COST OF ENERGY EVALUATION

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The cost of energy of a wind turbine generator system contains the three-elements of Capital Cost, Operation and Maintenance Cost, and Energy Capture. In equation form, the Cost of Energy in cents/kilowatt hour is

$$\text{COE} = \frac{0.18\ (\text{Capital Cost}) + \text{Levelized O\&M}}{\text{Kilowatt Hours Per Year}}$$

We at Hamilton Standard feel that this equation should be stenciled on the forehead of each of our designers, displayed prominently on office walls and, in fact, have the same emphasis as the THINK program at IBM.

Each of the elements of this equation is important and true. Low COE wind turbines will not become available until this is realized. Much emphasis has been placed upon reducing hardware capital costs, but if it is at the expense of increased O&M and reduced energy capture, we have accomplished nothing.

Much emphasis must be applied to reducing the indirect capital costs such as siting, foundations, and erection costs. The reduction in O&M costs is important because if we are not careful, this item can be a significant fraction of the numerator of the equation. Probably the greatest gains can be made in addressing the denominator of the equation - energy capture. Extremely careful attention to the one- and two-percent items that improve energy capture pay off in very significant reductions in COE.

The work that Glid Doman has described in his paper "System Configuration Improvements" is part of an extensive company-sponsored program to develop the concept of a wind turbine machine that Hamilton Standard feels is required for low energy costs. The results of this study in a machine we have named WTS-3 will now be presented.

An artists conception of the 3 MW WTS-3 wind turbine is shown in figure 1. The concept has a two-bladed rotor and a tubular tower. Major specifications and requirements of the WTS-3 are listed in figures 2 and 3. The power profile and yearly energy output variations are shown in figures 4 and 5, respectively.

The costs for the WTS-3 system were determined for 100 production units with a 14 mph wind at the 30 foot elevation. The results are:

INSTALLED COST - $420 PER KILOWATT

ENERGY COST - 2.4¢/kWh

Such low estimated costs are in deed encouraging and can well pave the way for acceptable commercial utilization.

DISCUSSION

Q. The COE formula that you use, which was also presented by NASA, has been critized by many people. Could you give us your recommendation on how the costs should be calculated?

A. We have no argument with the formula as it is presented, because that's a factor most of us will have to face. The big question seems to be the cost-of-money number (the 18 percent). That number is a general requirement for an investor-owned utility which has a responsibility for a return to its investors. Also, to make a return on investment internally requires that costs be covered. For a public utility - municipal or federal - the cost of money is reduced by a factor of almost two. Thus, in a federally sponsored project or a federally run organization, a relatively good COE value appears, and it is quite attractive. The essence of the problem is that if wind turbines can't be made economically satisfactory under this type of examination by the customer, then we may not have a product.

Q. What is the speed variation of the design?

A. It is a constant rpm machine.

Q. Have any market surveys been made to determine how many utilities would buy your machine at the 2.4 cent kilowatt hour rate?

A. We haven't done what might be called an exhaustive market survey. We have been in communication with several utilities who say that if these numbers can be realized, they would be more than happy to buy them. There are indications in the studies that we have done (which admittedly are crude), that there are sufficient wind area sites to make this machine economically attractive. If they could be produced fast enough, we could probably put up around 20,000 machines.

Q. What is the cut-in velocity of your design? One of the largest systems cuts in at wind velocities of 14 miles an hour, while in our program, the smaller machines started at 10 miles an hour. We feel there is a lot of useful wind at that lower level.

A. We start at 10 miles an hour at 30 feet. At the hub height, it is something like 11 or 12 miles an hour. At 50 feet, for the Rocky Flat machines, I think it is around 10 miles an hour or less.

Q. What is the annual production rate that was used in your assumptions?

A. About 200 to 250 units.

Q. Could you explain why a 50 hertz system is specified for your machine?

A. Most areas in the world have 50 hertz systems. In fact, the United States is one of the few countries in the world that runs at 60 cycles. The generator for use in this country would have a few more teeth on the gearbox so that it could operate at 60 hertz.

Q. Are you using a planetary gearbox?

A. Yes. We are currently planning to use a planetary gearbox system, although it isn't absolutely certain. There is some disagreement among our own designers whether to use a parallel shaft or some combination of planetary and parallel shafting. The particular design that is presented here did have a planetary box. It was found to be the cheapest and lightest arrangement.

Q. What is the conversion factor between 30 feet and the centerline?

A. We use the shear gradient that was contained in the MOD-3 proposal request last year.

COMMENTS:

On the fixed charge rate, the 18 percent number is roughly representative of utilities which account for 70 percent of all the electricity generated (not capacity) in this country. Furthermore, if a machine can become available at the estimated cost of 2.4 cents per kilowatt hour, if the wind resource in the utilities service area is assured, and if the reliability of the units is also assured, then the utilities will certainly buy these machines.

The wind conversion system engineering field is never static. It is always moving and there are many facets to explore. Much attention and work needs to be done on the indirect contribution to capital cost. Also, it is necessary to verify and pursue the items in the denominator of the COE expression. Attention must be paid to the details right from the start, and total dedication is needed to the equation in order to make these machines happen.

