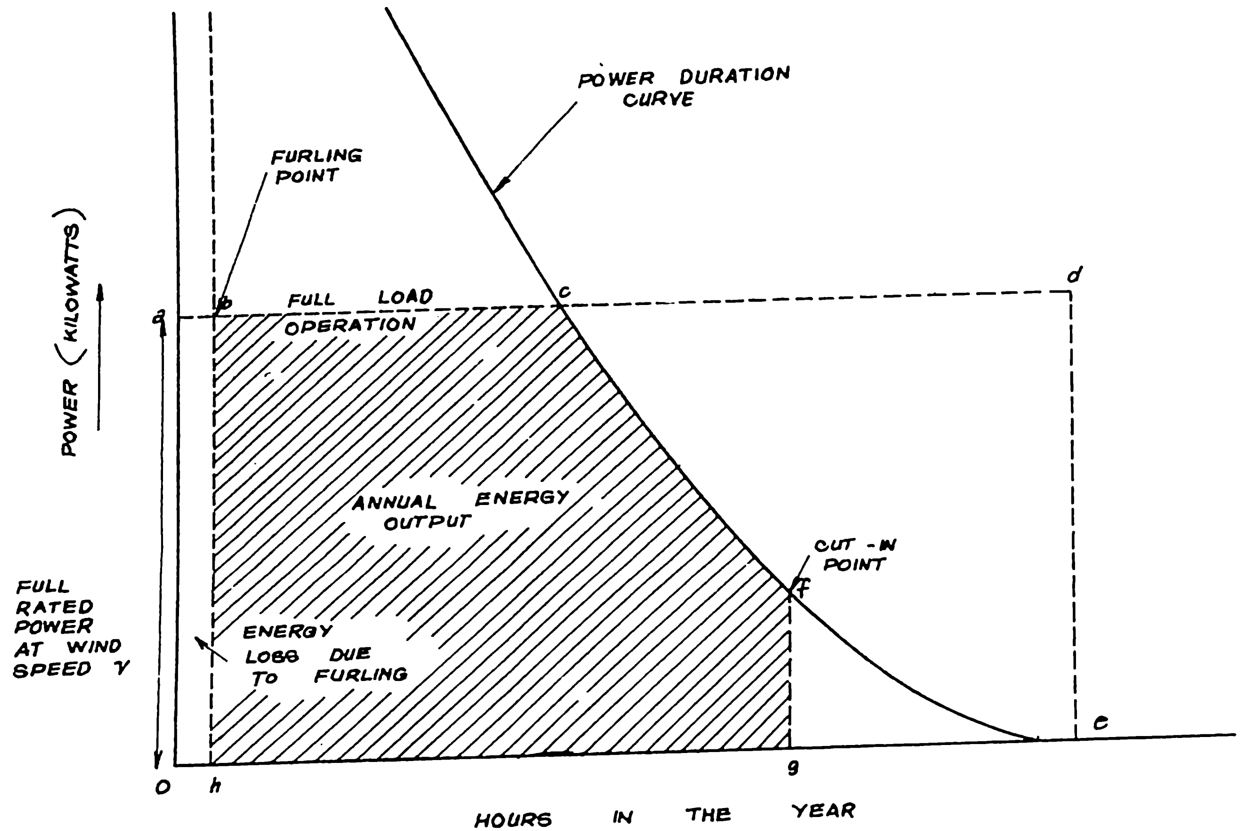


Figure 5. ESTIMATION OF ANNUAL ENERGY OUTPUT

From the PAGASA data, I have identified a number of sites which have good wind energy potentials, bearing in mind that actual wind speeds at these places may easily be twice or more of the PAGASA average. The average monthly wind speeds for each year of observation for the prospective sites are as follows:

a) *Basco and the Batanes Islands.* These would be ideal sites for an aerogenerator were they not in the path of the storms that originate in the South Pacific. The government offices there, like the Philippine Navy and the PAGASA Radar Station, have their power needs supplied by their individual diesel generators. Due to the extreme difficulty in bringing fuel there, wind energy conversion would be competitive, if not now, maybe in a couple of years. From the performance of a small Dunlite aerogenerator there, an operating wind speed of 25 mph blowing about 10 hrs per day is possible. Plans are underway to measure the detailed wind structure there.

