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RELIABILITY MODELING OF LARGE WIND FARMS AND ASSOCIATED ELECTRIC UTILITY INTERFACE SYSTEMS

Xifan Wang*
Non-Member
Department of Elec. Engin.
Xi'an Jiaotong University
China

Hui-Zhu Dai*
Non-Member
The Northeast Electric Power Institute
Jilin, Jilin
China

R. J. Thomas
Senior Member
School of Elec. Engin.
Cornell University
Ithaca, NY 14853

Abstract - This paper is concerned with modeling the reliability characteristics in both probability and frequency of large electric utility application wind turbine generators together with their associated utility interface equipment. A computationally efficient algorithm is developed and applied to a wind farm with a special AC/DC/AC interface currently under design. The effects of various wind turbine/interface system component forced outage rates on the expected annual energy output of the farm is examined.

I. INTRODUCTION

The capture of a significant amount of energy from the wind as a fuel-saving option is being considered by many U.S. utilities. The integration of large numbers of wind turbines of various size and manufacture will have a clear impact on the reliability performance of the aggregate system. The power output characteristics of any wind turbine generator (WTG) is quite different from that of any of the conventional generation units found in most utility systems. Wind generator output varies with the wind, minute-to-minute, daily, seasonally, and annually. Conventional reliability indicies such as forced outage rates (FOR) are affected by the wind characteristics since, for example, most utility application WTG's are removed from service whenever the wind velocity exceeds or falls below pre-determined values [1,2].

In order to effectively and fairly assess system reliability characteristics with wind turbines integrated into the system, it is desirable to create a reliability model for a wind farm that is compatible and consistent with conventional system margin table calculations. First attempts at this [3] do not generate such a model since frequency and duration indicies are not included.

Wind farms and their components will have a high initial failure rate because of the new and unconventional utility applied technology. Also, when we calculate the reliability indicies of a wind farm generation and interconnecting transmission equipment failure must be taken into account. A major difficulty in reliability analysis of a wind farm system is that each WTG will not have an independent capacity distribution because of the dependence of the individual turbine output on the same energy source, the wind [2]. The problem is exacerbated by the intended presence in many cases of several different types of WTG's within a single utility system and in some cases within a single farm. The analysis in [3] permits only one type of WTG per farm and several farms of the same type only if the wind correlation between farms is small. In this paper we derive a reliability model for systems with various intra-farm and/or intra-system wind turbine types possible. We apply the results to a special utility/wind farm/interface system presently being designed at Cornell [4].

*Currently Visiting Scientists with the School of Electrical Engineering, Cornell University, Ithaca, NY, 14853.

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In order to estimate the long term influence of wind farm output on power system reliability characteristics we form a wind power output table compatible with conventional system reliability margin tables [9,10].

In order to form this table we require wind velocity probability and frequency distribution function data. These data are used together with relevant wind farm input/output and reliability characteristics to determine expected farm output. In this paper P(x) is the usual notion of probability associated with random variable x (sometimes called the exact probability). If we have a particular value of random variable x in mind, say X, then two functions of variable X are of interest namely the cumulative probability

$$P^*(X) = \sum_{x \le X} P(x) = P(x \le X) \tag{1-1}$$

and the cumulative frequency

$$F^*(X) = \sum_{x \le X} f(x) = F(x \le X) \tag{1-2}$$

where incremental frequency f(x) is defined by

$$f(x) = P(x) \cdot (\lambda'_x - \lambda''_x) \tag{1-3}$$

and λ'_x and λ''_x are the up and down transition rates associated with random variable x, respectively. We note that in (1-3) $P(x)\lambda'_x$ is the frequency with which random variable x transfers to the up-state, that $P(x)\lambda''_x$ the frequency with which x transfers to the down-state, and that incremental frequency f(x) may be negative. The character of random variable x is thus described by a variable X which, for the purpose of tabulation, takes on discrete values X_i (i=0,1,...,m).

