PERCY THOMAS WIND GENERATOR DESIGNS

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For the benefit of all present, I would like to begin with a general description of the organization and responsibilities of the Federal Power Commission. The Federal Power Commission is a federal regulatory body, administering the National Gas Act and the Federal Power Act, and is comprised of five commissioners appointed by the President and confirmed by the Senate and supported by a staff, which includes members of all professions and activities - legal, engineering, economic, and many others.

As such, the Federal Power Commission has no responsibility, authority, or funds for any research and development activity. It, nevertheless, remains interested in all these activities and does contribute indirectly to the advancement of the art and science. Through the Uniform System of Accounts (the reports made to the Commission about the cost and expenditures of regulated industry and its actions through rule-making processes and hearings) the Commission can give encouragement to the regulated industry. One such example is allowing for the cost of research and development activity in the determination of allowable consumer rates (that is, wholesale rates) so that the costs may be recovered by the utility which makes the expenditure. The Commission and its staff is also interested in any development that would affect, of course, the various aspects of reliability, adequacy, economics, and things of that nature.

But I would emphasize that anything I say that might be construed as an opinion is mine and not that of the Commission. Any Commission activities always are a result of hearings in rate, or similar, cases, or are produced in the form of orders made public and followed by industry.

Mr. Thomas devoted about 10 years, in addition to his other duties, to a detailed analysis of wind power electric generation and its effect on the electric utility industry. He actually produced, and they were published by the Commission, four monographs, the first one was titled "Electric Power from the Wind" (March 1945). (Notes on these monographs appear at the end of this paper.) This first monograph was prompted by the 1941 to 1945 construction and operation of the 1,250-kilowatt installation on Grandpa's Knob near Rutland, Vermont, which we have just seen. This installation was integrated with the Central Vermont Public Service Corporation, and, as we know, it suffered fatigue in blade failure.

As Mr. Smith and Mr. Wilcox have advised, it was not rebuilt because of economic considerations.

Now, Mr. Thomas envisioned wind power electric generation for use on interconnected utility networks firmed up by hydroelectric storage facilities in order to overcome the firm power deficiencies of wind driven generators. He used to a great extent the economic data from the Grandpa's Knob operation, and he concluded that between 5,000 and 10,000 kilowatts were necessary for economic viability.

In the first monograph, he described the twin wheeled, two bladed propeller design for a 7500-kilowatt unit and a twin wheeled, three bladed propeller design for a 6500-kilowatt unit. In order to overcome, in part, the difficulty in coupling a variable speed, wind driven mechanical source to a synchronous speed, alternating current commercial system, Mr. Thomas' design proposed a wind driven, direct current generator, electrically coupled to a dc to ac synchronous converter. He calculated the cost, based on extrapolations and estimates from Grandpa's Knob, to be $68 per kilowatt capacity for the 7500-kilowatt unit and $75 per kilowatt capacity for the 6500-kilowatt unit. Mr. Thomas concluded that with certain assumptions the economics warranted the collection of wind data in greater detail and specifity than that then accomplished. He also suggested testing propeller designs in wind tunnels over and above that done, and, in addition, the necessity of constructing a full-size 7500-kilowatt prototype.

I would like to emphasize that in not only Mr. Thomas' first work but the three that succeeded it, and probably in all the works and treatises of people writing in the same area, that there is almost universal agreement that wind data including duration curves be acquired over a very wide area.

In March of 1946, the second monograph was published. It is devoted primarily to the detailed design features of the twin-wheel 7500- and 6500-kilowatt wind powered generators he discussed, in general, in the previous monograph. He commented on the March 1945 shutdown of the Grandpa's Knob installation and reiterated the desirability of larger units, between 5,000 and 10,000 kilowatts for utility operation.

In January 1949 the third monograph was published. In it Mr. Thomas compared the detailed aerodynamic designs of the Grandpa's Knob unit, an English designed unit, and his design. It's interesting that in this monograph Mr. Thomas modified, for comparison purposes, his 1946 design of the 7500-kilowatt unit by increasing the blades from two to three for each wheel, shortening each blade, and increasing the designed rotational speed. In all cases the general overall height of Mr. Thomas' design approximated that at Grandpa's Knob, though it has been postulated and he mentioned designs that might go up as high as the Eiffel Tower or the Washington Monument, 500 or 600 feet. In this third monograph Mr. Thomas again emphasized that, because of intangible characteristics and uncertainties of extrapolation, wind tunnel tests and full scale prototype construction were imperative to efficient design.

In February 1954 the last of Mr. Thomas' works was published. In this last work Mr. Thomas digressed from the detailed technical design features that he dealt with in his first three works. This work is largely general in nature, commenting on utilization or integration of wind generated electric energy in an electric utility network. He discussed generally the possible benefits of firm and secondary power, derived from wind power generation, when supported by large interconnected electric systems. By this time steam electric generating units having 250,000-kilowatt capacities were in operation, and the economic benefits of economy of scale of these units presented at that time a stiff challenge to competing electric generation sources. Mr. Thomas moved away from comparative cost base justification for windpower generation in favor of more general statements. In other words, windpower electric generation would be justified if the cost would be no greater than that then being produced by modern steam plants. So, if I may insert at this time from my readings of the literature that you can find today, there are no real good present day costs that one can put a handle on to make an economic comparison. Mr. Thomas also stated, regarding wind powered electric generation, and this is to a degree at variance with his earlier implications, that economies of scale were a questionable attainment and implied that capacities of 2,000 to 4,000 kilowatts might yield maximum economic benefits. He had moved away from the 5 to 10,000 kilowatt installations, and there is no reason given why he made his statements in what he had written. But he did say that the 2,000 to 4,000 kilowatt units might be a maximum size. Again the implication is that there is a lot of study needed in an economic way.

