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간략화한 다개상태 모델을 갖는 풍력발전계통을 고려한 전력계통의 신뢰도평가에 관한 기초연구

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A Study on the Probabilistic Reliability Evaluation of Power System Considering Wind Turbine Generators with A simplified Multi-state Model

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Abstract - Renewable energy resources such as wind, wave, solar, micro hydro, tidal and biomass etc are becoming important stage by stage, considering the effect of environment. Wind energy is one of the most successful sources of renewable energy for the production of electrical energy. What's more, due to wind speed random variation the wind turbine generators can not make two-state model as conventional generators. The method of obtaining reliability evaluation indices of wind turbine generators is different from the conventional generators. This paper presents a study on the reliability evaluation of power system considering wind turbine generators with a simplified multi-state model

1. Introduction

The utilization of renewable resources for electric power supply has received considerable attention in recent years[1]-[3]. This is due to the fact that these non-conventional energy units are environmentally friendly. And it has been proved that wind energy is the fast growing and most successful energy source of all available sources of renewable energy with high capacities, and generation costs of WTG(wind turbine generator) are becoming competitive comparing with the conventional energy source. However, WTG can not make two-state model as conventional generators, but should be presented as multi-state model[5] for reliability evaluation. In this paper, the wind speed model and power output model of WTG are combined to obtain this power multi-state model[2]. Convolution integral in ELDC(effective load duration curve) is used to calculate the multi-state model. The multi-state model is simplified by rounding method[6]. This paper introduces a study for reliability evaluation of a Jeju size similar system considering WTG with a simplified power multi-state model.

2. Power Output Model of WTG

A WTG is operated by extracting kinetic energy from the wind passing through its rotor[1]. The power output model of WTG can describe the variance of wind speed with the power output. Thus, a corresponding output power can clearly be found considering of any wind speed [1]~[4]. The following Eq.(1) [2] is the mathematical expression for the power output. The power generated Pi(i=1,⋯,Nb) corresponding to a given speed SWbi (i=1,⋯,Nb)can therefore be obtained.

$$\begin{aligned} Pi&=0,\ 0\le SWbi<Vci \\ &=PR(A+BxSWbi+CxSWbi2\ ),\ Vci\le SWbi<VR \\ &=PR,\ VR\le SWbi\le Vco \\ &=0,\ Vco< SWbi \end{aligned} \qquad (1)$$

Where,
Vci: The cut-in speed [m/sec]
VR: The rated speed [m/sec]
Vco: The cut-out speed [m/sec]
PR: The rated power [MW]
A, B, and C in Eq.(1) are formulated in [3].

3. Wind Speed Model

For the nature of wind, the wind speeds vary in time and space. Wind speed model[2] is created by Eq.(2) and Eq.(3). The probability distributions are divided in terms of the annual mean wind speed value μ and the standard deviation σ. The distribution considers wind speed up to 10σ including extreme values despite their low probability of occurrences. The distribution is divided into Nb number of interval steps, and each step has a length of 10σ/Nb, the midpoint value of step i is SWbi (speed), and one of the steps has a midpoint value of μ. The step value SWbi and the probability of each step Pbi are expressed by the following equation respectively.

$$\begin{aligned} SW_{bi}&=\mu+(10\sigma/N_b)x(i-0.5xN_b)\ \text{for even}\ N_b, \\ &=\mu+(10\sigma/N_b)x(i-0.5x(N_b+1))\ \text{for odd}\ N_b \end{aligned} \qquad (2)$$

$$P_{bi}=N_{bi}/(8760xN_y) \qquad (3)$$

The negative wind speed values are ignored, because the negative values in reliability assessment of WTG are not useful.

4. A Simplified WTG Power Multi-state Model

In the accurate system, due to the variance nature of wind, wind speed can not keep specified stable levels. The multi-state model[2]-[6] is used to evaluate reliability of WTG. In this paper, a WTG power output model made a relationship with the wind speed model which was showed in Fig.1 to obtain a WTG power multi-state model.

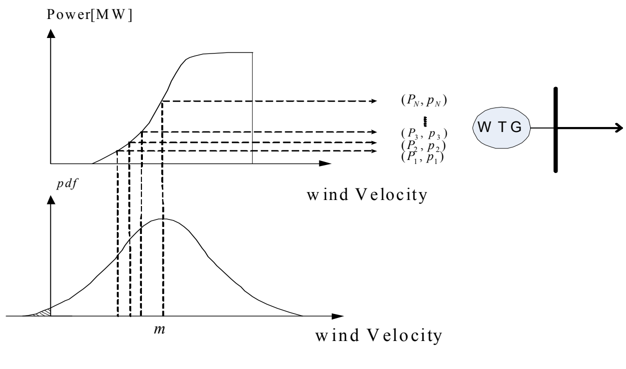

Fig.1 The relation between wind speed model and WTG power output model

The multi-state model is created. But the interval of each step of the multi-state model must have the same size by using convolution integral, the steps become much larger and it is hard to calculate the indices of reliability. Thus the multi-state model is simplified by rounding method to obtain a specified mode which people want with reasonable accuracy. The rounding method is presented in Fig.2 and Eq.(4), (5) clearly.