The process of developing an outage table requires combination of random events. In fact, once the models have been developed it is the efficient combination of events that is at the heart of the problem. Given n independent random events x^i, (i = 1, ..., n) to be combined into a single random event y the probability of y is

$$P(y) = \prod_{i=1}^{n} P(x^i) \tag{1-4}$$

and the incremental frequency of y is

$$f(y) = P(y) \sum_{i=1}^{n} (\lambda'_{xi} - \lambda''_{xi}) \tag{1-5}$$

Thus, the exact output power probability and incremental frequency of output power are or

$$f(y) = P(y) \sum_{i=1}^{n} \frac{f(x^i)}{p(x^i)} \qquad (1\text{-}6)$$

Using (1-1), (1-2) and (1-4) and (1-6) we may form the combined cumulative probability and frequency distributions

$$P^*(Y) = \sum_{y \leq Y} \prod_{i=1}^{n} P(x^i) \qquad (1\text{-}7)$$

and

$$F^*(y) = \sum_{y \leq Y} P(y) \sum_{i=1}^{n} \frac{f(x^i)}{P(x^i)} \qquad (1\text{-}8)$$

II. AN OUTPUT POWER DISTRIBUTION FOR A FARM OF IDENTICAL WIND TURBINE GENERATORS

In this section we model wind and WTG characteristics for single units and discuss aggregation methods for several identical units. In many cases the wind data has been distilled to a commonly accepted Weibull distribution description with the cumulative probability of hourly wind velocity given by

$$P_w(v_i) = P_w(v \leq v_i) = 1 - \exp\left[-(v_i/c)^K\right] \qquad (2\text{-}1)$$

where constants c and K characterize the distribution. Some researchers fit the data to a Rayleigh distribution which is a special case of (2-1). Unfortunately, the Weibull (or Rayleigh) distribution functions contain little information concerning the wind velocity cumulative frequency distribution function. If chronological wind velocity data are available, the distributions may be formed by using the algorithm for treating load models given in [5].

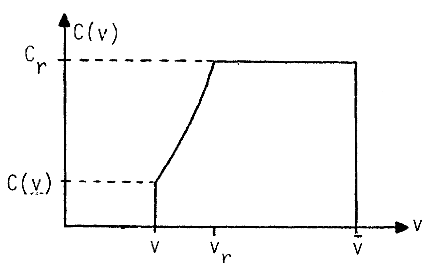

Figure 1. Typical WTG power output characteristics.

There are several functions used to approximate the wind generator output characteristics C(v) in the interval $\underline{V} \leq v \leq \bar{v}$ [7] where $\underline{v}$ and $\bar{v}$ are respectively the turbines' cut-in and cut-out wind speeds. The two that are most prevalent are linear and cubic representations. Thus we can usually describe C(V) as:

$$C(v) = \begin{cases} 0 & 0 \leq v < \underline{v},\ v \geq \bar{v} \\ av-b \text{ or } Av^3 & \underline{v} \leq v \leq v_r \\ C_r & v_r < v < \bar{v} \end{cases}$$

where C(v) is the output power of the wind generator as a function of wind velocity v, v_r is rated wind speed, and a, b, and A are constants. We note that when the wind velocity is less than cut-in velocity $\underline{v}$ or exceeds cut-out velocity $\bar{v}$ the WTG is shut down and its output power is zero. Using the transfer curve of figure 1 we can easily transfer the probability and frequency distribution of wind velocity to corresponding distributions of WTG output power. The cumulative probability distribution for the i^{th} WTG output power is given by

$$P_i^*(x) = \begin{cases} P_w^*(\underline{v}) + P_o & 0 \leq x \leq C(\underline{v}) \\ P_w^*(v) + P_o & C(\underline{v}) \leq x < C_r \\ 1 & x \geq C_r \end{cases} \qquad (2\text{-}2)$$

where $P_i^*(x)$ is the probability that the output power of the i^{th} WTG is less than or equal to x and

