RESEARCH ARTICLE OPEN ACCESS

Examination of Electromechanical Over- Current Relay Characteristics By Using Experimental and ANN Methods

Adnan Kakilli, Ugur Kesen
Marmara University, Department of Electronics and Automation, Vocational School of Technical Sciences 34722, Goztepe, Istanbul,
Corresponding Author: Adnan Kakilli

ABSTRACT:
Organizations which are responsible for theelectric power generation, transmission and distribution of the generated energy, has to deliver energy for their consumers. Companies should provide energy constantly with high quality and the cheapest way possible. Power plants are complex structure. Quality and reliability of the provided energy depends on fast and selective protection of it. One of the basic problems of electrical engineering is to protect these kind of facilities and deliver the generated energy efficiently. Protection relay plays a crucial role in deliveringpart of this process. Protection relays have the highest priority for protection of power systems and they are many and varied. In this study, an electromechanical overcurrent protection relay’s operating characteristic curves were obtained, thenexperimentally investigatedand presented. Experiment took place in Marmara University, Laboratory for Electrical Installations The experimental data were estimated using the Artificial Neural Network (ANN) method and the characteristic curves of the run time. Moreover, over-current relay in the validation study was carried out with the data obtained from the mathematical model.

Keywords: Artificial neural networks; Electromechanical relays; Over-current relays; Protection relays

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Date of Submission: 10-02-2018 Date of acceptance: 28-02-2018

I. INTRODUCTION

1.1 Properties of an Efficient Protection System

Switchgears like generator, transformer, line, cutter, splitter etc. can be damaged during an insulation error or short circuit in electrical delivery system. Therefore, errors need to be cleaned as soon as possible to limit the damage and eliminate the negative effects on the stability of the system.

In accurance of a short circuit or insulation error, relays protect the power system immediately or with anacceptable delay. If the changes in terminals happen instantly whenever relay is stimulated by the unit which is related with it then the relay is called instant time relay. Energy systems frequently observed transient faults and short-term overloads. Therefore, for theprotection of power systems, system protection relays which can delay the time are preferred [1], [2]. These protection relays are called delayed time relays. For these relays, delay time can be constant or inverse. Over current inverse time relays are manufactured and grouped in 3 main types: Standard inverse time (SIT) relays, very inverse time (VIT) relays and ultra inverse time (UIT) relays. In these kind of relays work time and work unit are negatively correlated.

Run-time is determined by stimulation magnitude for relay characteristics or operating characteristic curves. Relay characteristics (operating characteristics) curves are logarithmic scaled and plotted as appropriate relays set value, the value is determined by the size of the run-time warning. Different release times are obtained by selecting different curves for same excitation size. In particular this is to ensure the coordination of relay networks fed by successive curves (Time Dial Setting) will benefit [1].

1.1.1 Reliability

Reliability is the ability of interfering any kind of malfunctions with a secure and effective way. The reliability of a device or equipment defines its quality during its operational life. Acquiring the reliability as a numerical value allows obtaining information about the device or equipment’s rate of meeting the expectation during its operational time. The reliability of each device in the system defines the total reliability of security level. Also, parallel protection members are used in order to raise the reliability of the system. In order to raise the reliability over current, short circuit, earth leakage relays and subjective protection relays are used. Thus, in a malfunction moment, the magnitude of excitation is felt by more than one relays and the relay which has the shortest exposure time gives exposure and annunciation command and takes the transformer out of service.

1.1.2 Selectivity

Selectivity is the process that separates only the malfunctioned part from the system in order to keep the continuity of energy in the system, which are separated in protection zones while security systems are planned. These are; link protection zone, bar protection zone, transformer protection zone, feeder protection zone etc. In any malfunction that occurs in this protection zone, the relays that protect the zone activate. If those relays do not getactivated for some reason, then backup protection relays continue to protect the system. Therefore, the protection selectivity is the process that makes the protection setups to keep the other zones continuing the operation by deactivating the malfunctioned operator device after identifying the exact type and spot of the malfunction.

