Research of Solar Eclipse Impact on Power System Using Neural Network

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Abstract. This paper proposes a new strategy to evaluate and mitigate power system considering solar eclipse based on fuzzy neural network. An explicit model of solar eclipse is established to demonstrate its effects on power system. The mechanism and scheme of solar eclipse have been analyzed for their contribution to power system failures. The fuzzy neural network is used to obtain the impact and to give a solution that can decrease the affection. Extensive sets of training and test data have been utilized by Monte Carlo simulation. The result of a case study on a provincial power system illustrates the methodology.

1. Introduction
Solar eclipse is a kind of extreme environmental conditions which will determine many of the plant and system criteria. Solar eclipse occurs when the moon is in line between the earth and the sun. The moon cast a shadow on the earth's surface and obscures some parts on the sun. When only the moon's penumbral shadow strikes the earth, a partial eclipse of the sun is observed. However, if the moon's dark umbral shadow sweeps across earth's surface, a total eclipse of the sun is seen [1,2].

Power system runs in a certain environmental conditions. Nature such as solar eclipse imposes an environment on power systems which man hardly can influence at all in the short term. The basic mechanism is that the charged sunshine will cause perturbations in the earth's environment. These cause differences in luminance, temperature and wind velocity above the earth's surface along the locus of the moon shadow. These will result in dramatic changes in the power load of shadow areas. The magnitude of these changes will mainly depend upon location of the power system and characteristic of the load.

It is difficult to construct an appropriate function to achieve the level of accuracy desired. Reference [3] presents expert system, which relies on decision trees to evaluate the system stability and tend to be less robust to changes in power system state. Consequently, a more dependable and efficient approach is needed for adaptability evaluation under a variety of time-varying network configurations and events. Using neural networks is an ideal choice for this evaluation. Neural network methods rely on reducing the computational at the expense of intensive studies. By performing training of a neural network using results obtained from history data or extended equal criterion simulator, accuracy can be achieved within the computational and time constraints [4,5].

This paper proposes a new strategy at the system level to evaluate and mitigate the impact of solar eclipse on power system. Fuzzy neural network is used to improve accuracy and efficiency. Some high-impact nodes are pointed out based on this method.
2. Solar Eclipse Impact on Power System

2.1. Power System
Power system is a power production and consumption system which is composed of power plants, transmission lines, power supply and distribution stations and electricity consumption. Its function is to convert the primary energy of nature into electric energy by generating power plant, and then supply electric energy to all users through transmission, transformation and distribution.

2.2. Solar Eclipse Impact
The load of power system is equal to the generating capacity when power system is running in normal and near normal conditions. When solar eclipse happens, sunshine will change. The changed sunshine causes perturbations in the earth's environment. The perturbations cause differences in luminance, temperature and wind velocity above the earth's surface along the locus of the moon shadow. These will result in dramatic changes in the power load of shadow areas. Because the load of power system is not equal to the generating capacity, the frequency of power system changes drastically. This sometimes can cause serious accidents such as blackout.

The frequencies of power system during a solar eclipse were shown as follows. It is obviously that the changes of frequencies during the total solar eclipse were bigger than those during other period. The disturbance on frequency is a potential risk to power system during the total solar eclipse. Fortunately, the changes of frequency were limited in an acceptable level that time.

![Figure 1. Frequencies of power system during a solar eclipse](image_url)

3. FNN Structure and Algorithm

3.1. FNN Structure
A schematic diagram of the fuzzy neural network was shown as follows. Two subsections are separated from the dashed line. One is the data preprocessing subsection, the other is the network subsection.
The parameter vector PW, \( PW = [PW_1, PW_2, \ldots, PW_m] \), where \( m \) is the number of relays, has a close relationship with cascading outages adaptability, so it is used as input. In application to real systems, the dimension of input is always high. To avoid “dimension exploding”, fuzzy C-mean clustering approach is used to preprocess the input data. Fuzzy C-mean clustering approach can identify natural groupings of patterns from large data set through clustering [13]. The result of preprocessing is cluster vector \( x \), \( x = [x_1, x_2, \ldots, x_n] \), where the value of \( n \) ranges from 1 to 5 according to scale of the system.