$$P_o = P_w(v \geq \bar{v}) = 1 - P_w^*(\bar{v}) \qquad (2\text{-}3)$$

and the cumulative power output frequency distribution is given by

$$F_i^*(x) = \begin{cases} F_w^*(\underline{v}) + F_o & 0 \leq x \leq C(\underline{v}) \\ F_w^*(v) + F_o & C(\underline{v}) \leq x \leq C_r \\ 0 & x \geq C_r \end{cases}$$

where $F_i^*(x)$ is the frequency at which the output power of the i^{th} WTG is less then or equal to x and

$$F_o = F_w(v \geq \bar{v}) = -F_w^*(\bar{v}) \qquad (2\text{-}4)$$

Now, consider a wind farm consisting of Ng identical WTG's each of which may fail. The probability that $k\,(0 \leq k \leq Ng)$ generators are available is given by

$$P_g(k) = \binom{Ng}{k} r^{(Ng-k)} (1-r)^k \qquad (2\text{-}5)$$

where r is the forced outage rate (FOR) for all generators. With the cumulative probability given by

$$P_g^*(k) = \sum_{k \geq I} P_g(I) \qquad (2\text{-}6)$$

the corresponding formula for cumulative frequency is given by (see [5] for a proof by induction)

$$F_g^*(k) = \frac{Pg(k)\,(Ng-k)}{t_r} \qquad (2\text{-}7)$$

where t_r is the repair time. The incremental frequency function is given by

$$f_g(k) = F_g^*(k) - F_g^*(k-1) \qquad (2\text{-}8)$$

The tableau of cumulative probability and frequency as a function of the number of generators available is the wind generator outage table. The random variables v and k, the wind velocity and the number of WTG's available respectively, are assumed to be independent, so that for each discrete level of wind velocity v_i the exact probability of k generators available is

$$P(v_i \cap k) = P_w(v_i) \cdot P_g(k) \qquad (2\text{-}9)$$

and the incremental frequency of the joint event is given by

$$f(v_i \cap k) = P_g(k) \cdot f_w(v_i) + f_g(k) \cdot P_w(v_i)$$

The output power for the farm in this case is

$$x_j = k \cdot C(v_i)$$

$$P(x_j) = \sum_{k\cdot C(v_i)=x_j} P_g(k)P_w(v_i)$$

$$= \sum_{i=o}^{\ell} P_g\left(\frac{x_j}{C(v_i)}\right) P_w(v_i) \qquad (2\text{-}10)$$

where ℓ is the number of discrete velocity data points and

$$f(x_j) = \sum_{k\cdot C(v_i)=x_j} [\, P_g(k)\cdot f_w(v_i)+f_g(k)\cdot P_w(v_i)\,]$$

$$= \sum_{i=o}^{\ell} [P_g\left(\frac{x_j}{C(v_i)}\right)\cdot f_w(v_i)+f_g\left(\frac{x_j}{C(v_i)}\right)\cdot P_w(v_i)] \qquad (2\text{-}11)$$

Therefore, the corresponding cumulative probability and frequency distributions are

$$P^*(x) = \sum_{x\geq x_j} P_g(x_j) = \sum_{i=o}^{\ell} P_g^*\left(\frac{x}{C(v_i)}\right)P_w(v_i)$$

$$= \sum_{i=o}^{\ell} P_g^*\left(\frac{x}{C(v_i)}\right)\cdot [P_w^*(v_i)-P_w^*(v_{i-1})] \qquad (2\text{-}12)$$

and

$$F^*(x) = \sum_{x\geq x_j} f(x_j)$$

$$= \sum_{i=o}^{\ell} [P_g^*\left(\frac{x}{C(v_i)}\right)f_w(v_i) + F_g^*\left(\frac{x}{C(v_i)}\right)P_w(v_i)] \qquad (2\text{-}13)$$

