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Risk evaluation of security and stability control system for renewal energy cluster

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Abstract

With the aim to better direct the design, implementation, and decision making in the security and stability system of renewable resource cluster, the efficiency function and coefficients of Security and stability control system (SSCS) were defined. Combined with the distribution function of the primary energy of SSCS, the system risk was analyzed quantitatively based on the Monte Carlo simulation. The SSCS of one 330 kV substation was used to verify the proposed model and methods; it was utilized in the analysis of the influences of risk evaluation result and generation shedding strategies, renewable resources scale, stability control threshold value, reliability parameters, and economic parameters.

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Keywords: security and stability control system, risk evaluation, renewable resources, correlation

1. Introduction

In recent years, China's electric power industry has been developing rapidly, whereas, the power-grid construction falls behind the power source construction. Given that the security and stability control system (SSCS) can effectively improve the grid transfer capability, avoid stability problem, and prevent power system breakdown and large-area blackout, SSCS has been frequently applied to solve the power grid security and stability problems during the transitional period [1]. According to the preliminary statistics, the above 220 kV SSCS nationwide has reached higher than 2000.

With the adjustment and optimization of power source structure and further market-oriented reform of the power industry, an increasing number of renewable energy sources, such as PV and wind power, are

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access to power grid; resulting in more challenges in the electric power system dispatching [2]. Pursuing economic profit compels the power generation enterprises to hope that their renewable energy source system can transmit additional electric energy to the grid. To meet the stability demand of a power grid operation, grid companies request that the output of generators be limited within the stability limit because the mismatch between power source and grid construction speed, the grid's poor admitting ability, and primary energy may lead to further serious resource wastage. This situation highlights the ability of SSCS to ease the limited power supply, which could lead to improved digestion capacity of the renewable energy sources. Thus, SSCS plays a vital role in a security connection of renewable energy sources to the power grid, thereby focusing the attention toward the risk level of SSCS.

When the power system suffers from large disturbances, SSCS will act as a significant safeguard component. SSCS will ensure a secure and stable operation of the power system's second defense line through many control measures, such as generation shedding, load shedding, rapid reduction in output, urgent improvement or reduction of the direct-current power, and disconnection. The economic benefit evaluation model of SSCS has been established for grid companies [3]; however, the study neglected the risk of incorrect operations, energy fluctuation features of renewable energy power generation system, and evaluation of social benefit.

Reasonable reliability level is connected to the economy; thus, SSCS risk evaluation covers reliability and economy; the changing relation between reliability level and investment as well as operating cost can be analyzed. The normal operation of SSCS can assist in strengthening the transfer capability of power grid. However, incorrect operations will significantly affect the secure and stable operation of SSCS. Thus, in the quantitative analysis on SSCS risk, an evaluation should be in place; such evaluation should focus on the positive benefit in the improvement transfer capability. Furthermore, the negative benefit should be considered as well, such as the influence of incorrect operations and the cost of operation and maintenance. Accordingly, the annual average benefit function and coefficients for SSCS were defined; quantitative analysis on SSCS risk was achieved based on the Monte Carlo simulation. Furthermore, the model and methods proposed were verified using the SSCS at one 330 kV substation as example.

2. Risk indices

Evaluating failure consequence is a core function in risk evaluation studies; the consequence includes direct and indirect economic losses. The former is conventionally calculated according to the lost electricity amount, which is a simple process. However, when a large error is added, the process becomes complicated because it involves the operation of equipment, power quality, after sales service, safety, and environment. In some cases, the process includes the problems that affect the society, environment, economic order, such as the public's mental stress. Considering the limit from engineered cost and operability, outage loss evaluation conducted by the electric power sector is constantly concerned with the direct economic loss. However, with the development of the marketization of electric power, the increasing demand of users for service quality and the concern over environmental protection, as well the methods of evaluating and calculating indirect economic loss tend to be the agenda. For example, the evaluation of the consequence of the power failure in Northeast America and East Canada, as well as clean and renewable energy source utilization is largely based on its influence on society, environment, and economic order as well as mental pressure on the public rather than on the lost electricity quantity. In this paper, indirect economic loss is considered in the evaluation of SSCS.

Installing the SSCS in transition period promotes the transfer capability of the power grid. However, more operational risks are produced. Risk changes the following four aspects: economic benefit from improving the transfer capability, electricity quantity loss resulting from generator set shedding by false actions of SSCS, equipment burning and electricity amount loss from the failure to operate SSCS, and the construction investment and operation and maintenance cost of SSCS.

Before SSCS was put into production, the operation mode of power grid underwent strict inspection according to N-1 checkout, thereby controlling the transfer capability; After SSCS was put into