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Calculation Method of Voltage Stability Based on Neural Network

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Abstract: *With the deepening of the research on voltage stability(VS), the methods for analyzing VS have also been further developed. Although the probability of voltage collapse has been greatly reduced compared to before, the research on VS has always been a hot topic due to the seriousness of its consequences. This paper studies the sensitivity method of VS and other related calculation methods, corrects the power system through BP neural network, compares the load margin values obtained by the VS calculation method before and after the correction, and finds that the load margin obtained by the BP neural network algorithm proposed in this paper degree value error is minimal.*

Keywords: *BP Neural Network, VS, Sensitivity Method, Load Margin Value*

1. Introduction

With the continuous development of industrial production scale, the energy system has gradually become a real-time automation system with large scale, complex structure and advanced technology, which has prompted the electric power industry to enter a new development period. At the same time, this leads to a significant increase in energy demand, which in turn increases the load on the power system and may even exceed the operating limit of the system. The pressure of load variability and VS has become the biggest obstacle to the development of the power system.

At present, many scholars have conducted in-depth research on the VS calculation method based on neural network, and have achieved good research results. For example, based on the DAE uniqueness theory, scientists have studied the relationship between the transient VS β of different load models, proposed a transient VS estimation method based on a constant resistance motor paralleled induction motor, and found that the DC switch fault and control behavior can also lead to transient voltage instability [1]. The bipolar block of the DC line transfers the current to the AC channel, resulting in a dramatic increase in the reactive power demand of the receiving end network, resulting in voltage drops and voltage instability studied by the main power angle detection probe. Because the load factor plays an important role in voltage instability, load modeling has also become a major topic in VS research [2]. Although the research results of the VS calculation method based on neural network are good, in-depth research is needed to ensure the VS and meet the user's power demand.

This paper first classifies the VS according to the magnitude of voltage disturbance and stabilization time, and then proposes common methods for calculating VS, such as sensitivity method, power flow method, and Thevenin equivalent method. According to the research content of this paper, a model based on BP neural network is proposed. The BP algorithm of this paper is compared with the common method to calculate the load margin value of the power system, and the validity of the algorithm of this paper in judging the VS is verified.

2. Overview of VS

2.1 Classification of VS

(1) According to the degree of disturbance

Small disturbance VS: The ability to maintain normal operation to keep the voltage within the normal range when the user terminal is subjected to slight disturbances. Compared with the end user, this interference change generally does not affect the normal operation of the user end [3].

Large perturbation VS: This classification mainly focuses on large perturbation interventions compared to small perturbation interventions. These interventions mainly refer to major system failures such as connection failures and system crashes. Such large interference usually affects the user, and this phenomenon directly interferes with the normal use of the user, and the related voltage also exceeds the normal range [4-5]. The research on this problem mainly adopts the method of simulation, and through the simulation analysis of the problem, the appropriate conclusions for the problem are obtained.

(2) Classification according to the stable time scale

Long term voltage stabilization: The time range is between 20 and 30 minutes. The related factors are mainly the control measures adopted by the load, the self-recovery characteristics of the load itself, and the running time of the transmission line in the overload state exceeds the maximum value [6].

Mid-term voltage stabilization: The time range is between 1 and 5 minutes. The mid-term voltage instability is a relatively slow process, and the static method is often used for analysis in the early research. However, VS is essentially a dynamic problem, and the instability process is affected by dynamic factors such as load recovery characteristics, automatic adjustment and control devices of transformers and generators, and presents multi-dimensional dynamic characteristics. It is often difficult to study the mechanism of voltage instability with static methods, and the results obtained are not convincing [7]. So far, the medium-term VS simulation methods mainly include the quasi-steady-state method and the whole-process dynamic simulation method. The basic idea of the quasi-steady-state method is to maintain the differential equation describing the dynamic characteristics of each component in the mid-term, and replace the transition process with multiple equilibrium points caused by discrete events [8]. This approach is essentially a compromise between the accuracy of the time-field modeling approach and the speed of static power flow calculations. Dynamic modeling of the entire process can continuously combine electromechanical transitions and mid-term dynamic processes to simulate continuous-time field processes after power system faults [9].

