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Transmission reliability cost allocation method based on market participants' reliability contribution factors

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Abstract

Due to the complex and integrated nature of power systems, failures in any part of the system can cause interruptions which range from inconveniencing a small number of local residents to a widespread catastrophic disruption of supply. For this reason, the transmission reliability margin must be provided for the system to be operated at all times in such a way that the system will not be left in a dangerous condition even though unpredictable events occur. In this paper, Kirschen's tracing method is employed to find the usage contributions of individual generators to the line flows under normal conditions. Apparently, it seems plausible to compute the reliability contributions of all market participants based on the probabilistic approach which takes notice of the forced outage rate for each transmission line as well as the line outage impact factor and then to allocate the transmission reliability cost among all the system users in proportion to their "extent of use" of reliability reserves in transmission facilities.

Keywords: Forced outage rate; Reliability contribution factor; Transmission reliability cost allocation

1. Introduction

The electricity transmission system is an extensive, interconnected network of high-voltage power lines that pass electricity from generators to customers. Such a transmission system must be flexible enough, every second of every day, to accommodate the growing demand for reliable and affordable electricity.

Nevertheless, rapid growth in electricity demand and new generation, lack of investment in new transmission facilities, and the incomplete transition to fully efficient and competitive wholesale markets have allowed transmission bottlenecks to emerge. These bottlenecks increase electricity costs to consumers and increase the risks of blackouts. Today, power failures, close calls, and near misses are much more common than in the past. The transmission systems of tomorrow must be operated in ways that maintain adequate safety margins for reliability and allow customers to follow strict tariffs for reliability with appropriate penalties for non-compliance.

Despite the fact that transmission charges account for a small percent of operating expenses in utilities, we cannot afford to allow the relatively small transmission costs to prevent customers from enjoying the reliable and affordable electricity service that the properly managed competitive forces will deliver to our nation. Therefore, transmission pricing should be a reasonable economic indicator used by the market to make decisions on resource allocation, system expansion, and reinforcement [1]. The first step toward increasing the role of market forces in managing transmission system operations

Abbreviations: EUE, expected unserved energy; LOIF, line outage impact factor; LODF, line outage distribution factor; FOR, forced outage rate; RREF, relative reliability evaluation factor; NRREF, normalized relative reliability evaluation factor

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efficiently and fairly is increasing the role of price signals to direct the actions of market participants toward outcomes that improve operations. Improving operations by relying on accurate price signals may, by itself, alleviate the need for some construction of new transmission facilities. Moreover, when new construction is needed, price signals will help market participants identify opportunities and assess options to address bottlenecks. Several aspects of transmission operations, including congestion and losses, could be effectively addressed by pricing based on the principle that if market participants see the true costs of transmission services reflected in prices, they will use or procure these services efficiently. Thus, reliance on uplift charges, in which costs are recovered from all transmission users on an equivalent basis, should be minimized.

In the past few decades, many researchers have devoted themselves to achieving an efficient transmission pricing scheme that could fit all market structures in different locations so that participants in markets can see and respond to the true costs of using the transmission system. Generally, the transmission charge is grouped into the following parts: transmission line usage charge, system reliability charge, access charge, and so on [2]. Any transmission tariffs should be able to reflect these respective cost components without any distortion.

Particularly, this paper suggests a probabilistic approach to allocating the reliability cost of the transmission system to each market participant. Based on the transmission line utilization of all market participants under normal conditions, this paper provides a helpful comparative framework for allocating the reliability cost in the context of a competitive electric market by taking care of the forced outage rate as well as the line sensitivity factors after a loss of one single circuit or $(n - 1)$ criteria and then calculating the reliability contributions of all generators to the transmission lines. Finally, the case study exhibits the applications of the proposed methodology on a simple 6-bus test system.

2. Background of the work

Recent research has shown that the maximum transmission utilization over a period of time is, in theory, limited by the amount of spare transmission capacity or transmission reserves required for the reliability of the overall transmission network. These reserves must be secured to maintain the system reliability during circuit outages for contingencies such as the sudden loss of generation or transmission facilities. These reserves also allow sales to and purchases from other systems to change with times of the day and seasons of the year, and provide capacity for parallel-path or loop flows throughout the system. In this regard, the objective evaluation of reliability contributions in the transmission system and the reasonable allocation of transmission reliability costs are of growing importance. Accordingly, the transmission tariffs actually being enforced should apparently reveal fair and transparent properties, representing a crucial element for the installation of the market structures.

There was absolutely no consensus as to the transmission tariffs in terms of the reliability cost. In practice, each country or each restructuring model has chosen a method that is governed by the particular characteristics of its network.Yu and David [3] give convincing answers to the transmission pricing issue pertaining to the operating and embedded costs. Capacity use as well as reliability benefit is taken into account in the disbursement of charges for investment recovery, where the reliability benefit for a particular transaction is calculated as the increment of the total probability of system failure, with the line out of service, compared to when the line is in service. Some insights into the marginal pricing approach to the recovery of operating costs are also elaborated.Silva et al. pay special attention to the transmission cost allocation method associated with not only the probability impact of transaction on the electrical system but also the power flow values with and without wheeling transaction [4]. Their intention, then, is to carry implications that an important part of transmission assets is indispensable to system reliability as far as the power systems operations under both normal conditions and contingencies are specifically concerned. However, this suggestion has a drawback in the sense that it is heavily dependent on the base-case flow and the implementation of the cost allocation rule is not really easy.

In [5], with probabilistic criteria and appropriate software available, the planner can assess system-wide bulk power transmission reliability, impact of varying reinforcement expenditure levels, and reliability outcomes for many alternatives. Once the reliability merits of each reinforcement have been analyzed, ranking the merits among all alternatives is drastically performed with the so-called expected unserved energy (EUE), which serves to convert the predicted reliability to a cost value for a specific location and time. This rule's shortcoming is that it is not merely obscure but complex to assess the reliability criteria covering the residual uncertainties related to power system planning and operations.

To put it plainly enough, Kirschen explores a method to allocate the usage of transmission system based on the traceable contributions of each generator and/or of each load to the maximum branch flows determined by security considerations [6,7], while Bialek presents a topological approach to determining the contributions of individual generators or loads to every line flow based on the calculation of topological distribution factors, thereby applying it to the transmission supplement charge allocation [8,9].

3. Description of the algorithm

Contingency analysis techniques are commonly proposed to predict the effects of outages. And so, contingency analysis procedures model single failure events (i.e., one-line outage or one generator outage) or multiple equipment failure events (i.e., two transmission lines, one transmission line plus one