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Customer Satisfaction Based Evaluation Method of Voltage Sag in the Modern Power System

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Abstract

This paper is based on interval data of power customer satisfaction degree. The evaluation method of voltage sag or dip is an analytical one which is used to consider the satisfaction of not only the utility but also the user side. Determining function is from the length of fault line and the voltage magnitude in the modern transmission and distribution network. The critical failure positions method is getting through analytical algorithm combined with iterative features. The range characteristics of satisfaction degree of customer side and the distribution regularities of the uncertainty region are considered in the paper. Then, the quantitative frequency of voltage sag is determined using the interval sag frequency. A small size network and IEEE 30-bus RTS are chosen to comparing with existing and traditional methods. And this novel method is proved to have much more academic value and practical foreground.

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Keywords: power customer satisfaction degree, evaluation method, critical failure positions, interval data

1. Introduction

The fundamental objective for both customer side and utilities is meeting their satisfaction at the same time[1], especially under the background of the development of smart grid [2]. With the promotion and application of microelectronics technologies, the characteristic of electrical equipment has undergone a

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fundamental change. The complaint from power quality problems caused by voltage sag is increasingly prominent. Expressly with the widely application of sensitive equipments [3-4], including PC, PLC, ASD and ACC, the complaints caused by voltage sag present a rising trend year by year. According to international association of Electrical and Electronics Engineers (IEEE), the voltage sag is defined as a sudden dip or decrease of its RMS value during 0.5 cycles of the whole period to 1 min called duration. And the dip magnitude is in the extent from 0.1 to 0.9p.u. From the above, the promotion of the satisfaction degree relies heavily on the assessment of voltage dip frequency.

The internal factors including different sensitivity equipment types, working conditions, network topologies, loading types and have great influence on satisfaction degree. And the external factors are no exception, which means the type, location and impedance of fault [6].

Traditional voltage sag evaluation methods are based on the voltage magnitude of its RMS. The measurement statistic [7] and analytical modeling [8-9] are the principal methods. The former requires long surveying time and high installation and maintain cost even though it is simple and reliable. The later one has promotion and predictability due to its complex stochastic model but lacking of consideration for customer. The critical distance method, classical fault locations and analytical approach are the conventional methods.

After the scientific understanding of interval data of customer satisfaction degree in network, a novel analytic evaluation method is presented. With the help of Newton iteration method, this proposed method is validated as an accurate and applicable one under the small size network and IEEE 30-bus RTS.

2. The concept of power customer satisfaction degree and interval data

Customer satisfaction in a power system can be defined as the satisfaction indicators synthesized the power supply capacity, power, electricity, and power efficiency, utility and so on. Because of that prices are influenced by the impact on various aspects of capacity, electricity consumption and power sales contracts related, the customer satisfaction is decide by the operating conditions of weather it is normal. Therefore, the comprehensive concept of customer satisfaction is shown by the probability of the normal operation time divide by total operation time. The S % called power customer satisfaction is shown by the following expression:

$$S\% = \frac{T_s}{T_s + T_c} \times 100\% = \frac{T_s}{T_t} \times 100\% \tag{1}$$

Where, T_s means the normal operation time; T_t means the practical operation time of sensitivity equipment; and T_c is the non-normal operation time, which depends on the power quality of supply side and VTC of user side. Starting the point of power customer, their satisfaction is an essential serve.

Except the sag severity, the voltage tolerance is the principal element of electricity customer satisfaction degree. The VTC of equipment is constituted by the upper and lower thresholds shown in Fig. 1. The maximum and minimum thresholds of VTC about voltage amplitude and dip duration are expressed by $U_{\max}$ and $U_{\min}$, $T_{\max}$ and $T_{\min}$. Showed in the picture, when voltage sag happen in the external of curve one which is called satisfaction area, the sensitivity device operates normally as usually. Furthermore, the sensitivity device will take place the opposite situation if the real sag happens inside the curve 2. Even more critical is that the operation state of sensitivity device is uncertain when dip occurs in *L*- area mixed with the two curves, which are shown in Table 1 [3-4].