태양광발전원을 고려한 전력계통의 신뢰도평가에 관한 기초연구

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A Basic Study on the Probabilistic Reliability Evaluation of Power System Considering Solar/Photovoltaic Cell Generator

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Abstract - Renewable energy resources such as wind, wave, solar, micro hydro, tidal and biomass etc. are becoming importance stage by stage because of considering effect of the environment. Solar energy is one of the most successful sources of renewable energy for the production of electrical energy following wind energy. And, the solar/photovoltaic cell generators can not make two-state model as conventional generators, but should be modeled as multi-state model due to solar radiation random variation. The method of obtaining reliability evaluation index of solar cell generators is different from the conventional generators. This paper presents a basic study on reliability evaluation of power system considering solar cell generators with multi-states.

1. Introduction

The utilization of renewable resources has received considerable attention in recent years[1],[2]. This is due to the fact that these non-conventional energy units are environmentally friendly. And it has been proved that solar energy is the fast growing and most successful energy source of all available sources of renewable energy with high capacities following wind energy. Generation costs of Solar Cell Generator(SCG) or Photovoltaic Generator(PVG) will become competitive with the conventional energy source under environmental constraint in near future. However, the SCG should be presented as multi-state model as like as WTG[2]. Convolution integral in ELDC for reliability evaluation is presented to calculate the multi-state model. This paper presents a basic study for reliability evaluation of power system considering SCG with multi-state model. The solar radiation historical stochastic data from the specified locations in past years are used to make a probability distribution function of solar radiation and the reliability evaluation for a simple system is introduced in detail. Even if the case study is simple system, it will be useful for SCG considered reliability evaluation in future.

2. Power output model of SCG

The photovoltaic effect is the electrical potential developed between two dissimilar materials when their common junction is illuminated with radiation of photons. A solar cell generator in Fig.1 is operated by extracting photon energy from the solar radiation radiated on its photovoltaic semiconductor[1].

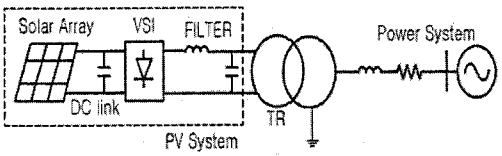

Fig.1 General structure of solar cell generator

As a power due to solar, it is very important to locate any electrical generators in areas of high mean annual solar radiation, and the available solar resource is an important factor in determining where SCG farms are sited. The area of high solar radiation usually is away from habitation and associated well developed electrical distribution network, leading to a requirement for careful consideration of the integration of SCG to relatively weak electrical distribution networks.

The SCG power output model presents the relationship between the power output and solar radiation. The model can describe the variance of SCG power output with solar radiation. Thus, a corresponding output power can clearly be found to any solar radiation[2]-[4].

The following Eq.(2) is the mathematical expression for the power curve. The power generated P_{pv} (G_{bi}) (i=1,..,Nb) corresponding to a given radiation G_{bi} (i=1,..,Nb) can, therefore, be obtained from Eq.(1)[2]. It is noted that PV cell temperature is neglected.

$$\begin{aligned} P_{pv}(G_{bi}) &= P_{sn}(G_{bi}^2/(G_{std}R_c)),\ 0 \le G_t < R_c \\ &= P_{sn}(G_{bi}/G_{std}),\ R_c < G_t \le G_{std} \\ &= P_{sn},\ G_t > G_{std} \end{aligned} \quad (1)$$

Where,

P_{pv} : Solar radiation-to-energy conversion function of the SCG[MW]

G_{bi} : Forecasted solar radiation at # i band [W/m^2]

G_{std} : Solar radiation in the standard environment [W/m^2]

R_c : A certain radiation point [W/m^2]

P_{sn} : Equivalent rated power output of the SCG [MW]

3. Solar Radiation Model

For the nature of solar radiation, the solar radiation varies in time and space, a few of solar radiation models have been developed and utilized[2],[3]. In this paper, a probabilistic distribution function (pdf) model of solar radiation is created by using actual data. A solar radiation

pdf model describes the solar radiation and the corresponding probability. Generally, solar radiation pdf model is near to binomial distribution rather than normal distribution. Because Zero radiation is occurred in night and remained half is distributed in day. The solar radiation pdf made from actual historical data at specified area/location is suggested in this paper.

