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The Reliability Evaluation Method of Generation System Based on the Importance Sampling Method and States Clustering

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Abstract

To improve the reliability evaluation efficiency of large scale power system, an efficient reliability evaluation method of generation system is proposed in this paper. It can improve the calculation efficiency both in the sampling method and states evaluation. Firstly, the importance sampling method is used to replace the conventional Monte Carlo sampling method, which can accelerate the convergence speed of iteration calculation. Secondly, the states clustering method is proposed to get several typical generating states to replace all sampling states, which can improve the calculation speed. Finally, the simulations based on the IEEE RTS-79 generating system and the actual power system are carried out, and the efficiency and accuracy of this evaluation method in this paper are verified.

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Keywords: Monte Carlo simulation; importance sampling method; reliability evaluation method; states clustering

1. Introduction

With the development of economy, the electric demands of the power system have increased and the power capacity of each generating unit has increased. What's more, the frequency to break down of the power units

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increases, which brings lots of economic lose to the society. Therefore, how to evaluate the operation reliability of the power system and find the risks to avoid the power cut accidents happen are extra important to the steady operation of the power system.

At present, the reliability evaluation methods of the generating system include two methods [1-2], which are analytic method and simulation method. The analytic method can calculate the precise value with the reliability evaluation model, and the recursive convolution method is now in wide application. However, it takes a lot of calculation time. And the Monte Carlo simulation method is applied the most in the simulation methods, the amount of calculation is related with the reliability level of the power system. In [3], the convergence characteristics of the sequential and non-sequential Monte Carlo method are discussed. The convergence characteristic of the sequential Monte Carlo method can be measured by the ratio of the variance and expectation of the reliability indexes, and it converge faster if the ratio is smaller. The convergence characteristics of the non-sequential Monte Carlo method can be evaluated by the probability of lose of load. With the same precision, the simulation time of the non-sequential method is shorter than the sequential method. Therefore, if there is no need to get the calculation frequency and duration time, the non-sequential method is more widely applied in the reliability evaluation of the power system.

The sampling efficiency of the Monte Carlo simulation method is strongly related with the probability of the events, which cause the convergence speed turns very slow in the power system with high reliability level. And it takes lots of simulation time in order to reach the calculation precision. Usually, the method to reduce the variance can accelerate the convergence speed [4-8]. And in [6], the modified variables controlling method is proposed, and it takes the risk level of the power system into consideration. In [7], the stratified uniform sampling method is proposed, and the breaks down states are sampled, which realize the reliability evaluation of the power system efficiently. In [8], the importance sampling method is proposed, and the variance of the reliability indexes decreases fast. The importance sampling method is the most efficiently method to accelerate the convergence speed at present [9].

However, the actual scale of the power system is large, and the numbers of the break down states are large. What's more, it takes lots of calculation time and resources to evaluate each break down state. Thus, it is especial important to accelerate the evaluation speed. In [10], the fault set classification method is proposed, the system fault states were divided into sorting fault subset and sampling fault subset and thus efficiency degradation was avoided. In [11-12], the fast sorting technique considering multi-states component models are proposed and based on the component outage state sequence and the neighboring system states, the technique can quickly select the required number of the system states in descending probability order. However, these techniques above are too complicated to realize in the actual power system reliability evaluation.

Above all, an efficient evaluation method of the generating system is proposed in this paper, which can improve the calculation efficiency both in the sampling method and states evaluation. The importance sampling method is used to accelerate the convergence speed of the iteration calculation. Secondly, the states clustering method is proposed to get several typical generating states to replace all sampling states, which can improve the calculation speed. Finally, based on the calculation of the IEEE RTS-79 power system and an actual power system, the efficiency and accuracy of this evaluation method are verified.

2. The non-sequential Monte Carlo sampling method and the importance sampling method

2.1. The principle of the non-sequential Monte Carlo simulation method

There are 3 steps in the reliability evaluation of the power system based on the Monte Carlo method, which are the states sampling, the states evaluation and the calculation of the reliability indexes.

The states sampling is the basic step of the non-sequential method, and the sampling times are the critical factor to decide the amount of calculation. If there are N_G components in the power system, and the random numbers which obey the uniform distribution can make up the random vector $\vec{x}$,

$$\vec{x} = \left(x_1, x_2, ..., x_i, ..., x_{N_G} \right) \tag{1}$$