The following equivalent expressions are generally more convenient for practical calculations:

$$P^*(x) = \sum_{k=0}^{Ng} P_w^*(\bar{C}(\tfrac{x}{k}))\cdot P_g(k) \qquad (2\text{-}14)$$

or

$$P^*(x) = \sum_{k=0}^{Ng} P_w^*(\bar{C}(\tfrac{x}{k}))\cdot\ P_g^*(k)-P_g^*(k-1) \qquad (2\text{-}15)$$

and

$$F^*(x) = \sum_{k=0}^{Ng} P_w^*(\bar{C}(\tfrac{x}{k}))\cdot f_g(k)+F_w^*(\bar{C}(\tfrac{x}{k}))\cdot P_g(k) \qquad (2\text{-}16)$$

or

$$F^*(x) = \sum_{k=0}^{N_g}\{ P_w^*(\bar{C}(\tfrac{x}{k}))\,[F_g^*(k)-F_g^*(k-1)]$$

$$+ F_w^*(\bar{C}(\tfrac{x}{k}))\ \ [P_g^*(k)-P_g^*(k-1)]\} \qquad (2\text{-}17)$$

where

$\bar{C}(\frac{x}{k})$ is the functional inverse of $C(v)$, i.e.

$\bar{C}(C(v)) = v.$

An application of equations (2-15) to (2-17) to a wind farm consisting of ten identical Boeing MOD-2 wind turbines is considered in the following example. The MOD-2 power output data are C_r = 2.5 MW, $\underline{v}$ = 6.3 m/s, v_r = 12.3 m/sec, and $\bar{v}$ = 20.117 m/s at a hub height of 61 meters. The Weibull distribution parameters for the annual distribution of hourly wind velocities at the wind site and at 61 meters are c = 10 and K = 2.8. We assume that the cumulative frequency function is the same as the probability distribution with the exception that the cumulative frequency of rated wind power is zero. Of course, this assumption is not essential for the method. The power output characteristics of the MOD-2 are assumed given by

$$C(v) = \begin{cases} 0 & v<6.3\text{m/s}, v\geq 20.117\text{m/s} \\ (0.3833\ v-2.215)\text{MW} & 6.3\text{m/s}\leq v\leq 12.3\text{m/s} \\ 2.5\ \text{MW} & 12.3\text{m/s}<v<20.117\text{m/s} \end{cases} \qquad (2\text{-}18)$$

Figure 2 is a plot of the cumulative frequency and probability distributions versus wind farm output assuming a forced outage rate for each wind turbine of 0.1 and a repair time of seven days, and no interconnection equipment failure. The mean power output for each generator is 1.131MW and the mean power output for the farm is 11.311 MW. The effect of different FOR's on the mean power output of the wind farm is shown in Table 1.

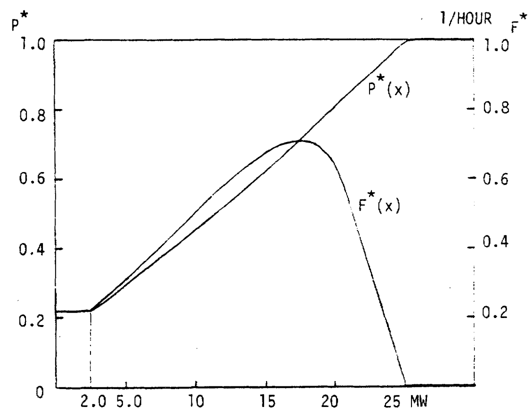

Figure 2. The cumulative probability and frequency distribution function for ten MOD-2 WTG's with FOR's of 0.1.

Table 1. Forced Outage Rate versus Average Power for a wind farm consisting of ten MOD-2 WTG's.

