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Composite system well-being evaluation based on non-sequential Monte Carlo simulation

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ABSTRACT

The reliability evaluation of composite power systems has historically been assessed using deterministic and probabilistic criteria and methods. The well-being approach was recently proposed in order to combine deterministic criteria with probabilistic methods and evaluates the system by healthy, marginal and risky states. This paper presents an efficient method for composite system well-being evaluation based on non-sequential Monte Carlo simulation. It is assumed that the system is coherent, and the frequency and duration indices are calculated by the conditional probability method. The system adequacy is evaluated by a non-linear power flow solved by the Newton–Raphson method and by an optimal power flow solved by the Interior Points method. Results are presented for the IEEE-RTS system with a constant load and with a variable load curve. It is demonstrated that the proposed method, as well as the assumed hypothesis, are valid and provide an efficient alternative for the well-being analysis of large scale power systems.

1. Introduction

The reliability evaluation of electric power systems may be accomplished in two domains, depending on the way in which the system performance evaluation is made: adequacy and security. The adequacy domain is related to the existence of enough resources in the system to satisfy the load demand and its operational requirements. This analysis is associated with static conditions that do not include the dynamics of the system and the answer to transitory disturbances. The analysis in the security domain is related to the ability of the system to compensate for disturbances, such as the loss of generation or transmission resources, and it can be of two types: transitory (dynamic) or steady state (static) [1].

The reliability evaluation can also be accomplished using deterministic or probabilistic methods. Deterministic methods are based on the evaluation of critical situations selected from the system operational history and from the experience of operators and planners. These methods have some attractive characteristics, such as direct implementation and the capacity to interpret the obtained results. However, the largest weakness of these methods is that they do not capture the stochastic nature of system operation [2]. Probabilistic methods are based on probabilistic and statistical theory and take into account the random behavior of the system, such as the load variation and the availability of generation and transmission equipments. These methods calculate reliability indices that are estimates of the risk associated with the system.

There is considerable interest in including security aspects in adequacy evaluations and in combining deterministic considerations with probabilistic indices. The necessity of reliability study, improving the understanding of the indices and facilitating the detection of alert states led to the proposal of the well-being evaluation.

Probabilistic methods were initially applied to composite system reliability evaluation in the 1960s [3], and afterwards, two evaluation methods were consolidated: the states enumeration method and Monte Carlo simulation (MCS). In sequential MCS, the states of the components are sequentially sampled simulating the chronology of the stochastic process of system operation, while in non-sequential MCS, the states of the system are obtained by randomly sampling the components states space with no relation to the chronology of the events [4–6]. Since then, different simulation forms have been proposed, such as the pseudo-sequential [7] and the pseudo-chronological [8] simulations. In the non-sequential MCS application, there are two highlighted methods for calculating the frequency and duration (F&D) indices: the conditional probability method [9,10], which uses the incremental transition rate concept to calculate the F&D indices without any additional

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