1.1.3 Speed

The malfunction time and equipment damage can be minimized by speed of the reaction time of the protection relays. The quicker the malfunction in an operating device is located and the device is deactivated, the cheaper will be the costs. Additional to that fact, the quick restoration of malfunction also provides the dynamic stability of the grid. Short circuit voltage and the short circuit resistance duration of transformers are related. According to VDE standards, the short circuit resistance duration of power transformers are given in Table 1, depending on rates of percentage of Uk. A power transformative which is Uk percentage equals to 5% and it can resist the short circuit for 2.8 seconds. If it does not taken out of service in the end of the duration represented in the Table 1, high temperature reaches to the ignition temperature of transformer oil and causes it to burn. Thus, in case of a malfunction the transformer and other equipment devices should be deactivated as soon as possible in case of a short circuit or short term over loads.

Table 1 The Short Circuit Resistance Duration of Power Transformers

Uk (%)		3.4	4	5	6	7	8	9	10
Ik/In		28.5	25	20	16.7	14.3	12.5	11	10
Permitted Short Circuit Time (s)	Cu	1.4	1.8	2.8	4	5.5	7.2	9	11
	Al	1	1.3	2	2.5	3.5	4	5	6

1.1.4 Economy

In this paper term economy refersto provision of best protection possible at lowest cost to deliver energy. One of the main concerns of the process of planning and selection of a protection system is cost efficiency of the relay. In this juncture, trade-off between the increased marginal cost of investment for protection and decreased repair time in return must be weighed up against each other. As a result, continuity of power and reduction in time waste for repairs are obtained depending on the ratio of investment in protection systems. In order to increase the efficiency of the system, the use of parallel protection settings sometimes may contradict with the principle of cost efficiency. In such cases, in order to attain the optimal solution, duration of power cut must be foreseen; cost of power cut and cost of protection setting need to be known. The optimal cost of protection settings are determined on graphs obtained, based on the number of unit of over-current relays used.

II. ELECTROMECHANICAL RELAYS AND THEIR USE IN PROTECTION SYSTEMS

Electromechanical relays have been reliably in use for protection of the power systems since the initiation of use of electricity in 1878. In recent decades, developments in semiconductor technology has enabled relays to work faster and more reliable [3]. Electromechanical relays work on a principle of adaptive current or voltage. Depending upon the type and kind of protection in need, relays which correlates with the magnitude of current -current, current-voltage or voltage -voltage are in use [4]. By using these magnitudes together, watt metric relays, directional relays, ratio relays and relays conduct comparison are obtained. There are two drawbacksof electromechanical relays. One of them is their system of operation with a certain amount of friction and the other is in some cases they need mechanical adjustment of their current reaction. During the time due to wear and tear their structural properties deteriorate which in turn leads to deviation from intended use via calibration degradation. In addition to this, another drawback of these relays come up : Electromagnethical relays cannot be remotely observed and alerted about their failures.

2.1 Over-Current Relays

There are wide variety of relays designed in different forms in use for protection from secondary over current and short circuit [6] , [8] – [10]. They illustrate great difference in terms of principle of operation and grouped under four different headings which are;

- Attracted – armature relays
- Induction relays

- Moving – coil relays
- Thermal relays

Among these induction and attracted – armature relays are widely acceptable for usage. Depending upon the structure and requirements of the system in protection one or more of these relays can be used. Each one of these protection relays in question here, should sense the unusual conditions during the operation of the system immediately and turn on the power switches to disable the sections where the error is occured. Working principles of most commonly used attracted-armature and induction relays are explained in terms of their characteristic current–time curves, current settings and properties.

2.2 Induction Type Over-Current Protective Relays

Operating principles of induction relays are similar to the induction motorsoperating principles. Rotation of the rotor is obtained through a moving transmitter (a disc) and magnetic fields placed on various parts of this particular disc. As magnetic fields and stators are fixed, the magnitude of induction applied to these points must be variable. The metal disk is inserted in between the magnetic fields with an insignificant friction and rotates easily.

