Study Committee D1

Materials and Emerging Test Techniques

Paper D1-PS1-10610

The Application of Artificial Neural Networks in the Diagnosis of High-Voltage Circuit Breakers

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Motivation

Instruments intended to monitor high-voltage equipment play a significant role in the operational safety of circuit breakers and help to determine the location of failure before an accident.

In the computational process, modern diagnostic systems fail to use the methods of artificial neural networks (ANNs) and machine learning that have proven themselves in other technology areas. The application of artificial neural networks in the diagnosis of high-voltage equipment is due to their advantages over other digital monitoring methods.

In this article, we suggest using artificial neural networks to diagnostically test high-voltage circuit breakers.

Method/Approach

Based on the specified parameters, we used the Neural Network Toolbox to implement an artificial neural network in the Matlab environment. For network learning, we chose the Levenberg-Marquardt algorithm and set 50 layers for a positive result. The Levenberg-Marquardt algorithm is the most frequent and convenient algorithm in terms of reducing squared deviations to a minimum value. The great advantages of this method, when compared with other methods of calculating analogous conjugate gradients, are high calculation speed and element convergence.

Objects of Investigation

To enter necessary data for neural network, we carried out research works using the VGT-110 circuit breaker with the PPrK spring drive and using the PKV\M7 control device.

Experimental setup & test results

As input parameters for the neural network, we introduced values characterizing the linear and velocity functions of the circuit breaker contacts, as well as such data as commutation life, SF_6 gas density pressure in the circuit breaker columns (tanks), temperature inside the drive cubicle and data from current measuring transformers. The parameters that characterize linear and velocity features include the forces of opening and closing springs, the adjustment parameters of on-/off absorbers, the distance between movable and fixed contacts and the time of contact movement in ms. At the outlet, we need to obtain the maximum speed of contacts and the displacement of the breaker traction in mm.

Discussion

The study resulted in learning graphs, neural network regressions and an error bar chart showing that the use of artificial neural networks in the diagnosis of high-voltage circuit breakers gives a rather accurate result. We also checked the functioning of the neural network, as a result of which the exact maximum speed of the circuit breaker contacts was obtained with its specified adjustments.

Conclusion

Based on the obtained data, we can confidently state that the use of artificial neural networks in the diagnosis of high-voltage circuit breakers is of great potential in terms of performance, and this algorithm can be used in the course of acceptance tests or at power facilities. However, in order to apply this diagnostic method, it is necessary to develop a special controller operating according to the specified algorithm.

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Figure 1. Network learning chart

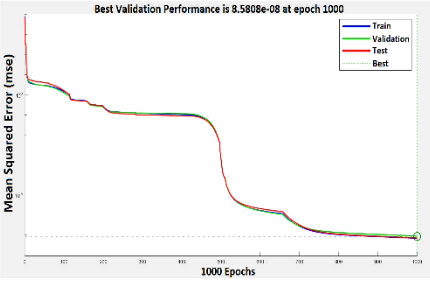
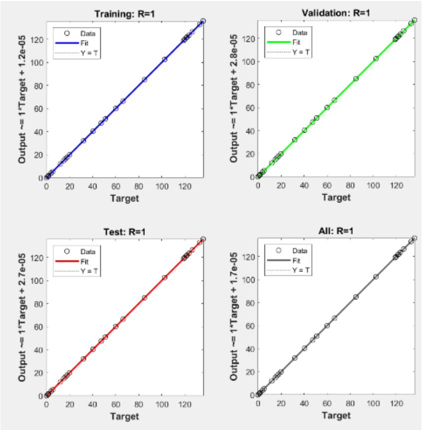


Figure 1 includes a network learning chart that shows the behavior of the training error. The result of neural network learning is that the value of the mean squared error $8.5808 \cdot 10^{-8}$ has been achieved over 1000 epochs (artificial neural network operations).

Figure 2. Neural network regression charts

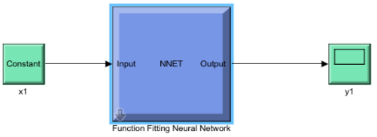


The charts given in Figure 2 characterize the linear regression of network learning results. For each result obtained, the system calculates a correlation coefficient. Based on the calculated data, charts are plotted, and a regression equation is deduced.

Figure 3. Neural network errors histogram

The histogram presented in Fig. 3 shows how many examples are required to see where the network gives one or another error. An error is the difference between the target values and the output of the network. The chart shows errors for the training, validation and test sets. The histogram shows that most errors occur within the range of -0.00019 to 0.000386.

Figure 4. Algorithm of the artificial neural network in the Simulink environment



To use artificial neural networks in the controller, we need to develop an algorithm in the Simulink environment, and then convert it into a machine code. When starting a developed script, the Simulink automatically simulates the calculation algorithm shown in Figure 4.

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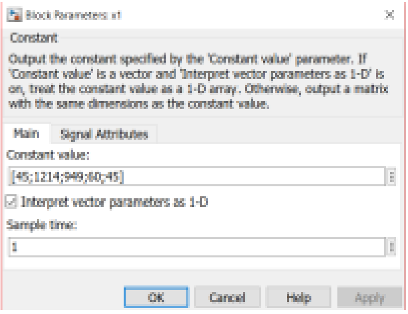
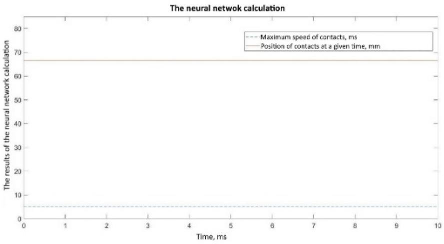
Figure 5. Breaker adjustment parameters input for calculation of the neural network



The required input values are recorded in the block ***x1***, as shown in Figure 5. Such parameters as commutation life data, temperature inside the drive cubicle and SF6 gas density pressure are automatically taken into account.

Figure 6. Result of calculation of the artificial neural network



As a result of the calculation, we obtained the calculated maximum speed of the circuit breaker contacts and the traction condition at the specified moment in the form of a function chart (Fig. 6).

Conclusion

As a result of the study, it was revealed that the use of artificial neural networks in the diagnosis of high-voltage switches gives a rather accurate result and depending on the input data (including the amount of information supplied to calculate the artificial neural network), information can be obtained that allows you to diagnose the state of equipment and predict emergency situations at the facility. Therefore, this method allows capturing a huge range of parameters for the analysis and diagnostics of high-voltage equipment during operation and, at our discretion, add or exclude unused data for further equipment monitoring. To use this diagnostic method, we need to develop a special controller operating according to the specified algorithm or incorporate a code in the Python language into the software of the diagnostic system.