I believe that no one in this room, or no one with any construction background whatsoever, would question the technical feasibility of constructing a windpowered electric generator. We have actually seen one work, and the fact that the blade suffered that failure is really no criticism, since in development activities things of that nature happen all the time. But even today there is a lack in economic justification for the use of the wind as a source of energy.

In his previous publications Mr. Thomas made some reference to the use of windmills to generate mechanical power, not necessarily associated with conversion to electric energy. In this last work he also commented on a windpowered waterpump and some general applications, including its use as a pumping source for hydroelectric pump storage operations.

That, essentially, gentlemen, constitutes the works of Mr. Thomas. They were rather lengthy, and in deference to the program I have abstracted them briefly and the abstracts are given at the end of this paper.

I might comment from my own reading that, while it is technically feasible to construct such a plan and to integrate it into a central station operation, in the economic evaluation of any generating source two main costs must be borne in mind. One is the cost of the fuel, which is a production cost for the energy so generated, electric energy. In the case of wind it essentially is nothing; therefore, it enjoys that advantage. Now, because of the nature of electric energy and its use by the consumer it does not allow, in general, a storage of that energy except in an indirect form. It can be stored in hydroelectric storage; it can be stored in fuels which then are called on in accordance with the demand of the customer. That is the serious defect in getting a good, firm power worth to electric generation if it's merely integrated into an operating system. And it appears, from what I have seen, the costs are the biggest obstacle to overcome to the adequate use of this source.

DISCUSSION

Q: You mentioned there were two costs. One thing that I didn't detect in your comment was the cost of eliminating the traces that had made the power, or to use the word "pollution." Do you see this becoming a factor, or do you see a shortage in fuels becoming a factor that would influence the balance of economic trade-off for this power?

A: We are very aware of the economic cost of environmental controls on methods of generating electricity. In the end the consumer, the purchaser of the energy, will be the one who actually determines what steps are taken in these regards.

We have coal resources that can be exploited for all the foreseeable energy needs until such times as our breeder nuclear reactor program, or our fusion program, or anything else comes into being. So what we are really asking, are we not, is what will we pay in an intermediate time period for the home environmental freedom that windpower offers?

Now, even though there is nothing in the sense of air pollution or water pollution that windpower generation implies, it does require certain land uses, and there are certain esthetic aspects of mile after mile of windmills scattered over the landscape. Those are environmental costs also. But, to answer your question, I think the consuming public by the cost of what they buy will be the eventual decider of what environmental degradation they will stand.

There is another thing, too. We are prone to, I think, attribute too great an advantage to some things and consider that the money supply is inexhaustible. After all, money is a resource and does come from production and other efforts, and if we waste money, then we are implying a resource waste in other areas.

Q: Could you tell me where I could get these four pamphlets?

A: They have long been out of print. I have four copies, which are actually the file copies. The Office of Information of the Federal Power Commission can arrange to have them reproduced.

Q: What are your impressions on the subject of storage, not just on the wind energy system, but the solar energy system?

A: Whenever I look at pumping energy into the electric utilities system, I relate it really in terms of the proportion of windpower that could be supplied in proportion to the total power output of the utility. If the proportion of windpower is relatively small, I really don't see the need for storage, because you have basically three systems in the utility where the intermediate and backing systems essentially can perform the storage function. Obviously, if a large proportion of wind energy is being pumped into the utility, then is there a storage problem. I disagree that carte blanche storage is a problem. It depends on how much of the energy is being supplied.

There is a cyclical value to energy produced in the electric utility operation; in other words, the cost of energy varies second by second. The economic computers that load and unload the various components of generation are so programmed that they evaluate the incremental cost of energy as it's produced on cyclical basis.

If I might use a rather basic evaluation, if you are generating under pump-hydro, or even run-of-the-river hydro, that has a nonline at the time worth of 2 mills, then any energy produced by wind power will not have a higher value in the planning phase.

Q: Do you have any information on the attempt to get money to build a larger prototype in 1951? I have a copy of the Congressional Record in which the hearing was reported, but I have not been able to get any information on what happened in that attempt.

A: I have no other information except the hearing record myself.

Q: I was wondering if Mr. Smith had any comments to say in collaboration with the Federal Government. Were there ever any attempts to work with Mr. Thomas of the FPC?

A: We had a good many sessions. We came to New York very frequently and discussed this with Mr. Thomas. The problem Mr. Thomas had was that his economic evaluations were rather broad.