b) *Laoag, Ilocos Norte, Aparri, Cagayan, and Vigan, Ilocos Sur.* These 2 places are among the oldest cities in the Philippines. Unlike in Basco, these places are included in the national grid. Thus the economics of windmill there maybe more complicated. But there is wind potential in these places throughout the year. These places would likely be candidates in case there will be a need to displace or compliment existing capacity. The effect of the high mountain ranges in Luzon can be seen in Fig. 6 causing the southwest wind to skirt north along the western coast.

c) *Cuyo, Palawan, Iloilo and Western Negros.* There is definitely wind potential in these southern places. The data from Cuyo Island gives the highest average in the Philippines. The winds apparently reach Iloilo as verified by the PAGASA observation. In Western Negros, however, there is no PAGASA station. Also in Palawan, there is a mountain range that parallels the island. This may be the reason why PAGASA data at the airport in Puerto Princesa there does not give a good wind speed. However, due to growing economic importance of the place, as well as in Western Negros, and the absence in these places of other indigenous energy resources, the wind structure there must be carefully determined. Again, it would be a gross mistake to assume that the PAGASA data taken at the airport in Dumaguete City is the same for the entire island of Negros. The airport is on the eastside and also shielded from the west by mountain ranges and on the east by Cebu.

d) *Other wind potential areas.* So far, I have not touched the eastern coasts facing the Pacific. No doubt there are a number of