4. Reliability Evaluation of SCG

4.1 SCG Multi-state Model

Because solar radiation does not maintain a specified stable level, this two-state model is not suitable for modeling SCGs for the same purpose. The multi-state model is found effective for reliability evaluation of SCGs. Because of the linear change of solar radiation, direct interchanges from state 1 to state 3 without processing state 2 can not occur. As a result, the multi-state model for the power output of a SCG takes the form of a chain.

In the paper, a multi-state model based on convolution integral is used to obtain to the reliability indices for SCG. A SCG power output model made a relationship with the solar radiation model to obtain a SCG power multi-state model, and the relationship is expressed in Fig.2. The two proposed models presented in Ch. 2 and Ch. 3 are combined to obtain indices of reliability assessment of power system considering SCG. The models can express the corresponding probability to any SCG power output, and it is very important to evaluate the SCG farm reliability.

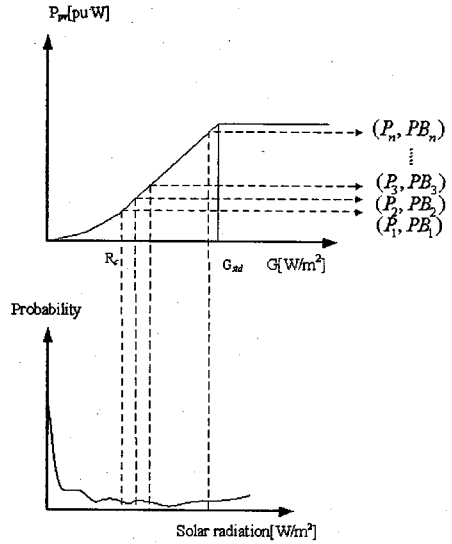

Fig. 2 The relation between solar radiation model and SCG power output model

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.[5]. The flow chart of the SCG considered power system reliability evaluation is expressed in Fig.3.

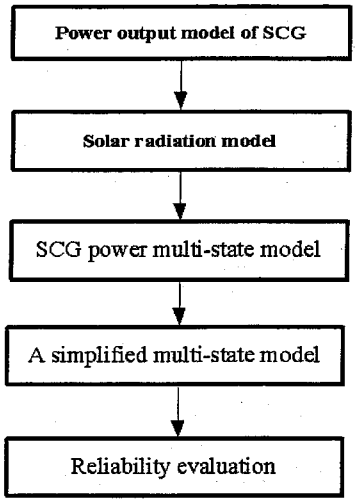

Fig.3 Flow chart of evaluating reliability of SCG system

5. Case Study

A simple test system as Fig.4 is used to prove usefulness of the proposed method. CG(conventional generator) and SCG are expressed as two state and five state model respectively. The generator capacities are 30MW and 10MW respectively and the peak load is 20MW. Load duration curve is specified in Fig.5.

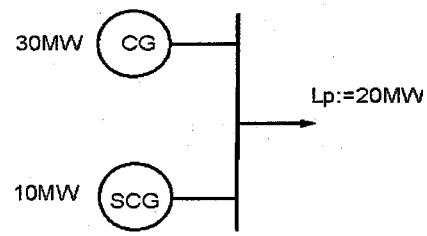

Fig.4 The simple test system

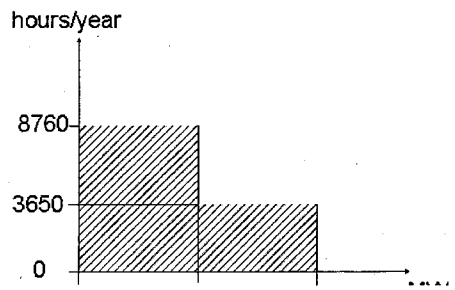

Fig.5 Load duration curve

The data of solar radiation on 2007 at Jinju is presented in the following Fig. 6.

