CHAPTER 5

A NEW GRAPHICAL BASED ANALYSIS: SOLID-STATE CIRCUIT BREAKER ENHANCES METAL OXIDE VARISTOR IN COMPENSATING VOLTAGE SAGS

5.1 INTRODUCTION

Voltage sag is a major impediment in preserving the power quality of a system. Most of the controllers used for controlling the voltage sag of a system measures the voltage values and adjust the parameter values based on the amount of sag. It is possible for these methods to miss some values and it is considered as their major drawback. Hence, we have proposed a graphical analysis method to overcome this issue by reducing the voltage sag in the system. The proposed method avoids the possibility of missing any values by measuring them directly from graphs. The rest of the paper is structured as follows. Normally, voltage sag is distinct as a reduce to among 0.1 and 0.9pu in rms voltage or current at the power incidence for durations of 0.5 cycles to 1 min. Voltage sags mainly occur due to nonlinear loads and faults of the system. These voltage sags not only affects the performance of the system, but also causes damage to the system. Normally on the basis of the voltage sag values measured at each stage, appropriate control action is taken to reduce the voltage sag. It is always possible for some of the sags to go unnoticed thereby affecting the system which is considered as a drawback of this method. To reduce voltage sags in a system by overcoming this drawback, we propose a graphical based analysis method which will not miss
out several of the sag values that take place in the system. For this, the voltage values are considered from the graph and the system is trained using the reference graph values. When the system graph is given to the neural network, the network compares it with the reference graph and identifies whether voltage sag is present or not present in the system. If voltage sag is present in the system, then it calculates the amount of voltage sag in the system and this value is given to a solid-state metal oxide varistor and by adjusting the controller parameters the voltage sag values are reduced.

5.2 REDUCING VOLTAGE SAG USING SOLID-STATE METAL OXIDE VARISTOR CIRCUIT BREAKER

Varistor are nothing but variable resistors commonly used for protecting circuits. The nearly all common type of varistor is metal oxide varistor (MOV). Metal oxide varistor is primarily engaged for dropping voltage sags in the scheme. Generally, the MOV operating based on the values calculated in the system. There are chances for missing some values during measurement. To surmount this, here the standards are precise from the graph, so that there is no possibility of missing any of the values. Further, whether voltage sags exists in the method or not is recognized. The subsequent steps are old to locate whether voltage sags exists in the system or not and to decide the value of the voltage sag so as to exists in the system. From the calculated and based on the requirement the values of the resistors are adjusted to improve the voltage of the system.

Varistor give dependable and inexpensive defense against high voltage transients and surges which may be formed, for example, by switching or electrical clatter on AC or DC power lines. They have the advantage over transitory suppressor diodes in as to a large extent as they can take up much advanced passing energies and can suppress positive and negative transients.
When a momentary occurs, the varistor resistance changes from a very far above the ground reserve value to a very short conducting value. The transitory is consequently captivated and clamped to a safe level, protecting receptive circuit components.

Varistor are artificial from non-homogeneous objects, giving a rectify action at the get in touch with points of two particles. Many sequence and parallel relations decide the voltage rating and the current ability of the varistor.

### 5.3 NEURAL NETWORK FOR IDENTIFYING THE PRESENCE OF VOLTAGE SAG IN THE SYSTEM

Artificial neural networks (ANNs) are excellent tools for complex manufacturing processes that have many variables and complex interactions. Basically neural network consists of three layers specifically input layer, hidden layer and output layer. At this time we use the neural network to make out whether voltage sag is in attendance in the system or not. The neural network used for our method has two variables in the input layer, n variables in the hidden layer and one variable in the output layer. Back propagation algorithm is used to train the neural network (Cannas et al 2001). The network accepts time and voltage as input and output as whether the system has voltage sag or not.

