WIND AND TURBINE CHARACTERISTICS NEEDED FOR INTEGRATION OF WIND TURBINE ARRAYS INTO A UTILITY SYSTEM

Gerald L. Park
Division of Engineering Research
Michigan State University
East Lansing, Michigan 48824

ABSTRACT

Wind data and wind turbine generator (WTG) performance characteristics are often available in a form inconvenient for use by utility planners and engineers. The steps used by utility planners are summarized and the type of wind and WTG data needed for integration of WTG arrays suggested. These included long-term yearly velocity averages for preliminary site feasibility, hourly velocities on a "wind season" basis for more detailed economic analysis and for reliability studies, worst-case velocity profiles for gusts, and various minute-to-hourly velocity profiles for estimating the effect of longer-term wind fluctuations on utility operations.

Wind turbine data needed includes electrical properties of the generator, startup and shutdown characteristics, protection characteristics, pitch control response and control strategy, and electro-mechanical model for stability analysis.

INTRODUCTION

Although a large number of reports and papers have been published on the integration of wind turbine generators (WTG) into electric utility systems [1,2,3,4] utility planners and engineers still have some difficulty assembling wind and WTG data in a form applicable to their planning and analysis methods. The situation is improving and it is the purpose of this brief paper to summarize utility needs so that wind data and WTG performance characteristics can be presented to facilitate utility application of WTG's in a manner consistent with the evaluation of conventional and other alternative sources of electric power.

UTILITY EVALUATION PROCEDURES

It would be presumptuous of any author to claim to describe/generation evaluation procedures in a complete utility generic way. Nevertheless, many observers could agree that the following steps are encountered by most utilities who become involved in wind integration.

- Sensitivity of utility management, public or regulatory agencies of need to evaluate wind as an alternative energy resource.

- Determination whether the technology and projected production of WTG's are adequately defined and characterized for preliminary evaluation. At this point one can differentiate between smaller customer owned WTG's (under 100 kW) and larger utility-owned machines (more than 100 kW). The smaller customer-owned machines are primarily a problem for distribution personnel and are addressed elsewhere [5,6]. The paper concentrates on larger utility-owned WTG's in arrays.

- Determine rough WTG size and siting parameters. Are feasible sites available in the service territory? What wind data is available for these sites?

- Estimate average annual energy (in kWh) available from several projected commercial WTG's at potential sites. Determine penetration levels (wind capacity as percentage of total capacity). Calculate rough economic cost of energy on fuel displacement basis.

- Use hourly wind data for potential sites and a simplified production costing program to determine generation mix with wind and an improved estimate of generation costs for the wind seasons present at the various potential sites.

- Estimate collection costs for interconnecting and controlling the array, transmission costs to the existing network for reasonable voltage variations and current flows under fault conditions, and protection (relaying) configuration and costs. Load flow, stability, and short circuit programs likely used in this step where effects of gusts, short circuits, and synchronizing are analyzed.

- Calculate or simulate the operation of arrays under various wind fluctuation conditions to determine effect of WTG's on area control error, frequency, and thus dispatch. Investigation of protection of the WTG's themselves, noise, and extreme weather conditions may be done at this point.

WIND DATA NEEDED

The steps in the previous section require various types of information about the wind regime in the potential array site areas.

For Rough Economic Estimate

Yearly average or distribution at potential sites. If the yearly average is not an adequate estimator for certain WTG's, the manufacturer should specify what data is needed for an estimate of annual energy.

For Simplified Production Cost

Either data or a probabilistic model to generate hourly wind velocity samples characteristic of the potential sites to yield monthly or seasonal wind velocity behavior typical of the site. Either minimum WTG spacing or corrections for WTG interactions which reduce energy production should be specified. The production cost program will indicate reliability of power production as well as cost along with an appropriate generation mix for the array and site configuration chosen.

For Collection, Protection and Stability

Here the analyst needs peak expected wind velocity, time profile of gusts, and interarray wind behavior.