Induction over-current relays are manufactured in two main types which are directional and non-directional. If the relay was designed to operate in single induction magnitude, regardless of the polarity of the current, it shall operate in single direction. In some cases, relays are required to be sensitive towards the currents beyond where they are fixed only. In such cases, relays are manufactured to operate with both current and voltage induction magnitudes and reverse rotation is mechanically inhibited.

Induction overcurrent relays' switching on time has inverse relation with the current. They generally are manufactured as standard inverse timers. Through percentage switch placed on these relays they can be adjusted to any value between 0 and 100 to coordinate the over-current. The actual operation in essence is nothing more than bringing moving contact and fixed contact closer and apart. Thus, different switching times are obtained at the same relay characteristic and current.

Time lag delays for the over current relays can be calculated by using the manufacturers manuals provided for the particular relay. Over-current relay manufacturers provide characteristic time-current chart for their product based on the magnitude of the current in terms of percentage value for various currents. Time-current characteristics and standard inverse time characteristics correlation of over-current relays manufactured by some manufacturers are given through (1).

$$t = \frac{0.14}{(I_f / I_s)^{0.02} - 1} \cdot \frac{T}{2.97} \quad (1)$$

In this statement: T denotes the time curve (Time Dial Setting), I_s denotes the value of the set current, I_f denotes the faulty current on protective current transformer. The other relay characteristics are obtained through changing the constants of (1).

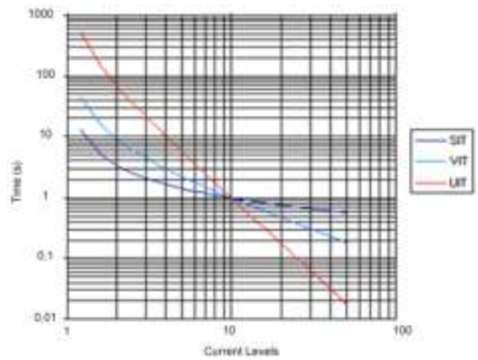

Figure 1 Time-to-current levels of characteristic of standard, over and ultra over inverse time over-current relays

III. ARTIFICIAL NEURAL NETWORKS

The operating characteristics of over-current relay have been observed using multi layered forward feedback propagation in Artificial Neural Networks (ANN) [5], [6]. Optimum topology of the network has been obtained at a level of iteration as a result of experiments and tests conducted and outcomes of which have been analysed. In ANN used at this study, there exists 10 neurons entry layers represents the inputs and single neuron exit layer. ANN's input and output illustration is shown in Fig. 2.

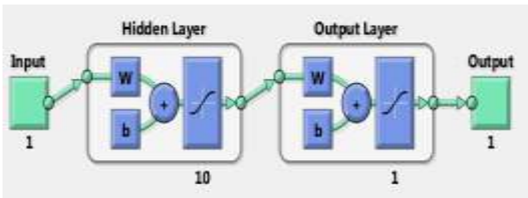

Figure 2 The structure of ANN

3.1 Multilayer Perceptron

Multilayer networks are sometimes called layered networks. They can implement arbitrary complex input/output mappings or decision surfaces seperating pattern classes.

The MLP network generally consists of an input layer, one or more hidden layers and an output layer. The processing units are arranged in layers. Generally an iterative nonlinear optimization approach using a gradient descent search method is applied to MLP. It provides a feed forward neural network, giving the capacity to capture and represent relationships between patterns in a given data sample. The hidden layer neurons have sigmoid activation functions and output neurons have linear activation function [11].

The most common learning algorithm for MLP is error backpropagation, in which synaptic strenghts are systematically modified so that the response of the network increasingly approximates the desired response can be interpreted as an optimization problem. The generic criterion function optimization algorithm is simply negative gradient descent with a fixed step size. This can be very slow if learning rate α is small. Practically, α must be chosen as large as possible without leading to oscillation.Every supervised training algorithm, including the error backpropagation training algorithm, involves the reduction of an error value. For the purpose of weight adjustment in a single training step, the error to be reduced is usually that computed only for a pattern currently applied at the input of the network. For the purpose of assessing the quality and success of the training, however the joint error must be computed for the entire batch of training patterns.