Fig. 6-a

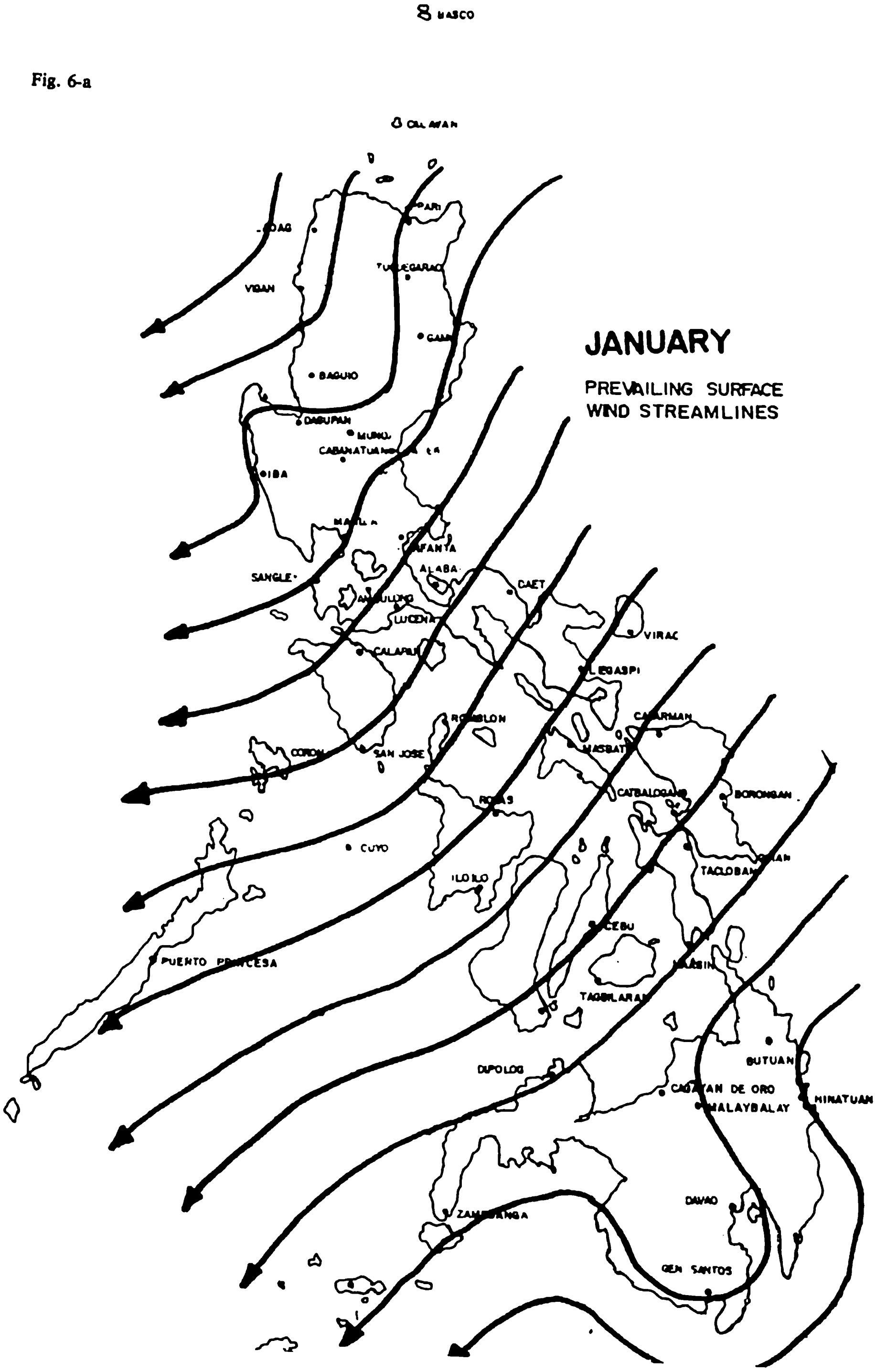