For Array Operation

Trends and oscillations in wind velocity over the array on a 20 to 40 minute time interval are needed [7]. This is to determine area control error, frequency of system, and demands on conventional regulating units. Generator unit commitment and system dispatch usually requires adjustment if wind penetration is over several percent.

The key point is that the utility system is not affected directly by the wind velocity (unless it is of destructive force) but by the electrical behavior of the WTG array. The utility will be concerned about excessive array power output fluctuations and above excessive var and voltage fluctuations.

This list of needs suggest the following wind data set as desirable and useful:

- Yearly long-term average velocities or distributions for rough estimation of yearly array energy output.
- Hourly wind velocity model across a potential site for refined economic feasibility and reliability estimates. This data should indicate the range expected over high and low wind years.
- Expected worst-case (extreme) velocity profiles for gusts, as caused by storms and fast frontal passages over a time frame of seconds to a few minutes. These profiles should included space variables to describe velocity over potential array sites. Note that wind direction primarily affects array configuration and may have operating affects if wind direction changes rapidly.
- Wind velocity profiles from a few minutes to an hour to represent effects of array power output on the utility system operating variables.

WTG SPECIFICATIONS NEEDED

Since the WTG design and controls, as well as array configuration, determine the transfer relation between wind velocity and power output, WTG specifications should include:

- Electrical parameters specifying characteristics of the generator for short circuits, load flow and stability studies.
- Startup and shutdown characteristics as a function of present and past wind velocity for operating effects determination and for resynchronization studies.
- Protection characteristics of the WTG itself, eg: trip settings for overcurrent, phase angle, voltage and frequency relays.
- Characteristics of the blade pitch controller, especially at and below rated power.
- Electro-mechanical model for stability and synchronizing studies.

REFERENCES

[1] Park, G.L. et al., "Planning manual for utility application of WECS," Michigan State University Division of Engineering Research, East Lansing, MI, June, 1979. Available from NTIS as COO-4450-79/1.

[2] Marsh, W.D., requirements Assessment of wind Power plants in Electric Utility Systems, General Electric Company, Electric Utility Systems Engineering Department, ER-978-SY (RP740-1), January 1979. Available from EPRI Research Reports Center.

[3] Wind Energy Systems Application to Regional Utilities, JBr Scientific Corp. Final Report under contract Ex-76-c-01-2438, 1979.

[4] Lindley, C.A. and W.C. Melton, Electric Utility Application of Wind Energy Conversion Systems on the Island of Oaku, Aerospace Corporation, ATR-78(7598)-2. Feb 1979, Available from NTIS.

[5] Park, G.L. and O. Zastrow, Interconnection Issues Concerning Consumer-owned Wind Electric Generators. To be presented at 1981 IEEE T & D Conference, Minneapolis, Minn., Sept. 1981.

[6] Curtice, D. and J. Patton, "Operation of small wind turbines on a distribution system," Final report prepared by Systems Control, Inc. for Rocky Flats Systems Program under subcontract PF-94445L, March, 1981.

[7] Schlueter, R.A., G.L. Park, H. Modir, J. Dorsey, and M. Lotfalian, "Impact of storm fronts on Utilities with WECS Arrays." Final Report to U.S. Department of Energy Under Contract EG-77-S-4450, COO/4450-79/2, September, 1979.

QUESTIONS AND ANSWERS

G. L. Park

From: A. Swift, Jr.

Q: Do utilities prefer utility-owned or consumer-owned wind generators?

A: *That is a function of the utility and specifically apparently the size of the utility grid and the location of the proposed wind generator with respect to the utilities lines. Large utilities don't mind privately-owned wind generators, small ones are more inclined to object.*

From: G. G. Biro

Q: Do you have any difficulty getting wind turbine response times for various startup and shutdown conditions?

A: *No, for Boeing but it still took many hours to get it straight.*

Q: How do the WECS manufacturers supply the station energy need for operations, which is needed for evaluation of total net energy production?

A: *They state peak power consumption for auxiliaries.*