3.2 Calculation of Operation Characteristics of Over-Current Relay by Using Feed-Forward Back Propagation ANN Method

The main reason for using multilayered feed-forward back propagation ANN model [6] is that they are globally recognized approximations and in line of the data available thismodel is the best in terms as performing among ANN models [7]. In previous studies and in literature , there are so many training algorithms for neural network . It is very challenging to know which training algorithm will in presented problems previous chapters. As for the algorithm of training in this particular case Levenberg-Marquardt and Gradient Descent with ANN Adaptive Learning rate has been used for its simplicity and high performance rates.

With standard steepest descent, the learning rate is held constant throughout training. The performance of the algorithm is very sensitive to the proper setting of the learning rate. The performance of the steepest descent algorithm can be improved if we allow the learning rate to change during the training process. An adaptive learning rate will attempt to keep the learning step size as large as possible while keeping learning performance stable. The learning rate is made responsive to the complexity of the local error surface.

The operating characteristic of electro mechanic over-current protective relay has been obtained as a print-out as a result of 190 experimental values obtained through measurement at the laboratories of the power system. 114 experimental measurement values out of 190 experiments (60%) have been inputted into the network as a training set and 76 of which (40%) has been inputted as test set.

The following schema indicates in figures 3(a), 3(b) and 3(c) respectively, Gradient Descent with Momentum used in the training of ANN model, for testing and validation data and finally Mean Squared Error (MSE) of ANN model has been submitted.In this particular case, for the training algorithmGradient Descent with AdaptiveLearning has been used.

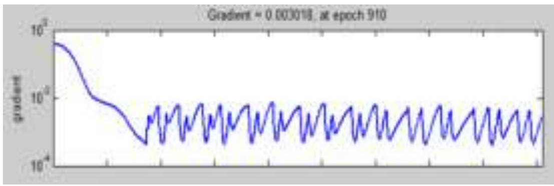

Figure 3 (a) Gradient Descent with Momentum used in the training of ANN model

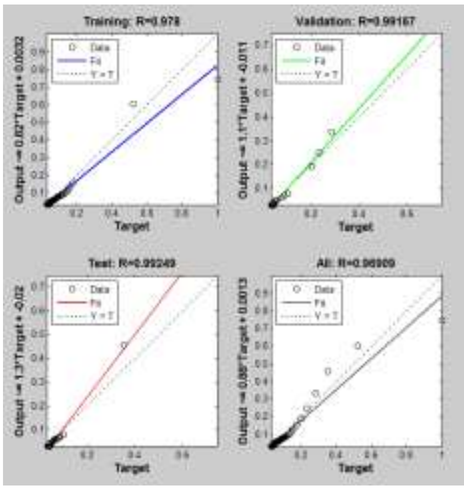

Figure 3 (b) Testing and validation data for performance values used in the training of ANN model

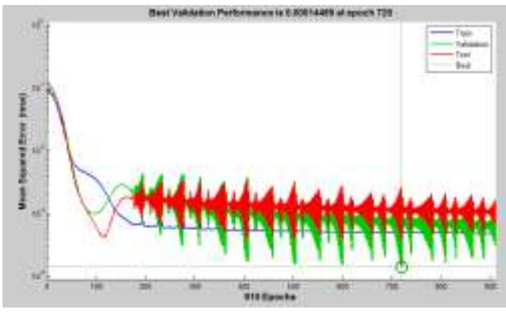

Figure 3(c) Mean Squared Error for the values of validation in training of ANN model.

The following schema indicates in figures 4(a), 4(b) and 4(c) respectively, Levenberg-Marquardtused in the training of ANN model, for testing and validation data and finally Mean Squared Error (MSE) of ANN model has been submitted.In this particular case, for the training algorithmLevenberg-Marquardt has been used. Electromechanic over-current relay experimental setup is given in Fig. 5.