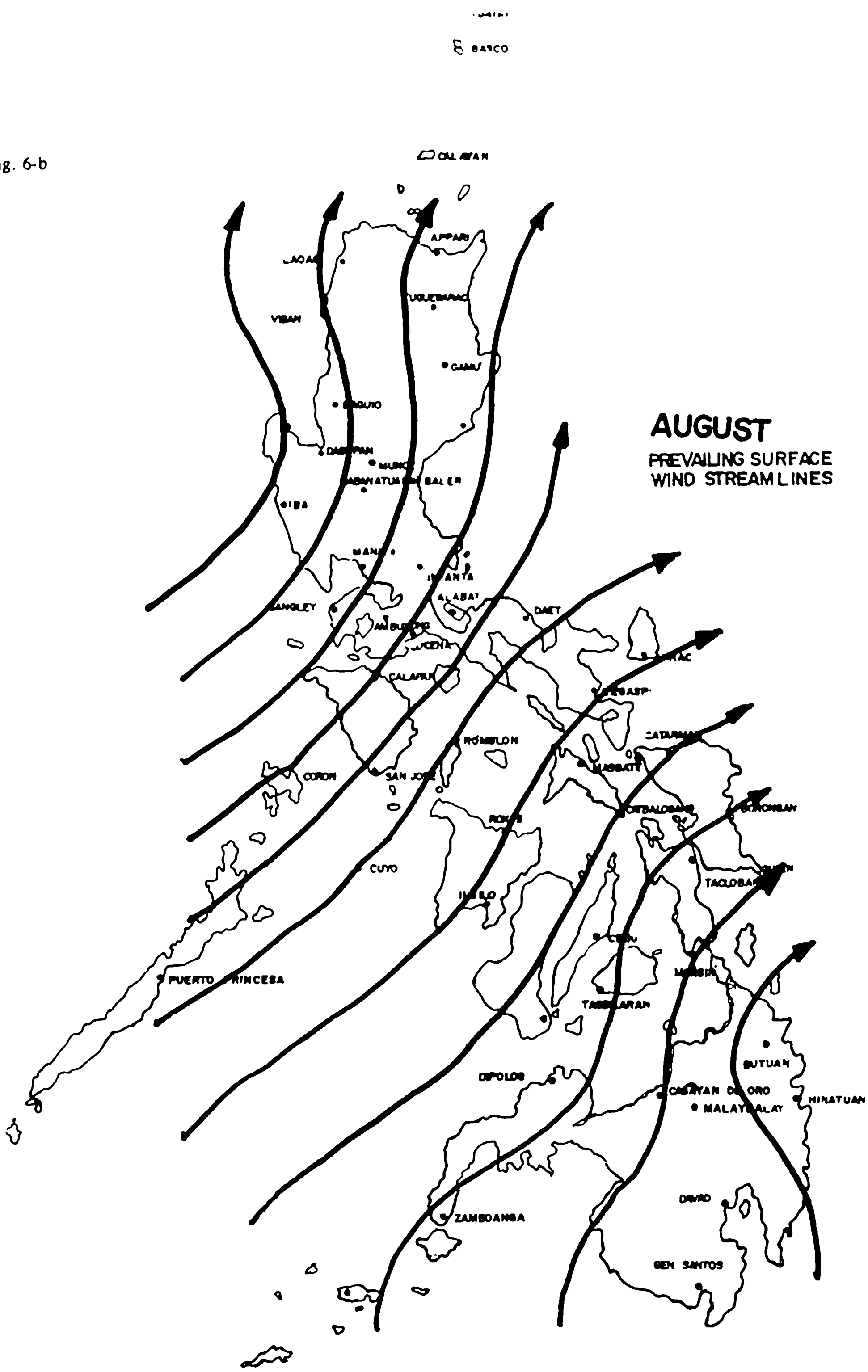