Transient voltage stabilization: The time range is 0 to 1 second. Transient VS is short-term large disturbance VS. Compared with angular transient power stability, the research in this area is still insufficient. This limits the understanding of the transient voltage stabilization mechanism. In the past, the engineering experience method was often used, that is, the voltage drop amplitude and duration of the central point were used as the criterion for voltage instability. This criterion holds that as long as the voltage is lower than the voltage dip amplitude for more than the duration, it cannot automatically return to normal or higher values [10-11].

2.2 The Main Methods of VS Analysis

VS research has become an important part of power system stability, depending on the structure, load and operation mode of the power system, so how to quickly and accurately determine which factors will lead to voltage instability has become the key research direction of the power stability analysis system. Here are a few ways to analyze VS.

(1) Sensitivity method

According to the sensitivity, appropriate control measures are taken to control the input of the independent variable, so as to achieve the purpose of controlling the output of the dependent variable of the system. In terms of time, the sensitivity algorithm is systematically analyzed and divided into static sensitivity and trajectory sensitivity according to the classification method. At the same time, sensitivity research has the following problems. First, there is no common theoretical basis. Both of these issues can make the sensitivity calculated for the analysis wrong or even meaningless. When the voltage control measures related to the stability limit are reprogrammed, corresponding control measures are taken according to the different fault types, and a new optimal control method is established to realize the safe and reliable control of the system. This new approach has many advantages that the model does not have. The most obvious advantage is that it can be used without standardization, which makes the analysis of the results safer, more reliable, and less error-prone.

(2) Continuous flow method

The continuous power flow method revises the power flow equation written in the system and uses the revised equation for calculation, which effectively avoids the defect of uniqueness and even critical non-solution points when solving the normal power flow equation. The Jacobian power flow equation can be solved under any load and has a solving effect. The solutions of the power flow equations decrease in pairs with increasing load, and the solutions are unique when the limit is reached. When the power flow equation reaches the solvable limit, when the load increases, the maximum continuous

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power load capacity is obtained [12].

(3) Thevenin Equivalent Method

The specific content of Thevenin's Equivalence Theorem is that for any gate system with invariant characteristics, the part of the system that needs to be studied in detail can be fully simplified to a simple circuit model with a voltage source connected in series with a resistor. The discovery of this theorem has a positive value, using this theorem we can calculate the exponent of the resistivity of a node, and with this exponent we can determine whether the voltage there is constant. Because the theorem has a good effect on the research of VS, the theorem is widely used in the research of VS. Regarding the issue of VS, the theorem is not so accurate, there are always errors. There are many reasons for the error, such as the error in calculating the equivalent resistance angle when calculating the ratio.

(4) Jacobian matrix method

Generally, VS assessment attempts to study the distance from the current operating point of the operating system to the VS limit, and determining the stability limit requires a proper understanding of the VS mechanism. The Jacobian matrix tends to be unique with the increase of the load power, and the single-value index is obtained by using the smallest single value to reflect the degree of the adjacent VS limit.

2.3BP Neural Network

The application of neural network can be divided into two steps: the first step is the learning process, which uses a large number of training samples to train network parameters; the second step mode is classified.

$$x_{k+1} = x_k - \alpha_k g_k \tag{1}$$

where x_k is the current weight and threshold matrix, g_k is the gradient of the current performance function, and α_k is the learning rate.

Assuming that the expected value of the output is t_{pk}, then the error of the output node is δ'_{pk}, and the sum of the squares of all errors E_p is:

$$E_p = \frac{1}{2}\sum_k \delta'^2_{pk} = \frac{1}{2}\sum_k (t_{pk} - o_{pk})^2 \tag{2}$$

Where w_{ji} represents the weight between the ith input node and the jth hidden layer node, then the output of this node can be expressed as o_{pk}.