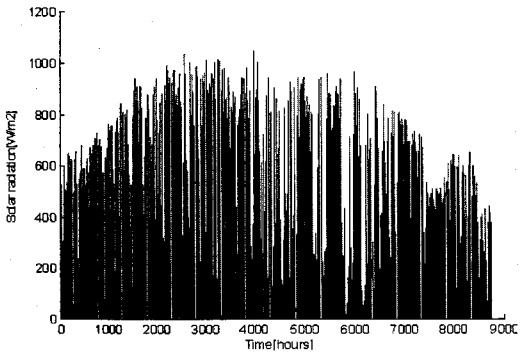

Fig. 6 The data of solar radiation on 2007

Fig. 7 shows probabilistic density function of an actual solar radiation data at Jinju in 2007.

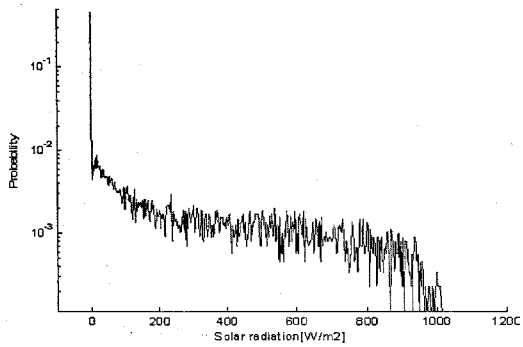

Fig. 7 A probabilistic density function of solar radiation at Jinju in 2007.

The assumed parameters of SCG power function for the simple system are shown in Table 1.

Table 1 The parameters of SCG

R_c	150W/m^2
G_{std}	1,000W/m^2
R_{sn}	10MW

The two proposed models are used to the SCG power and the corresponding probability to obtain the multi-state model. Because the interval of each step of the multi-state model must be the same by using convolution integral, so the steps become much large. Thus this multi-state model should be simplified by the rounding method. Finally, the five states outage capacity pdf modeled equivalent generator is obtained. The FOR (Forced Outage Rate) and OC (Outage Capacity) of the five states outage capacity pdf modeled equivalent generator are presented in the Table.2.

Table 2 Power multi-state model of SCG

OC[MW]	0	3	5	7	10
FOR	0.027584	0.078017	0.087627	0.1407	0.66607

The three cases coming from three kinds of systems in which just consider one 30MW conventional generator, one 10MW SCG and one 30MW conventional generator, and two conventional generators as like as Table 3 are studied.

Table 3 System data for three case studies

	G1(CG)		G2(SCG)	
	Capacity [MW]	FOR (states)	Capacity [MW]	FOR (states)
Case I	30	0.1(2)	-	-
Case II	30	0.1(2)	10	5 states
Case III	30	0,1(2)	10	0,1(2)

The results of three case studies are compared in Table 4. The convolution integral method for reliability evaluation of three case studied is used[5].

Table 4 Reliability indices of three case studies

	Case I	Case II	Case III
LOLE [hours/day]	2.4	2.36137	1.14
EENS [MWh/day]	34	29.96274	12.4

The results show that the SCG produced power can not keep on a specified level due to the nature and the contribution of SCG in view point of reliability is lower than it of the conventional generators that have the same capacities. And it also proves that the multi-state model can present the reliability of SCG farms more accurately than two-state model.

6. Conclusion

This paper presents a basic study on reliability evaluation of power system considering SCG. Solar radiation pdf model and SCG power output model are combined to obtain the outage capacity pdf with multi-state of SCG. This model can express solar radiation variance more accurately than two-state model. Due to the effect of the variance for reliability evaluation, SCG farms should be located in the place of which there is a perennial high quality solar radiation.

Acknowledgment

This work was supported by the Korea Science and Engine ering Foundation(KOSEF) grant funded by the Korea gover nment (MEST) (No. R01-2008-000-10567-0)

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