The configuration of the network with two input variables and one output variable are shown.
Figure 5.1  The structure of neural network utilized in the proposed technique

In the Figure 5.1 shows the structure of neural network used in our method. Present are three dissimilar stages for neural network process. They are, generating training data set, training neural network and testing neural network. Primary step is generating dataset for preparation neural network.

5.3.1 Generating training data set for neural network

The training dataset is generated from the reference graph. For generating the training dataset from the graph, first the number of curves in the graph is analyzed and then, x and y values are selected as follows. From the graph, let \( x_1, x_2, \ldots, x_r \) be the time with certain interval and corresponding voltage values are \( y_1, y_2, \ldots, y_r \), where \( x_1 \) is the starting value of the graph i.e. 0 and \( x_r \) is the last value of the graph and \( r \) is the number of \( x \) values taken for generating the training dataset. The training data set
is \{(x_1, y_1), (x_2, y_2), \ldots, (x_{r-1}, y_{r-1}), (x_r, y_r)\}. By using the above set of x and y values the neural network is trained. The next step after generating the training dataset is training the neural network.

5.3.2 Training the neural network

The system is taught by means of the generated training dataset. Back propagation algorithm is second-hand to prepare the neural network. The effort variables are time and voltage and the productivity is whether system has voltage sag or not. Certain steps are used for training neural network.

Steps for training neural network are as follows.

**Step 1:** Initialize the input weight of each neuron.

**Step 2:** Apply the training dataset to the network. Here \( p \) and \( q \) are the input to the network and \( y \) is the output of the network.

\[
y = \sum_{r=1}^{n} w_{2r1} \cdot y(r)
\]  

(5.1)

\[
y(r) = \frac{1}{1 + \exp(-w_{1r} \cdot (p + q))}
\]  

(5.2)

Equation (5.1) and (5.2) represents the activation function performed in the input and output layer respectively.

**Step 3:** Adjust the weight of each neuron.

**Step 4:** Determine whether the system has voltage sag or not.

Repeat the above process from the starting point to end of the graph.
After completion of training, neural network is ready for application. The next step is the testing of the system graph using neural network to identify whether voltage sag is present in system or not.

### 5.3.3 Testing system graph in neural network

During testing, the system voltage graph is given as input and the network calculates the values from the graph as we take values for generating training dataset. After that the network compares the testing graph value with the reference graph assessment. Condition the test system voltage graph and the reference graph are equal then the amount produced of the system is system has no voltage sag if not the output of the network is system has voltage. After identifying that the system has voltage sag, the next step is calculating the amount of voltage sag present in the system.

### 5.3.4 Differential approach to calculate voltage

Subsequent to detection of voltage sag in the coordination, the after that process is to work out voltage from the graph. For calculating voltage, first calculate voltage from the reference graph and then calculate voltage from the experiment system voltage graph. Obtain dissimilar time with same period and the equivalent voltages is noted in position voltage graph and then find the voltage with similar time in test system graph and then measure up to the voltage values from both graph and the difference between the voltage values between both graphs at same time are illustrious and mean values are taken.

\[
V_{sag} = \frac{Z_F}{Z_s + Z_F} \cdot E
\]  

(5.3)
Where, $V_{sag}$ is the voltage sag, $Z_f$ is the fault impedance, $Z_s$ is the source impedance, $E$ is the nominal voltage.

Through using the above equation voltage sag is considered and next procedure is to diminish the voltage sag in the system by adjusting resistor values in metal oxide varistor.

### 5.3.5 Reducing voltage sag using metal oxide varistor

After calculating voltage sag values, next step is to improve the voltage sag by adjusting the resistance in the solid-state metal oxide varistor. Within solid-state metal oxide varistor, the voltage increases if the resistance is decreased. So, by declining the resistor values in the solid-state MOV, the voltage is greater than before and the system is made to remain in nominal voltage value. To reduce the voltage sag here we derive one formula which shows the relationship between the voltage and the resistor. First the voltage is calculated and then after changing the resistor values the voltage is calculated again. This progression is recurring turn over the voltage reaches its ostensible value. The derivation is as follows.