FOR	0.01	0.05	0.1	0.15	0.2
P_{mean}(MW)	12.442	11.939	11.311	10.683	10.054

III. POWER OUTPUT CHARACTERISTICS OF WIND FARMS CONTAINING WIND TURBINES OF DIFFERENT TYPE

Recent studies concerning large wind farms have shown that individual WTG average power output and farm average power output tend to be identical however, the associated distributions are different [6]. The following model allows the power output distribution for a large wind farm to be estimated from individual wind site data. The mean wind speed and standard deviation at hub height and at a representative site are denoted $\bar{v}_S$ and σ_S. The farm is assumed to consist of n sites having average wind velocity spatial cross correlation $\bar{\rho}$. The mean hub height wind velocity for the farm is $\bar{v}_F = \bar{v}_S$ with standard deviation

$$\sigma_F = \sigma_S \left[\frac{1}{n} + \frac{(n-1)}{n}\bar{\rho}\right]^{1/2} \tag{3-1}$$

The Weibull distribution parameters are estimated by

$$K = K_S\left(\frac{\sigma_F}{\sigma_S}\right)^{-1.086} \tag{3-2}$$

and

$$C = \bar{V}_F / \Gamma\,(1 + 1/K) \tag{3-3}$$

where Γ is the usual gamma function and K_S is the shape factor of the Weibull distribution at the representative site.

Now, suppose there are M wind generator types contained within the farm with type J composed of N_J identical machines. Suppose further there are ℓ wind velocity states v_i, $i=1, \ldots, \ell$. Although we assume failure events for different WTG types are independent their power output characteristics are not independent due to the correlation in wind velocity. If there is a basic random event E_B for which the number of generators of type J that are available is K_j and the wind velocity is v_i, then the random variable associated with power output for this event is

$$x = C(E_B) = \sum_{j=1}^{M} C_j(v_i)\cdot K_j \tag{3-4}$$

Because generator failure events and wind velocity are independent the exact probability and incremental frequency of this event are found to be

$$P(E_B) = P_w(v_i)\cdot\prod_{j=1}^{M} P_J(K_j) \tag{3-5}$$

$$f(E_B) = P(E_B)\cdot\left[\frac{f_w(v_i)}{P_w(v_i)} + \sum_{j=1}^{M}\frac{f_j(K_j)}{P_j(K_j)}\right] \tag{3-6}$$

where $P_w(v_i)$ and $f_w(v_i)$ are the exact probability and incremental frequency associated with wind level v_i and $P_j(K_j)$ and $f_j(K_j)$ are the exact probability and incremental frequency of K_j generators available in group type J.

All basic events being mutually exclusive, we may form the power output exact probability P(x) and incremental frequency f(x) for the farm according to

$$P(x) = \sum_{M}\,[P(E_B)\,|\,C(E_B) = x] \tag{3-7}$$

$$= \sum_{i=0}^{\ell}\,[P_w(v_i)\prod_{j=1}^{M} P_j(K_j)\,|\,\sum_{j=1}^{M} C_j(v_i)\cdot k_j = x] \tag{3-8}$$

and

$$f(x) = \Sigma\,[f(E_B)\,|\,C(E_B) = x]$$

$$= \sum_{i=0}^{\ell}\{P(E_B)\left[\frac{f_w(v_i)}{P_w(v_i)} + \Sigma\frac{f_j(K_j)}{P_j(K_j)}\right]\;\sum_{j=1} C_j(v_i)\cdot K_j = x\} \tag{3-9}$$

The number of basic events or number of calculations is $N_E = (\prod_{j=1}^{M} N_j)\cdot\ell$. For example, if we have a wind farm of one-hundred WTG's, consisting of ten types of ten each and ten discrete levels of wind velocity the number of calculations required is 10^{11}. A computationally efficient recursive algorithm has been developed for calculating the farm power output distribution which takes advantage of the fact that under certain wind conditions the output power for every WTG type is conditionally independent. Given wind velocity v_i the recursive combination procedure is as follows:

1. From the outage table of generators of type 1, form the output power exact probability and incremental frequency:

$$P_1(x|v_i) = P_1(K_1) \tag{3-10}$$

$$f_1(x|v_i) = f_1(K_1),\quad K_1 = 1,2,\ldots,N1 \tag{3-11}$$

where $P_1(K_1)$ and $f_1(K_1)$ are the generator outage table entries, and $x = C_1(v_i)$.