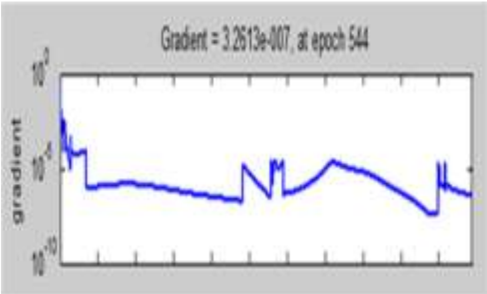

Figure 4(a) Gradient Descent with Momentum used in the training of ANN model

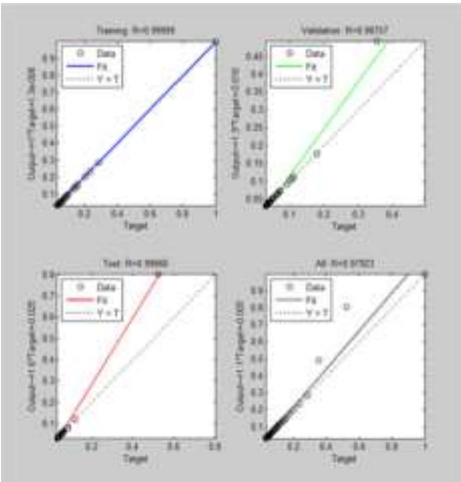

Figure 4(b) Testing and validation data for performance values used in the training of ANN model

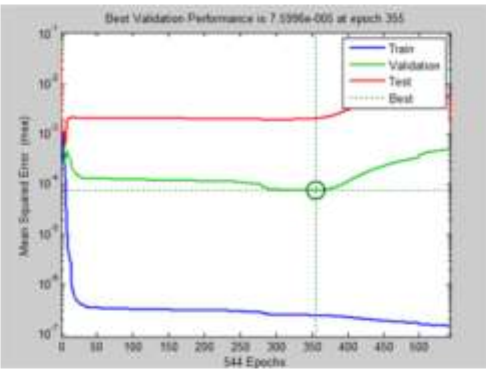

Figure 4(c) Mean Squared Error for the values of validation in training of ANN model.

In this particular case, for the training algorithmLevenberg-Marquardtand Gradient Descent With Adaptive Learning has been used. The Levenberg-MarquardtAlgorithm(%97,9) is the better than Gradient Descent With AdaptiveLearning Algorithm(%96,9).

Figure 5 Experimental Setup of Electro mechanic Over-Current Relay

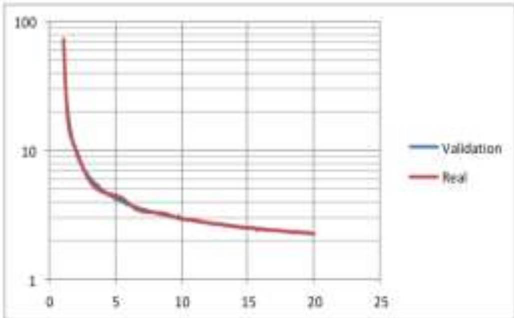

Figure 6 Feed-forward back propagation (ANN) method performance graph

IV. CONCLUSIONAND SUGGESTIONS

According to performance values and graphics represented above, for the forecast of operational characteristics of electro-mechanic over-current protective relay ANN has illustrated a high performance with 97.9% accuracyas seenin Figure 6. When calculation methods are taken into the consideration it has been noticed at contrary of conventional methods, ANN works with high performance and speed. To sum everything up, ANN becomes the ideal tool in solution of complex problems in electrical system’s delivery and safety, because its ability to eliminate the need for traditional statistical techniques such as regression. This elimination of complex mathematical expressions reduces the burden of mathematical calculation. Conduct of such studies exemplify effective use of ANN which is a form of artificial intelligence techniques.

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Adnan Kakilli. " Examination of Electromechanical Over- Current Relay Characteristics By Using Experimental and ANN Methods" Journal of Engineering Research and Application (IJERA) 8.2 (2018): 01-06