The input of the network section layer 1 is \( x = [x_1, x_2, \ldots, x_n] \). The nodes of this layer is connected directly with \( x_i \), and transmit \( x \) to the next layer. The number of nodes in this layer is \( N_1 = n \).

Every node in the network section layer 2 represents a language variable. There are generally five values of the language variable according to the parameters of relays. They are Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Small (PS), and Positive Big (PB). The nodes in this layer is used to calculate the membership function \( \mu_{i}^{j} \) of input, where \( i = 1, 2, \ldots, n, j = 1, 2, \ldots, 5 \). In this paper, Gauss function is used as the membership function. The number of nodes in this layer is \( N_2 = 5n \).

Every node in the network section layer 3 represents a fuzzy rule. The using degree of every rule is

\[
\alpha_j = \text{FUN}(\mu_{i_1}^{j}, \mu_{i_2}^{j}, \cdots, \mu_{i_n}^{j})
\]

(1)

where \( i_1, i_2, \cdots, i_n \in [1, 2, \cdots, 5] \), \( j = 1, 2, \cdots, 5^n \), \( \text{FUN} \) stands for multiplication. The number of nodes in this layer is \( N_3 = 5^n \).

The network section layer 4 is used to normalizing by

\[
\bar{\alpha}_j = \alpha_j / \sum_{i=1}^{n} \alpha_i
\]

(2)

where \( j = 1, 2, \cdots, 5^n \). The number of nodes in this layer is \( N_4 = 5^n \).

The network section layer 5 is output layer. The output of traditional security analysis using yes-no logic is coarse. The output of this approach is adaptability index, and it is a more accurate result after defuzzification as formula (15). The number of nodes in this layer is \( N_5 = 1 \).

\[
y_1 = \sum_{j=1}^{5^n} w_{ij} \bar{\alpha}_j
\]

(3)

where \( w_{ij} \) is weighting factor.
3.2. Learning Algorithm
In the network section, back-propagation algorithm is used to modify the weighting factor $w_{lj}$ in layer 5, where $j = [1, 2, \ldots, 5n]$, and fuzzy membership parameters, mean value $\mu_{ij}$ and width value $\sigma_{ij}$ in layer 2, where $i = 1, 2, \ldots, n, j = 1, 2, \ldots, 5$. It is assumed that the input of node $j$ in layer $q$ is
\[ f^{(q)}(x_1^{(q-1)}, x_2^{(q-1)}, \ldots, x_n^{(q-1)}, w_{j1}, w_{j2}, \ldots, w_{jn}) \],
and the corresponding output is $x_j^{(q)} = g^{(q)}(f^{(q)})$ as follows.

![Figure 3. Structure of single node](image)

4. Case Study
In order to demonstrate the proposed strategy, a case study is given based on a provincial power system. Matlab is used for detailed modeling of power system and simulation of Solar eclipse. Monte Carlo method is used for simulation. One simulation course is shown as follows.

![Figure 4. Simulation course](image)

The training error is listed as follows.
5. Conclusions
This paper proposes a new strategy at the system level to evaluate and mitigate power system considering the impact of solar eclipse. An explicit model of solar eclipse is established to demonstrate its impacts on power system. Some results are used to evaluate the impact of solar eclipse. The neural network is used to obtain the impact and to propose a solution that can decrease the impact of solar eclipse on power system. A provincial power system is used to illustrate the methodology and present the results.

6. Acknowledgments
This work is sponsored by Basic Research Program of Qinghai Province, China (No.1986-ZJ-764): Research on Control Strategy of Long-Distance Consumption of Distributed PV Stations via HVDC.

7. References
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