3. Experimental Research

3.1 Research Purpose

The VS margin refers to the period of time during which the voltage of the load applied by the user gradually increases and finally collapses, starting from the operation of the system. In this paper, the calculation method of VS is used to obtain the load margin value of the power system. A small calculation error indicates that the voltage is stable. It is hoped that the research results of this paper have important theoretical significance and engineering value for improving the safe operation level of the power grid and reducing the probability of blackout accidents.

3.2 Research Methods

The VS calculation experiment in this paper analyzes its stability according to the size of the VS

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margin. Compare and find the best calculation method for judging VS.

4. Analysis of Calculation Examples of VS

To study VS, it is necessary to calculate the index of VS margin to reflect its changes. There are many methods to solve the VS margin. In recent years, the methods often used by researchers include sensitivity method and power flow method.

Table 1: Nodal Impedance Mode Margin Value Calculations

	Nodal Equivalent Impedance Modulus	Nodal Impedance Modular Margin
1	0.725	0.854
2	0.369	0.934
3	0.471	0.927
4	0.862	0.628
5	0.786	0.946
6	0.217	0.352
7	0.139	0.967
8	0.443	0.980
9	0.201	0.312
10	0.143	0.974

Taking 10 nodes in a certain power system as an example, the modified nodes of the BP neural network are used to calculate the Thevenin impedance modulus margin, as shown in Table 1. It can be seen that the impedance mode margins of nodes 1, 4, 6, and 9 in the power system are relatively small, that is, weak load nodes with small VS, and No. 6 and No. 9 are the weakest.

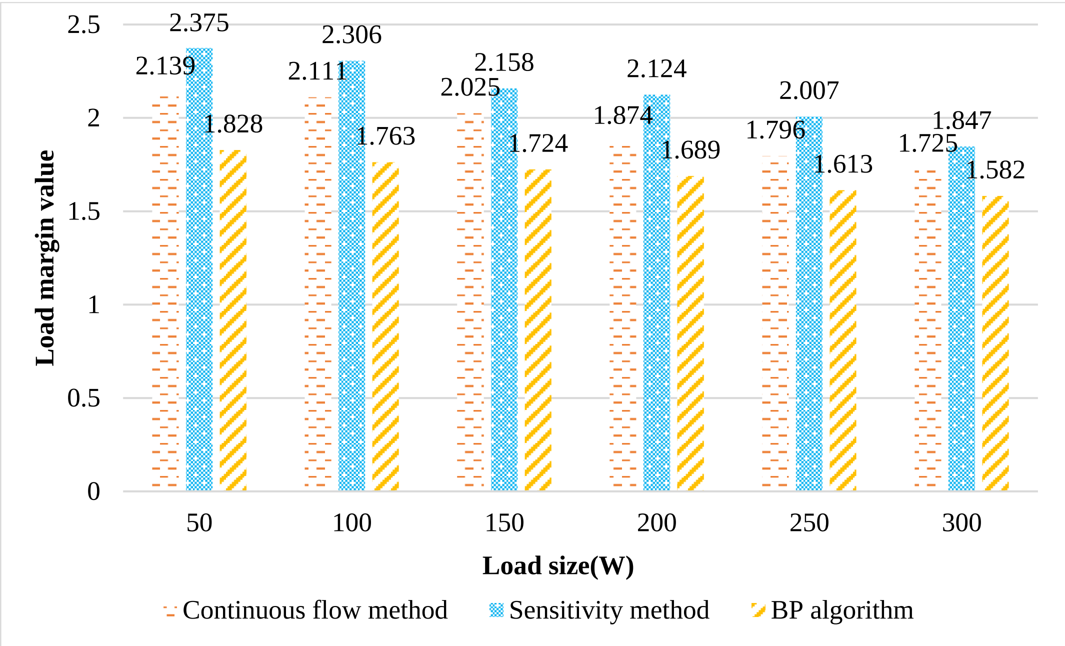

Figure 1: Comparison of load margin values calculated by three methods

It can be seen from Figure 1 that the load margin values under different power loads obtained by the continuous power flow method, the sensitivity method and the BP algorithm are different, but they can all evaluate the VS of the system. Each method is suitable for different power systems. For example, the sensitivity method is suitable for networks whose parameters and operating states are known.