2. Form $P_j(x|v_i)$ and $f_j(x|v_i)$ from $P_{(j-1)}(x|v_i)$ and $f_{(j-1)}(x|v_i)$ recursively as follows:

$$P_j(x|v_i) = \sum_{k_j=1}^{Nj}[P_{(j-1)}(x - C(v_i)\cdot k_j)\cdot P_j(K_j)] \tag{3-12}$$

$$f_j(x|v_i) = \sum_{k_j=1}^{Nj}[P_{(j-1)}(x - C(v_i)\cdot K_j)\cdot f_j(K_j) + P_j(K_j)\cdot f_{(j-1)}(x - C(v_i)\cdot K_j)],\; j = 2,\ldots,M \tag{3-13}$$

3. $P_M(x|v_i)$ and $f_M(x|v_i)$ are the exact conditional probability and conditional incremental frequency distributions of the wind farm output power under wind velocity v_i. The wind distributions are assumed to be independent of failure events producing farm power output exact probability and frequency distributions for wind speed v_i given by

$$P^i(x) = P_M(x|v_i)\cdot P_w(v_i) \tag{3-14}$$

and

$$f^i(x) = P_M(x|v_i)\cdot f_w(v_i) + P_w(v_i)\cdot f_M(x|v_i) \tag{3-15}$$

4. Repeat 1-3 for each wind level and sum according to

$$P(x) = \sum_{i=o} P^{i}(x) \qquad (3\text{-}16)$$

and

$$f(x) = \sum_{i=o} f^{i}(x) \qquad (3\text{-}17)$$

5. Compute the distribution functions for the farm

$$P^{*}(x) = \sum_{x \geq y} P(x) \qquad (3\text{-}18)$$

$$F^{*}(x) = \sum_{x \geq y} f(x) \qquad (3\text{-}19)$$

The algorithm described in steps 1-5 is far more computationally efficient than calculations by equations (2-14) and (2-16). If generators of different types have approximately the same output capacity then the number of calculations using (3-12) and (3-13) is

$$N_{E}' = \sum_{j=1}^{M} N_j \left(\sum_{k=1}^{j-1} N_k \right) \cdot$$

which for our previous example is 45×10^3 as opposed to the considerably larger value of 10^{11}.

IV. CONSIDERATION OF INTERFACE EQUIPMENT FAILURE

Large wind farms consisting of large megawatt sized WTG's will undoubtly require utility interface equipment consisting of transformers, transmission lines, protection and control equipment, and farm monitoring and management devices. A typical arrangement might be the sectionalized T-bus shown in Figure 3.

Preferred arrangements are currently under consideration by several researchers however, conventional utility protection practices would probably dictate some form of the sectionalized T-Bus for constant speed wind machines. The tradeoffs in the interface are as usual, reliability versus economics. For a variety of technical and economic reasons [4] an AC/DC/AC interface which takes into account problems of fault protection, control, and stability and can accomodate variable speed wind turbines as well as fixed speed machines is being designed at Cornell University. The specific interface is as shown in Figure 4.

Obviously the interface reliability characteristics of the configurations presented in Figures 3 and 4 are quite different. When we seek to quantify the economic benefits of wind power it is clearly desirable to account for interface system failure otherwise, wind farm output power characteristics will be determined only by wind velocity distributions and wind generator outage tables. Although the techniques developed in this paper are applicable to either configuration, we examine the effects of interface FOR's on the interconnected system reliability for the AC/DC/AC configuration since we feel that this configuration offers the greatest potential for non-disruptive penetration of large blocks of intermitten energy sources into utility systems.