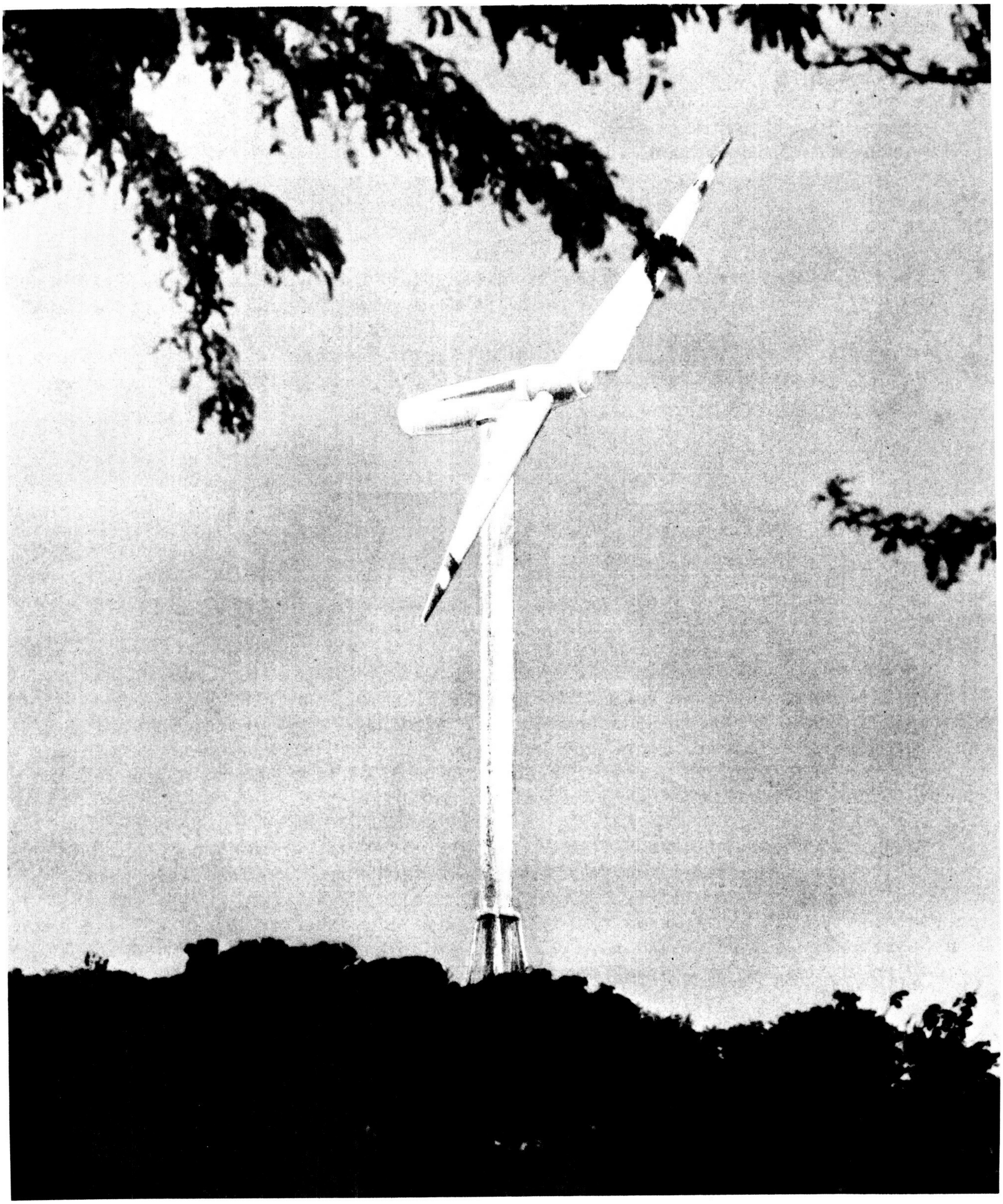

Figure 1. - WTS-3 concept (artist's rendition).

WTS-3 SPECIFICATION

Rotor Diameter	255 Ft. (77·6 M)
Tower Height	262 Ft. (80 M)
Generator	
Type	Synchronous AC
Rating	3·0 MW
Capacity	3,750 KVA
Voltage	6,000 V, 3-Phase
Frequency	50 Hz
Maximum Survivable Windspeed	125 MPH (55 M/S) At Hub
Design Life	30 Years

Figure 2

WTS-3 CHARACTERISTICS

- Downwind Rotor
  - Teetered
  - Full Span Control
  - Fiberglass Blades
  - Infinite Fatigue Life
- Free Yaw
- Soft Tower
- Low Maintenance Requirements
- High On-Line Availability