The power formula of solid-state varistor is given by

\[
I = A \cdot V^\alpha
\]  \hspace{1cm} (5.4)

\[
\alpha = \frac{\log(I_2/I_1)}{\log(V_2/V_1)}
\]  \hspace{1cm} (5.5)

where, $I$ is the varistor current, $V$ is the voltage, $\alpha$ is the voltage index, $V_1$ and $V_2$ are the voltages employed across the varistor in two specific test currents $I_1$ and $I_2$ respectively and $A$ is constant.

Substituting equation (5.5) in (5.4) and simplifying we get,
\[ I = A \cdot V^\log(V_2/V_1) \]  \hspace{1cm} (5.6)

\[ \frac{\log(I_2/I_1)}{\log(V_2/V_1)} = \log_V(I/A) \]  \hspace{1cm} (5.7)

\[ \log I_2 - \log I_1 = X - \log V_2 + \log V_1 \]  \hspace{1cm} (5.8)

where, \[ X = \log_V(I/A) \]  \hspace{1cm} (5.9)

\[ V_2I_2 = 10^X + \log(V_1I_1) \]  \hspace{1cm} (5.10)

Substituting, \[ I_2 = \frac{V_2}{R} \] in equation 5.10, we get

\[ V_2 = \sqrt{R[10^X + \log(V_1I_1)]} \]  \hspace{1cm} (5.11)

The equation 5.11 shows the relationship between the voltage and the resistor. By using the above equation, voltage is calculated and by adjusting the solid-state resistor value, whether the voltage reaches the insignificant value or not is checked. Condition the voltage reaches the nominal voltage value after that it stops functioning. If the voltage does not reach the nominal voltage value then the resistor value is reduced more and the above process is repeated till the voltage reaches the nominal value.

By using the above method the voltage sag in the system gets reduced and these improve both the power superiority and the existence time of the system.
5.4 RESULTS AND DISCUSSIONS

The proposed technique was implemented using matlab software and tested for different voltage sag graphs. First we generated the sine voltage graph using matlab as shown in Figure 5.2.

![Sine voltage graph](image)

**Figure 5.2 Sine voltage graph generated for training neural network**

The above graph is used to train the neural network. The performance, regression and training graph of neural network are shown in the Figure 5.3 a,b,c
Figure 5.3 Neural network to identify whether voltage sag is present in the system or not. a. Performance, b. Training state and c. Regression
Subsequent to training the neural network, the structure graph is experienced using three unusual voltage sag graphs and the obtained output flourish form by by means of our technique is shown.
Figure 5.4  a, c and e are the voltage sag graph that shows the occurrence of sag in three different places and b, d and f are the corresponding sag cleared wave form
Here resistance decreases to reduce the voltage sag in the system. Figure 5.5 shows the graph for resistance change for each iterations and Figure 5.6 shows the corresponding voltage sag change.

**Figure 5.5 voltage sag reduction in each iterations**

**Figure 5.6 Resistance Change in Each Iterations**
The results show the effectiveness of our proposed approach in removing voltage sags from any given power system.

5.5 CONCLUSION

In this paper we proposed a voltage sag reduction method using a graphical analysis technique. Here, voltage sags are reduced by measuring voltage sag values from the graph and adjusting the resistance of the solid-state metal oxide varistor based on the measured values. First, it generated a sine wave voltage graph and the data’s were trained using a neural network. If any voltage sag occurs in the system the solid-state metal oxide varistor operates and reduces the voltage sag and makes the voltage to remain in the nominal value. The approach was implemented in the working platform of mat lab and tested. For testing, we generated different voltage sag graph and our technique was used to reduce voltage sag and make the voltage reach the nominal value. The implementation results showed that our method was effective in removing voltage sags and improving the performance of the system.