In discussing the configuration of Figure 4 we use the notion of series and parallel connections that were used in [5]. That is, two elements are said to combine in parallel when the capacity of the combination is equal to the sum of the capacities of the individual elements and two elements combine in series when the capacity of the combination is the lesser of the absolute values of the capacities of the individual elements with the appropriate sign.

The outage table for transmission elements in terms of their forced outage rates r and repair times t_r is shown in Table 2.

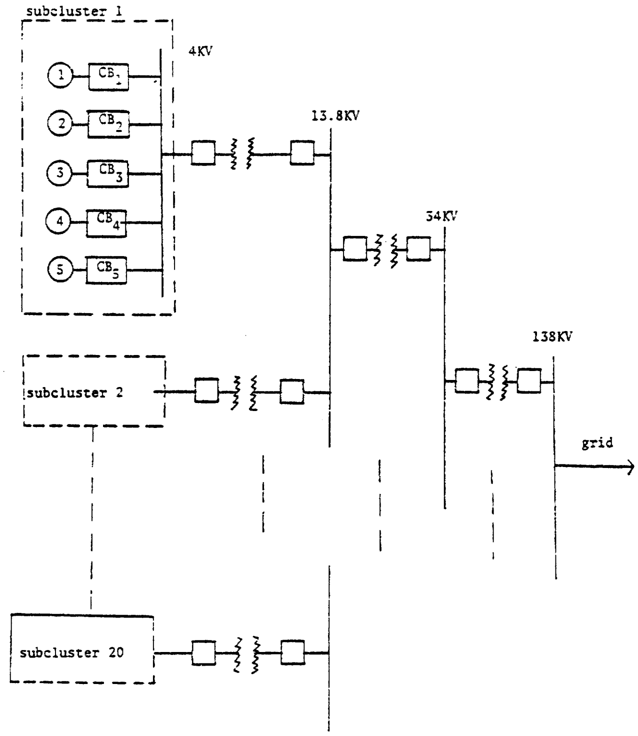

Figure 3. A sectionalized T-bus interface configuration.

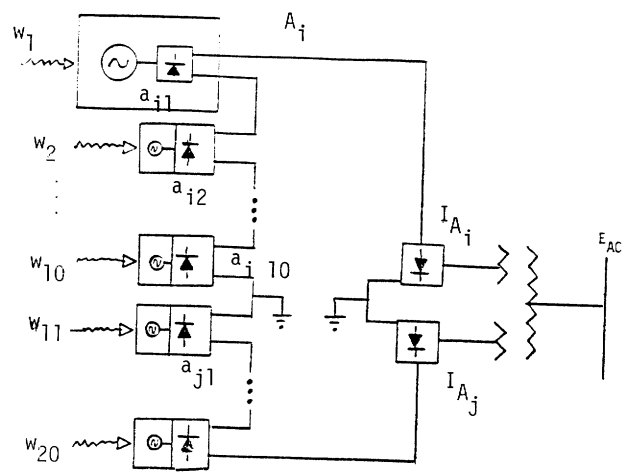

Figure 4. An AC/DC/AC utility interface for large wind turbines.

Table 2. The outage table for transmission elements

Operating capacity	Outage capacity	P^*	F^*
K	0	1	0
0	K	r	r/t_r

In the system of Figure 4, every WTG in any group A_i combines in series with a rectifier to form group element a_{ij}. A group may consist of, say, ten group elements and a one-hundred WTG farm may consist of ten groups or five group pairs. Figure 4 shows a single group pair. As part of the farm protection scheme any group element may be short-circuited at its output and thus removed from service while the remaining group elements continue to function. The group elements combine in series with the DC transmission lines and the inverter I_{Ai}. On this basis, we can recursively and systematically combine system elements and produce an outage table for each group. By parallel combination of outage tables for each group pair and subsequent series connection with transformers T_P we obtain the outage table for the entire WTG/interface system.

