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Short-term reliability evaluation using control variable based dagger sampling method

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ABSTRACT

Most of the reliability theory and applications are in the planning domain. When reliability concepts are applied in operations or operational planning, computational burden of the algorithms becomes a bottleneck as the speed of execution of algorithms becomes critical. This paper presents an efficient control variable based dagger sampling technique for reducing the computational effort in Monte-Carlo reliability evaluation for composite systems. The proposed variance reduction method is unique in combining the offline calculations with online computation. A large number of system states are simulated to calculate their consequences offline and stored. Short-term reliability sampling uses the information on offline computed consequences to construct a variance reduction function. In short-term reliability evaluation, the outage probability of each component is much smaller compared to long-term system reliability calculations. Dagger sampling is used to reduce the computation time under this condition. Test results on RTS show the improvement and effectiveness in convergence speed.

1. Introduction

Large area blackouts have occurred in many countries in recent years. The severe social and economic impact of these blackouts has raised concerns on the security and reliability of modern power systems. It is critical to assess the reliability associated with a real-time operating state and to warn the system operator to take corrective action if the reliability is low.

Probabilistic power system reliability evaluation theory has been mainly applied to off-line evaluation in the planning of power systems. Most reliability evaluation techniques [1–8] have been developed based on the steady-state probability of component states and have been used for power system planning for many years. Reliability indices based on the steady-state probability of components represent long-term system reliability.

The planning reliability evaluation theory, which reflects long-term average reliability level of power systems in the typical operating mode, enumerates the states and analyzes the consequences based on the steady-state probability of the components. It evaluates the expected value of long-term reliability indices under a fixed operating mode, and generally ignores the impact of real-time operating conditions [9,10] on system reliability.

During the short-term framework of power system operation and dispatch, load level variation, integrated wind power fluctuation, component failure or scheduled maintenance has great impact on system security and stability. Reliability of system components may deteriorate under adverse weather conditions or other external environmental factors. Thus system will become less reliable, and conventional planning reliability methods cannot illustrate this change. Then power system cascading failure and blackout are usually short-term processes—before blackout, system will go through several system states. If we can evaluate short-term reliability level of each state, this information will be beneficial for blackout prediction and prevention. In China, Special Fund of the National Basic Program ("973 Program") has illustrated the importance of bulk interconnected power system operational reliability evaluation, and presented the conceptualization of system operational reliability of power systems under current operating condition and external environment [11].

As is the case in planning reliability evaluation, both Monte-Carlo method and analytical method could evaluate short-term reliability indices. Monte-Carlo method is more effective for composite reliability evaluation because of the complexity, but one possible limitation is the strong dependence of computational effort (proportional to the number of samplings) on the desired accuracy of the estimates. So it is necessary to develop a fast reliability evaluation algorithm to meet the needs of system operation and controls so as to assist system operators make timely decisions. Refs. [12,13] show that the control variable from generation

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