COMMENT: I am manager of a municipal light plant in Massachusetts. With regards to the economics and to energy storage, let me say that, at the time that these wind generators were being made the total demand for electric energy was quite different than it is today.

For example, total electric living was not being pushed to as great degree at that time. Today they are pushing a total electric home, as an example. In the total electric home, your greatest need is for heat, almost 70 percent.

Therefore, the greatest potential of the wind generator is to generate heat directly, not to go to electricity and then make heat. The efficiencies of a direct conversion from mechanical to heat energy, such as in our community, are greatest when it is the coldest. That's when the wind is blowing the hardest and all the heat is blown out of the buildings, and therefore we would have a direct need at that time for the greatest amount of heat and a peak demand for electrical needs.

This appears to have significance. I mean heat storage is becoming a great thing - using heat exchanges, heat pumps, and storing up by water in tanks for big commercial buildings - all of this in order to combat the problems. If you buy power on peak, the cost of power is greater than off peak, so all these things figure into peaking and storage which is being substantially pushed already to reduce the demand costs.

The following are abstracts of Percy H. Thomas' four monographs which were the results of his studies on the potentialities of wind power.

ELECTRIC POWER FROM THE WIND
March 1945

Percy H. Thomas

Federal Power Commission
Washington, D. C.

This monograph by Mr. Thomas on the general subject of power from the wind was prompted by the 1941-1945 construction and operation of a 1,000-kilowatt installation at Grandpa's Knob near Rutland, Vermont, on the system of the Central Vermont Public Service Corporation. This unit suffered a blade failure on March 26, 1945, and was abandoned because of economic considerations.

Mr. Thomas envisioned wind powered electric generation for use on interconnected utility networks, firmed up by hydroelectric storage facilities in order to overcome the firm power deficiencies of wind driven generators. Using certain economic data from the Grandpa's Knob operation, the author concluded that units of a size between 5,000 and 10,000 kilowatts were necessary for economic viability. The author described a twin-wheeled, two-bladed propeller design for a 7,500-kilowatt unit, and a twin-wheeled, three-bladed propeller design for a 6,500-kilowatt unit. In order to overcome in part the difficulty in coupling a variable speed, wind-driven mechanical source to a synchronous speed alternating current commercial system, the design included a wind-driven, direct-current generator electrically coupled to a dc to ac synchronous converter. The author's calculated costs were $68 per kilowatt of capacity for the 7,500-kilowatt unit, and $75 per kilowatt for the 6,500-kilowatt unit.

Mr. Thomas concluded that, with certain assumptions, the economics warranted the collection of wind data in greater detail and specificity than that then accomplished, the testing of propellor designs in wind tunnels, and the construction of a full size (7,500 kW) prototype.

THE WIND POWER AEROGENERATOR -- TWIN WHEEL TYPE
March 1946

Percy H. Thomas

Federal Power Commission
Washington, D. C.

This monograph is devoted to the detailed design features of the twin wheel, 7,500- and 6,500-kilowatt wind powered generators discussed in the previous monograph.

The author commented on the March 1945 shutdown of the 1,000-kilowatt Grandpa's Knob unit, and he reiterated the desirability of larger units having capacities between 5,000 and 10,000 kilowatts for utility operation.

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AERODYNAMICS OF THE WIND TURBINE
January 1949

Percy H. Thomas

Federal Power Commission
Washington, D. C.

In this monograph, the author compares the detailed aerodynamic designs of the Grandpa's Knob unit, an English design, with his design. Mr. Thomas modified his 1946 design of a 7,500-kilowatt unit for this comparison by increasing the blades from two to three for each wheel, shortening each blade, and increasing the designed rotational speed.

Mr. Thomas again emphasized that, because of intangible characteristics and uncertainties of extrapolations, wind tunnel tests and full scale prototype construction were imperative to fix a design.

FITTING WIND POWER TO THE UTILITY NETWORK
February 1954

Percy H. Thomas

Federal Power Commission
Washington, D. C.

This is the last of the four monographs published by the Federal Power Commission relative to the studies made by Mr. Thomas in the 1944-1954 period regarding wind powered electric generation.

The author's prior works involved highly technical and specific design matters, particularly in the field of aerodynamics. This shorter work was largely general in nature, commenting on the utilization, or integration, of wind generated electric energy in an electric utility network. He discussed generally the possible benefits of firm and secondary power derived from wind powered generation when supported by large interconnected electric systems. By this time, steam-electric generating units having 250,000-kilowatt capacities were in operation, and the economic benefits of economy of scale of these units presented, at that time, a stiff challenge to competing electric generation sources. In this monograph, Mr. Thomas moved away from comparative cost based justification for wind powered generation in favor of more general statements; i.e., justification would be sufficient if steam generation costs were met. He also stated, regarding wind powered electric generation and to a degree at variance with earlier implications, that economies of scale were of questionable attainment, and he implied that units having 2,000- to 4,000-kilowatt capacities might yield maximum economic benefits.

In previous publications, Mr. Thomas had made some references to the use of wind mills to generate mechanical power, not necessarily associated with conversion to electric energy. In this work, he also commented on a wind-powered water pump and some general applications, including its use as the pumping source for hydroelectric pumped storage operations.