From the above examples of VS, it can be seen that within a certain operating range of the system, although the load margin calculated by the three algorithms has a larger error compared with the Thevenin equivalent parameters, for the same power system, The error has a certain regularity with the increase of the system load, that is, the load margin increases with the increase of the power load, and the calculation error also increases; when the load is large, the load margin decreases with the decrease of the power load. decreases, the calculation error also decreases, and the direction of the error is always the same. There is an approximate linear relationship between the error and the load margin.

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For each power system to be studied, the linear model can be determined first through off-line analysis, and then the BP neural network is used to correct the load margin to obtain more accurate results. As shown in Figure 2, the load margin calculated by these three methods is still calculated when the charge size is 200W after the correction.

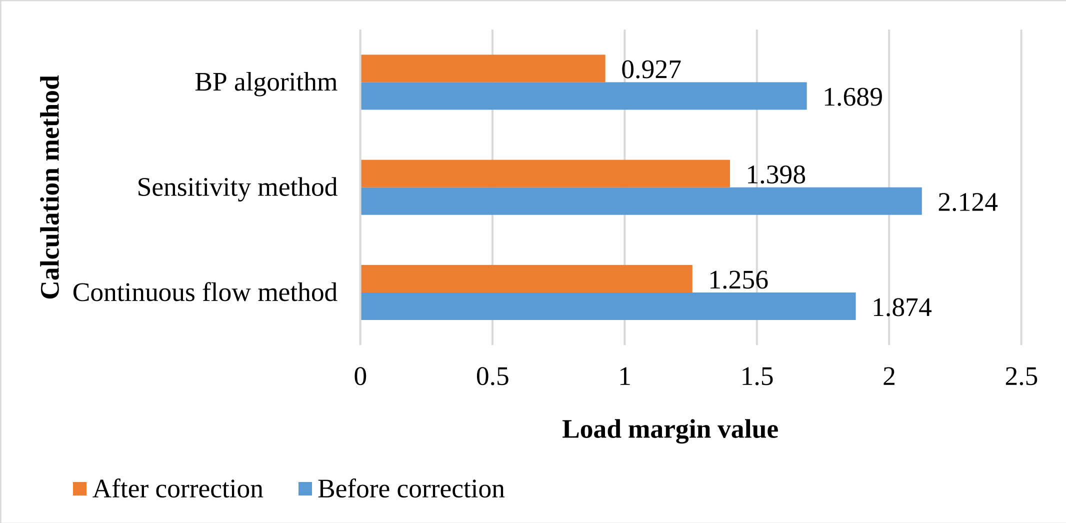

Figure 2: Comparison of load margin values before and after BP neural network model correction

The comparison effect of these three methods can be clearly seen from Figure 2. Compared with the continuous power flow method, the BP-based algorithm adopted in this paper has shorter operation time, accurate calculation results and small error, which fully proves the load margin of the BP neural network model. The effective correction of , reduces the calculation error, which can improve the feasibility and accuracy of the VS judgment.

5. Conclusion

In this paper, three VS calculation methods are used to analyze and calculate the VS of the system. According to the BP algorithm, the margin indexes of the system nodes under different power loads are estimated, and the indexes are compared with the results of the continuous power flow method and the sensitivity calculation. , it is found that the error of the BP algorithm is small, and the magnitude and direction of the error have certain rules and characteristics. According to this, the BP neural network model is used for correction, and the estimation accuracy can be greatly improved with a small amount of calculation. Therefore, based on the analysis and comparison of various VS analysis methods, using the BP algorithm to obtain the load margin index is an important method to analyze the system VS, and has a wide application prospect.

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