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A study of Electrical Security Risk Assessment System based on Electricity Regulation

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ABSTRACT

With the expansion of China's power system, there are more and more factors contributing to Large-area Power Outages. The snow disaster that hit Southern China in 2008 caused serious damages to the power systems, which made Chinese government realize that they cannot solely depend on power enterprises to effectively control the risk involved in power system. The Chinese government needs to collaborate with power enterprises in strengthening Electricity Regulation and taking countermeasures to reduce the risk of Large-area Power Outages. This paper first proposes an objective, practical and adaptive Electrical Security Risk Assessment System based on Electricity Regulation. The system consists of an assessment process with 278 indices, which are used to calculate the risk of Large-area Power Outages by the use of Analytic Hierarchy Process and the Delphi Method. Then, an example of Guangdong power system serves to illustrate the detailed implementation procedures of the proposed assessment system and the results show that Guangdong power system faces a moderate risk of Large-area Power Outages. Finally, some countermeasures are proposed to overcome the defects in the existing power system.

1. Introduction

In 2008, Southern China encountered a severe ice and snow storm lasting from January 10 to February 20. Transmission lines and power towers were covered with thick ice and had collapsed throughout large areas. According to official statistics (GPLBAERLC, 2008; SBSERC, 2008a, 2008b), by February 26th, the freezing weather had caused 7541 power transmission lines with a voltage of 10 kV and above to fail and had forced 859 substations providing 35 kV and above to stop working. The power loss totaled to 6.209 billion kWh, and the afflicted population reached as high as 261.82 million. What is worse, in many areas, the power equipment was so severely damaged that power supply was even cut down. Many provincial power grids fell apart for several days and some local areas even were in blackout for over 10 days. This situation seriously affected the normal production and life of the public. Many people lived through the Chinese Lunar New Year in total darkness in Guizhou and Hunan provinces (Hui et al., 2008). Learning a lesson from this serious disaster, the government of Guangdong province commissioned the State Electricity Regulatory Commission (SERC) to assess the risk associated with Guangdong power system and to develop countermeasures after the disaster.

SERC is a government agency in China, whose major responsibility is to strengthen the Electricity Regulation, perfect the Electricity Regulatory System (ERS) and guarantee the Electricity Safety. It is also its duty to formulate a contingency plan for handling grave power system accidents.

A big challenge facing SERC is to establish an Electrical Security Risk Assessment System (ESRAS), and to develop countermeasures against electrical catastrophes that originated from non-technical reasons, such as natural disaster and artificial damage.

Three types of methods are commonly used in current studies of electrical security assessment, which are Certainty Assessment, Probability Assessment and Risk Assessment. Certainty Assessment only concerns the most serious and credible accidents, so its operating point is too conservative. Probabilistic Assessment, though taking into account the probability of the accident, fails to consider the economic losses caused by the accident. Risk Assessment, in contrast, takes into consideration both the probability and the consequence (such as economic loss, etc.) of the accident, but it does not calculate the risk brought by natural disaster and artificial damage. Since none of the abovementioned methods give an overall consideration to all the risk factors that affect power system, alternative approaches are to be pursued.

Through tapping into various issues concerning power system security at home and abroad, this paper proposes an objective, practical and adaptive ESRAS based on Electricity Regulation. The Risk Assessment Indices (RAI) of the ESRAS are designed to assess

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the risk of Large-area Power Outages (LPO) from three aspects (see details below), and the result flowing from ESRAS is mainly a reference for government regulatory departments, before they made the contingency plan. ESRAS does not make simulations of power system operation under hypothetical natural disasters, which will be done by power corporation's dispatching department. ESRAS is used as a method for the power system regulators to assess system risk.

With the aid of the ESRAS, SERC is able to assess the risk involved in power system, perfect the current ERS and Emergency Management System (EMS), and urge power enterprises and departments to develop effective measures to reduce the level of risk.

2. The ESRAS based on Electricity Regulation

The China Power System (CPS) has developed into a stage characterized by the interconnected large-scale system, high voltage, long-distance transmission and high electrical capacity. In terms of scale and power load, CPS ranks first in the world, even ahead of the United States. In large-scale power systems, more and more factors are contributing to LPO, which present a challenge to security management and pose a serious impact on the politics, economy and people's life. Currently, the power enterprise and their regulators apply the norm and the method of determinacy, which is based on the Certainty Assessment, to assess risk. For example, the long-time used percentage reserve in generating capacity planning and N-1 principle applied in power transmission planning (GPEPDC, 2009; SETC, 2001). The main disadvantage is that it cannot show the probability of power system's evolution, load change, component malfunction, etc. Thus it is of great importance for the government to fully assess the risk involved in power system, and it is the high time that the ESRAS based on Electricity Regulation was called into play. After a full analysis of the LPO events at home and abroad, the factors contributing to LPO are identified, which then provide a basis for the classification of RAI.