Figure 3

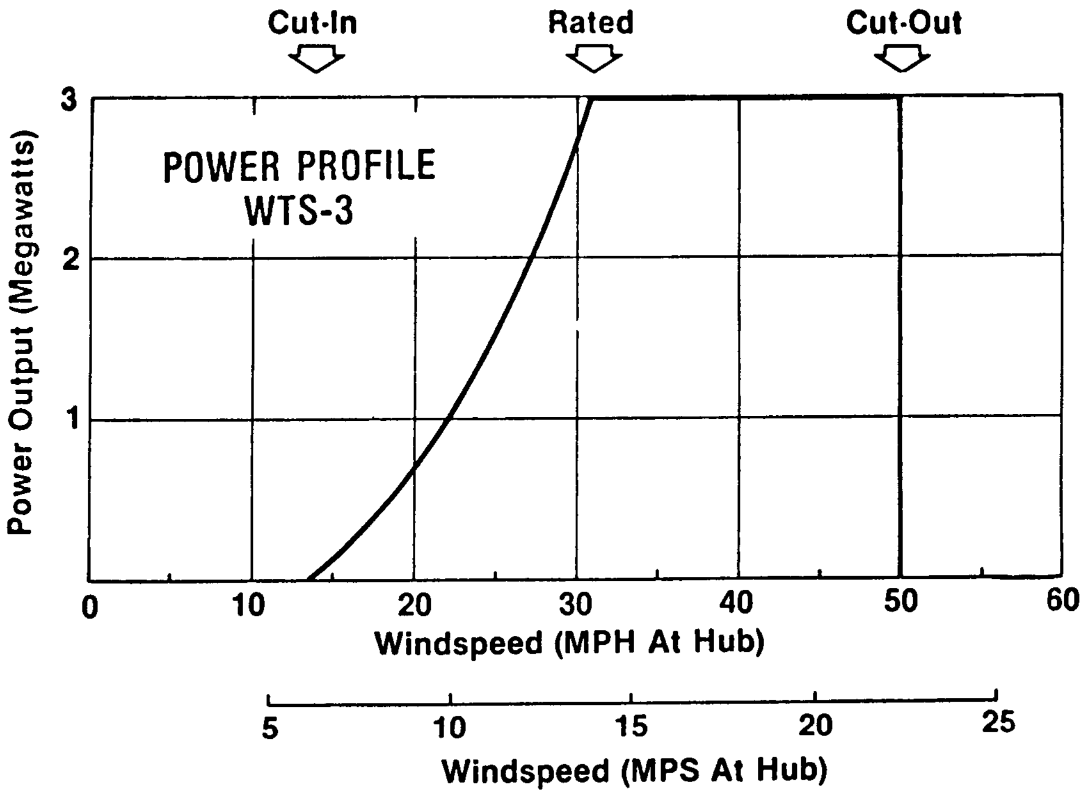

Figure 4

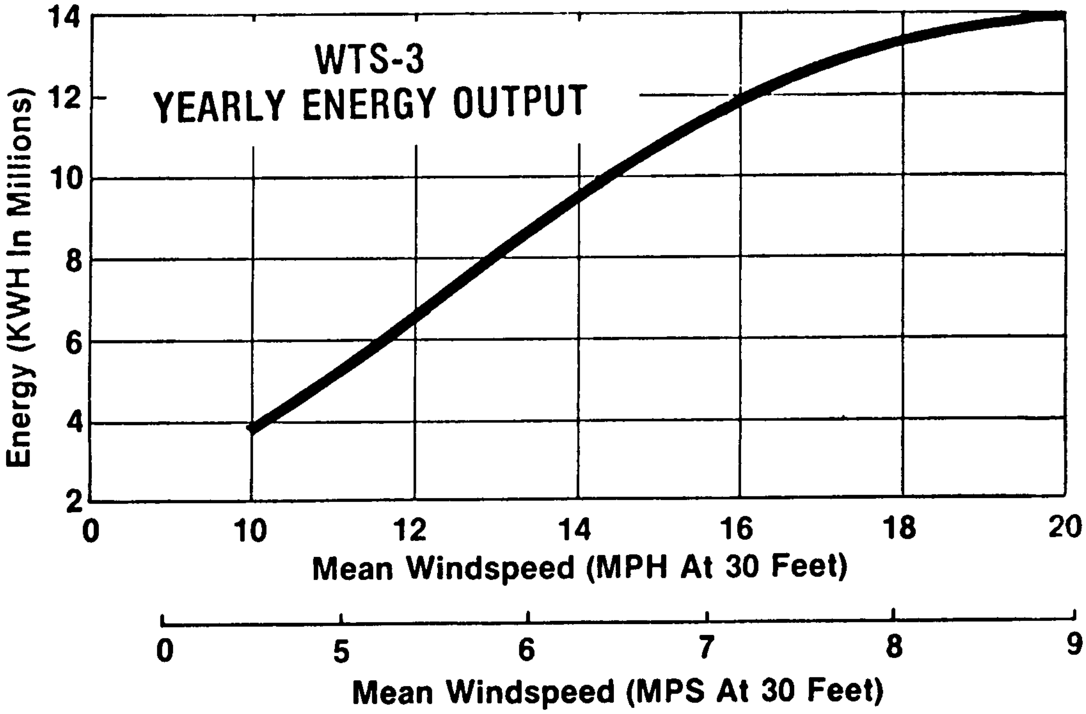

Figure 5