An outage table can be formed for every system element if we know its forced outage rate r and repair time t_r. When two system elements a and b are connected in parallel, the outage table of the resultant element c is given by [5]

$$P_c^*(k) = \sum_j P_a^*(k-j)\cdot[P_b^*(j)-P_b^*(j-1)] \qquad (4\text{-}1)$$

$$F_c^*(k) = \sum_j \{ F_a^*(k-j)\cdot [P_b^*(j)-P_b^*(j-1)] + P_a^*(k-j)\cdot[F_b^*(j)-F_b^*(j-1)] \} \qquad (4\text{-}2)$$

The corresponding formulae for series connection of elements a and b are [5]

$$P_c^*(k) = P_a^*(k) + P_B^*(k) - P_a^*(k)\cdot P_b^*(k) \qquad (4\text{-}3)$$

$$F_c^*(k) = F_a^*(k)\cdot[1-P_b^*(k)] + F_b^*(k)\cdot[1-P_a^*(k)] \qquad (4\text{-}4)$$

Although (4-1) through (4-4) can be used throughout, if the WTG's in Figure 4 are identical we would use (2-12) and (2-13) instead of (4-1) and (4-2) to compute the parallel group element connection table.

The impact of different forced outage rates on the interface of Figure 4 are shown in Table 3. It should be noted that the interface configuration presented here is of simple series/parallel structure and contains no loops. If a more complex interconnecting structure containing loops is to be considered, the methods of [12] can be used.

In this study the forced outage rates r_g of twenty MOD-2 WTG's was varied from 0.025 to 0.2 [9] and the forced outage rates of the DC stations r_{DS} (rectifier or inverter) was varied from 0.001 to 0.05 [11]. The forced outage rates of the DC transmission lines and the transformers were held constant at 0.001. The table entries are expected energy from the twenty 2.5 MW WTG's for one year.

Table 3. The influence of various wind generator/DC station FOR's.

r_{ds} \ r_g	0.025	0.05	0.1	0.2
0.001	202.1	194.8	170.2	111.3
0.005	200.1	192.3	167.0	109.3
0.01	198.2	189.2	163.1	106.8
0.02	192.5	182.5	155.2	102.2
0.05	172.9	160.4	132.6	90.2

V. CONCLUSION

In this paper we develop a reliability model together with a computationally efficient algorithm which takes account of the utility interface system. The wind farm output power characteristics include the frequency distribution function which is compatible with conventional margin table calculations.

VI. ACKNOWLEDGEMENT

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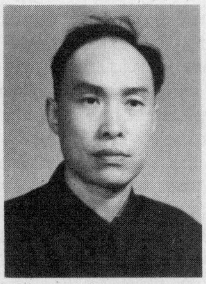

Xifan Wang was born in Hebei, China, in May, 1936. He graduated from Xian Jiaotong University in 1957. He has since been with the Electrical Engineering Department of the University, and now is an Associate Professor of Electrical Power System Analysis.

Since 1972 he has been conducting research on Computer methods in electric power systems. He is the chief author of the book "Computer Methods in Electric Power Systems" (Bejing Electric Power Press, 1978).

Mr. Wang is a member of the Electrical Engineering Society of China.

Huizhu Dai was born in Jiangxi, China, in January 1939. She graduated from Qinghua University in 1963. She has since been with the Electrical Engineering Department of The Northeast Electric-Power Institute and now is an Instructor of the Circuit Theory and Electro Magnetic Fields. Her research interests include computer methods and microcomputer applications in electric power systems.

Robert J. Thomas (S'-66, M-73, SM-82) was born in Detroit, Michigan in June, 1942. He received the B.S.E.E., M.S.E.E., and Ph.D. degrees from Wayne State University in 1968, 1969 and 1973 respectively. He has been with the School of Electrical Engineering at Cornell University in Ithaca, NY since 1973. He currently holds the rank of Associate Professor of Electrical Engineering. His research interests include analysis and control of large-scale electric power systems.

Dr. Thomas is a member of the IEEE Power Engineering Society and Automatic Control Society, Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.