An intelligent overcurrent relay to protect transmission lines based on artificial neural network

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ABSTRACT

Power systems are susceptible to faults due to system failures or natural calamities. This could be caused by damage to power system components, resulting in an interruption of power delivery to clients. Overcurrent relays are important relays that protect distribution feeders, transmission lines, transformers, and other components. The intelligent relay can perform both primary and secondary functions. Line-to-ground (L-G) faults are the most common occurrence in long transmission lines, posing a serious threat to electrical equipment. This article presents improved fault classification for transmission line overcurrent protection and highlights the use of artificial neural network (ANN) techniques to protect transmission lines of 100 km (terco type). An ANN is used to classify the faults. A back propagation neural network (BPNN) is used in this case. The neural network has been trained to classify faults in transmission lines for overcurrent protection. Various fault conditions are considered. In the event of a fault condition, the output of a neural network will be a tripping signal. The MATLAB neural network tool and the Simulink package are used to model the suggested method.

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1. INTRODUCTION

Faults are currently an important issue in the power system network. With rising electricity demand, the distribution system for electricity is expanding year after year. As a result, protection and maintenance of power system equipment are crucial for lowering prices and extending the lifetime of dependable and unbroken components of the power system [1]–[3]. The electricity grid should always be operated safely. Faults will cause a partial or total system blackout. To safeguard the power system from disruptions, a protective mechanism is required. To address this issue, a variety of protective relays are available [4].

Overcurrent relays are one type of protection relay that is used to protect power system circuits. By measuring the current value, an overcurrent relay detects a failure in the power system and separates the faulty zone from the rest of the system. It can be used to safeguard transmission or distribution feeders, transformers, bus couplers, and other components as either primary or secondary protection [5]. Fault analysis can aid in the selection and development of the appropriate protection apparatus. Due to the high value of current in the three-phase fault compared to other faults, CBs and their specifications should be introduced as soon as possible [6].

Over the last several years, there has been a lot of study done on the applications of artificial neural networks (ANNs), particularly in the field of the pattern recognition. The ANNs try to replicate the human brain's processes of generalization and learning [7]. This strategy is focused on distinguishing between operating states and defects [8]. As an academic study, artificial neural network (ANN) methods are successfully implemented in many recognition or pattern challenges. ANN approaches are regarded as a healthy condition for recognition [9].

Each neuron in an artificial neural network performs the task of aggregating external inputs and providing an output based on the aggregated inputs. Synaptic weight is a numerical strength assigned to a relationship between two neurons. The development of ANN is divided into two stages: preparation and testing. ANN training is accomplished by presenting the network with examples referred to as “training sets” [10]. This study aims at determining the many varieties of rumor faults, which are classified as symmetrical and asymmetrical faults. To evaluate this circuit and acquire data on the various simulation constraints of fault types, the MATLAB environment is used.

2. AIM OF THE STUDY

The purpose of the research is to use the ANN technique to identify all kinds of faults, reduce delay time, and protect transmission lines only during faults in their zone. Because of the good coordination, ANN output is preferable to computed output. Furthermore, ANN output reduces miscoordination time and increases relay operational time. This work was utilized in the back-propagation ANN method, and ANN technology complete an adaptive procedure any defect classifier.

3. LITERATURE REVIEW

Shagila and Rajeswari [10], employed ANN for overcurrent relay protection to identify the fault. They concluded that the NRDE Board's overcurrent data was trained in ANN and implemented through coding. When an overcurrent condition is detected in NRDE testing software, a trip command is generated. Karupiah *et al*. [11], examined the relay's TMS and PS settings throughout a fault incidence to suggest a new relay operation time and anticipate the relay's miscoordination time using ANN. They found that the ANN output is more appropriate than the computed output since it demonstrates strong coordinate. Furthermore, the ANN output minimizes miscoordination time while increasing relay operational time. Thoeurn *et al*. [12], The Bayesian regularization backpropagation neural network (BRBPNN), which is used to represent nonconventional curves, was investigated. They established that the BRBPNN is a reliable method for modeling the characteristic curves of overcurrent relays (OCR). It is evident that the errors between real data and the simulation and real-world use of a prototype are extremely satisfying.

4. THE PROPOSED METHOD

Overcurrent protection is the protection that occurs when the magnitude of the current exceeds the predicted pick-up value (setting value). A system short circuit usually results in a decrease in circuit impedance. and hence the failure is accompanied by a significant current. Overcurrent protection safeguards against overloads [13]. When the input current value exceeds a certain threshold, the overcurrent relay detects it and sends a signal to the C.B., disconnecting the protected device by opening its contact. When a fault is detected by the relay, the clause in this case is recognized as “fault pickup”. When a flaw is detected, the relay can promptly send a trip signal. prompt the overcurrent relay or bid for a predetermined amount of time before issuing a trip signal [14]–[17]. The “relay operational time” is the time it takes the relay to calculate it, and it is calculated using the microprocessor's protection algorithm [18], [19]. The logical form of an overcurrent relay is shown in Figure 1.