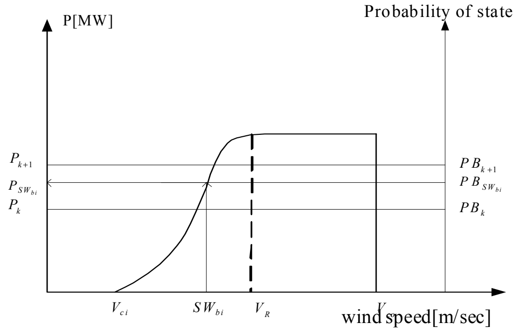

Fig.2 Rounding method

$$PB_k = \left(\frac{P_{k+1} - P_{SW_{bi}}}{\Delta P}\right) \times PB_{SW_{bi}} \qquad (4)$$

$$PB_{k+1} = \left(\frac{P_{SW_{bi}} - P_k}{\Delta P}\right) \times PB_{SW_{bi}} \qquad (5)$$

Where,
△P=Pk+1-Pk [MW]
k: number of state

This multi-state model can present the corresponding probability to any WTG power output. A flow chart of WTG considering power system reliability evaluation is expressed in [6].

5. Case Study

In this paper, the same indices system is used as like as reference[6]. Total capacity and peak load of the model system is 945MW and 681MW. The multi-state model which combines the two models that proposed in Ch.2 and Ch.3 is created and simplified by using rounding method. The OCPDFs(outage capacity probability distribution function) come from three wind farms, JCN, SSN and HWN are presented in Fig.3, Fig4 and Fig5, respectively.

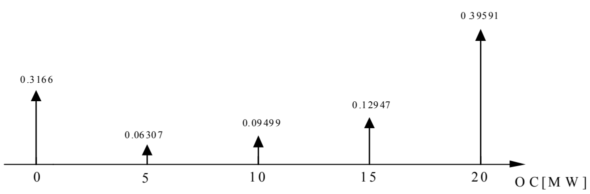

Fig.3 OCPDF of JCN wind farm

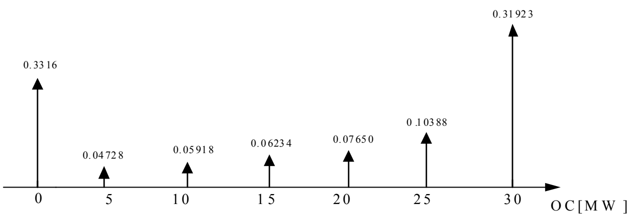

Fig.4 OCPDF of JCN wind farm

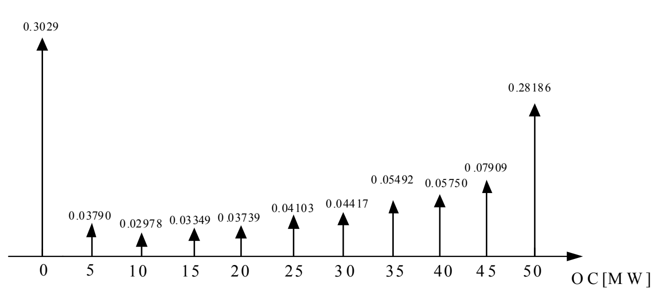

Fig.5 OCPDF of JCN wind farm

The indices of this system are introduced in Table 1.

Table 1 Reliability indices of model system

	With WTG	Without WTG
LOLE[hours/year]	0.81	1.63
EENS[MWh/year]	33.66	84.51
EIR	0.99999	0.99997

Because system reliability is very sensitive to change in the peak load, the LOLE are compared in Fig.5

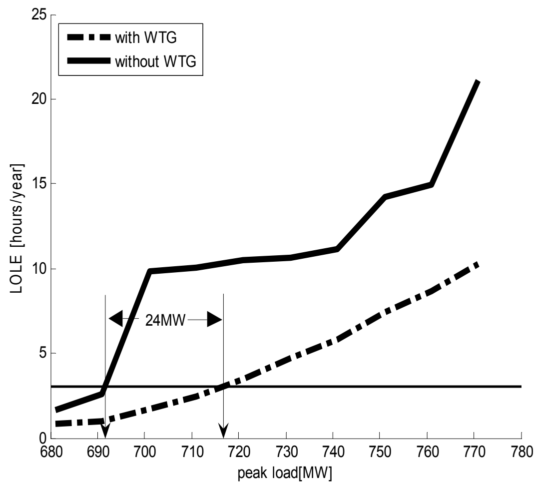

Fig.5 LOLE for different peak load levels

The load power difference between with WTG and without WTG at the assumed LOLE*=3[hour/year] is about 24MW. The actual capacity of WTG is about 24MW in view point of the system reliability. Therefore, the capacity credit of the WTG is about 24%.

6. Conclusion

This paper presents a study on the reliability evaluation of power system considered WTG with a simplified multi-state model. Wind speed model and WTG output model are combined to obtain WTG power multi-state model. This multi-state model is useful for the reliability evaluation of WTG. This model can express variance of wind more accurately than two-state model. Due to the effect of wind speed variance for reliability evaluation of power system, wind farms should be located in the place of which there is a perennial big wind or being far from the electrical generation stations.

[References]

1 Nick Jenkins, Ron Allan, Peter Crossley, David Kirschen and Goran Strbac: EMBEDDED GENERATION, 2000, PP. 31-38
2 Rajesh Karki, Po Hu, and Roy Billinton: A Simplified Wind Power Generation Model for Reliability Evaluation, IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 21, NO.2, JUNE 2006
3 Singh and Lago-Gonzalez: Reliability Modeling of Generation Systems Including Unconventional Energy Sources, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-104, No.5, May 1985
4 Billinton, R., Gan, L.: Wind Power Modeling and Application in Generating Adequacy Assessment, 14th Power Systems Computation Conference, Sevilla, Spain, June 24-28, 2000.
5 M. R. Bhuiyan, R. N. Allan: Modeling multistate problems in sequential simulation of power system reliability studies, IEE Proc.-Gener. Transm. Dsitrib., Vol. 142, No. 4, July 1995
6 Liang Wu, Jeongje Park, Jaeseok Choi, A Basic Study on the Probabilistic Reliability Evaluation of Power System considering WTG, KIEE May 2008, pp.149-152