2.1. Analysis of the LPO events

SERC had organized experts and engineers to analyze some LPO events in recent years, and the four main factors contributing to LPO are identified as follows:

(1) Climatic and environmental factors
Despite the fact that environmental and climatic conditions have been taken into account in designing of the power system, they still act as major contributors to a lot of equipment failures, such as the line break, dance, or short-circuit fault caused by ice cover; the insulation flashover caused by gel, frozen fog and lightning; the flashover between overhead lines and trees. The United State was hit by large-area outages twice in 1996, both due to the tripping of transmission lines on flashover (He Dayu, 1996).
Other environmental and climatic factors that pose potential hazards to power systems are typhoons, ice disaster, earthquakes, floods, war, etc. Some famous blackout accidents, including Quebec blackout in 1988, Hainan Province blackout in 2005, and southern China blackout in 2008, all were caused by extreme weather (SERC, 2006; Tang Si-qing et al., 2006).

(2) Power equipment failure
Besides environmental or climatic factors, electrical properties and mechanical properties inherent in power equipment may also cause malfunction or failure. Through the analysis of LPO that happened at home and abroad in recent years, it is found that a lot of blackouts resulted from the cascading protection trips triggered by the relay protections misoperation, misstrip or a large load transfer. For example, the Brazil blackout in 2002 is a direct consequence of the misoperation of relay protections (CPNN, 2008).

(3) The imbalance between supply and demand
The imbalanced system power caused by the abrupt change in load capacity or generating capacity constitutes another factor leading to LPO.
Many reasons will cause the load capacity or generating capacity to change abruptly, such as the climatic changes, the failure occurring in important transmission channels at the receiving grid, or system splitting, etc. For example, the great blackouts in western France and Tokyo in 1987 were the consequence of an abrupt change in load or generating capacity (Gomes, 2004).

(4) Human error
Human error may occur at all stages of power generation, including the stage of planning and designing, manufacturing, operating and maintenance, etc. An investigation report on "8.14" US-Canada blackout revealed that grid company did a bad job in maintaining power transmission channels, implementing the reliability standard, maintaining the scheduling communication system and handling the emergency (UCPSOTF, 2004).

The Fault Tree Analysis (FTA) method, developed from the fault tree analysis, is an important method for safety system engineering analysis (Gao Shang, 2007). It can identify and evaluate the risks involved in a variety of systems, not only capable of verifying the direct cause of the accident, but also capable of revealing the potential causes of the accident. FTA could describe the causal relationship between the accidents in a visualized, clear and logical manner and it blends both qualitative analysis and quantitative analysis. Fig. 1 shows the basic structure of the tree for LPO.

As shown in Fig. 1, the LPO event can be decomposed into a number of small events based on the principle that the decomposition can clearly reflect the factors that cause blackout and can provide convenience for the supervision of Electricity Regulatory Commission. Therefore, in this paper, the LPO event can be first

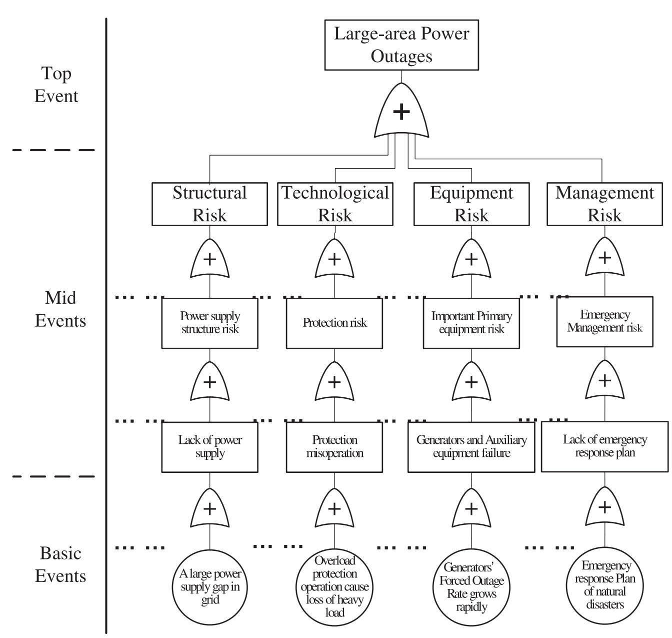

Fig. 1. Tree diagram of LPO.