JANUARY
PREVAILING SURFACE
WIND STREAMLINES
BASCO
VIGAN
BAGUIO
DAGUPAN
IBA
SANGLE
VIRAC
LEGASPI
COTABATO
CUYO
ILOILO
CEBU
PUERTO PRINCESA
DIPOLOG
BUTUAN
HINATUAN
MALAYBALAY
DAVAO
GEN SANTOS

Fig. 6-b


AUGUST
PREVAILING SURFACE
WIND STREAMLINES
BASCO
APPARI
VIGAN
BAGUIO
BALER
IBA
SANGLEY
INFANTA
ALABAT
DAET
LUCENA
CALAPAN
ROMBLON
CORON
SAN JOSE
MASBATE
ROXAS
CUYO
ILOILO
CEBU
TACLOBAN
PUERTO PRINCESA
TAGBILARAN
DIPOLOG
BUTUAN
CAGAYAN DE ORO
MALAYBALAY
HINATUAN
ZAMBOANGA
DAVAO
GEN SANTOS

places there with strong winds, like Quezon, Camarines Norte, Romblon and others. Site selection in these places should be done more carefully due to the presence of intervening obstructions. Moreover, the storms hit the eastern coasts with their full fury so that bigger capital investment would be necessary for safety measures.

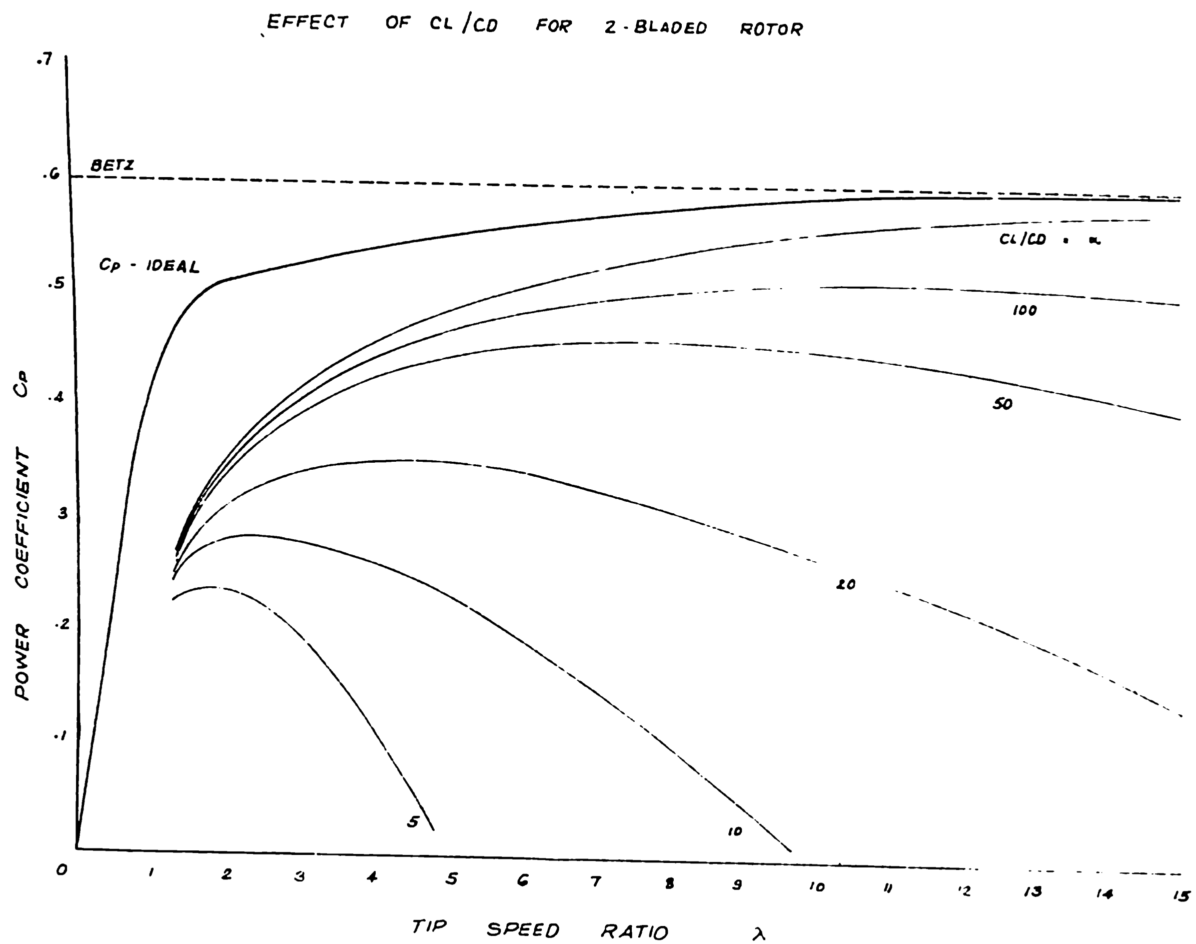
Economics of Wind Power Generators

With the present cost of electricity, no small user can possibly afford a windmill in the presence of a grid. Even the relatively inexpensive windmill for water pumping cannot compete against an electric motor that uses electricity at the rate of P2.00/Kwhr. The initial cost is simply large. For example, the common multi-bladed Reymill sitting on a 40 ft. tower and equipped with a 1000 gallon tank costs about P35,000.00 in Manila and vicinity. Compare this with a 1/2 hp motor, plust adaptations and installation, which costs about P5,000.00. To pump 1000 gallons, this uses only about 1 kw-hr. Thus, you can see that the difference in initial investment is P30,000.00, which when placed in the bank will more than earn for the fuel expenses.

The windmill electric generators are more expensive. A useful index for cost analysis is the price per watt of rating. For instance, if a power device installed has a capacity of 10 KW and the overall cost is $30,000.00 then the cost/rated watt is $3.00. The current cost/rated watt in the US for windmills ranges from about $4.00 to less than a dollar. The smaller, independent units are more expensive. The bigger units have the advantage of scale, so that we achieve better economy this way. The 3-megawatt Bendix windmill near Los Angeles, for instance costs $1,000,000.00. This yields a cost/rated watt of only $0.33.

This cost must be balanced with the annual power output per watt of rated capacity.

Appendix 1. Effect of CL/CD for 2-bladed rotor



Appendix 2. Effect of CL/CD for 3-bladed Rotor.