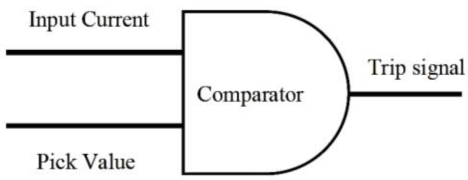

Figure 1. Overcurrent relay logical representation

Overcurrent relays are categorized into three classes based on their operation time:

- Instantaneous overcurrent relays: When a problem is detected, these relays immediately send a trip instruction to the breaker (because the value of the input current is greater than the present value). They have no deliberate timing lag. They are typically implemented near the source, where the fault's current is relatively large and a minor delay in relay functioning could result in catastrophic equipment damage.
- Definite time overcurrent relay (DTOR): This sort of overcurrent relay serves as a backup protection device. When there is a fault in the line and the distance relay is not detected and does not send a signal to C.B., after a predetermined delay, the relay sends a signal to C.B. In this situation, the relay has been delayed for a duration significantly longer than the distance relay's normal operating time as well as the operating time of C.B.
- Inverse definite minimum time overcurrent relay: A relay's operating time is inversely proportional to the fault current and vice versa. When the fault current is very high, the operating time is shortened. It may be rated for a wide range of fault currents and operation times [1], [20]. The flowchart of the overcurrent relay protection for transmission lines is depicted in Figure 2.

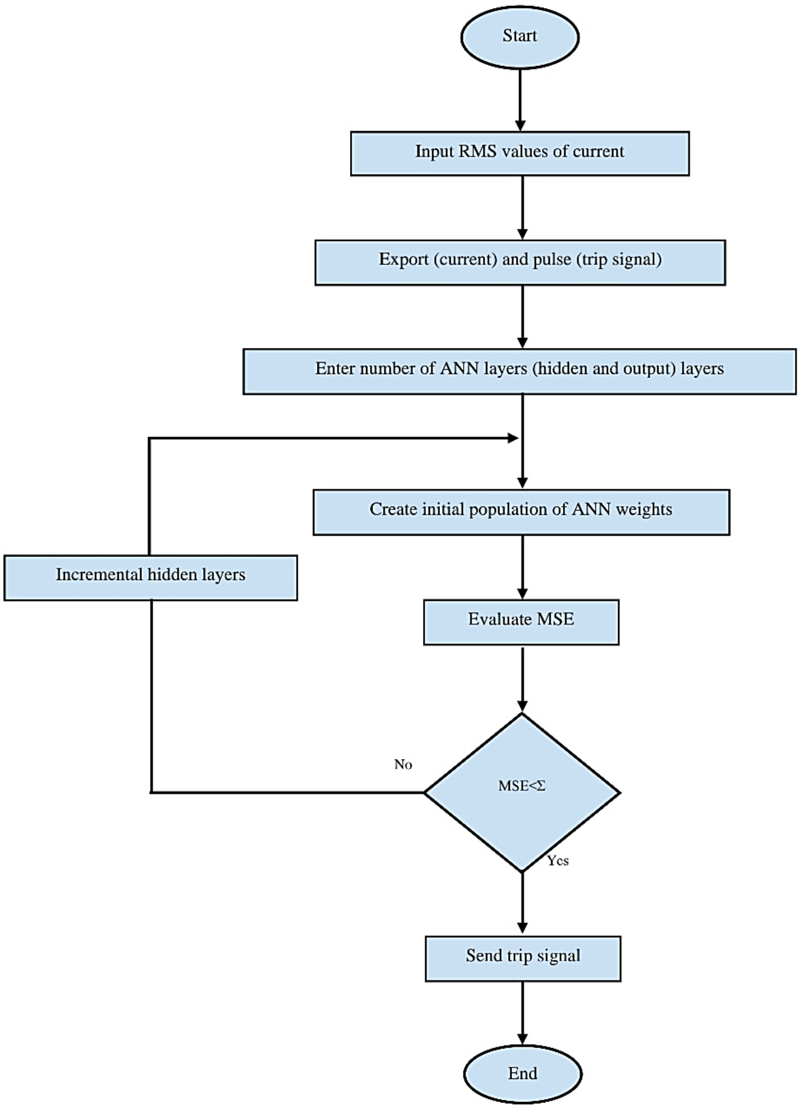

Figure 2. Flowchart of ANN structure for transmission line protection

The input data is the load currents, and the pickup current is set to 1.2 A. The fundamental overcurrent prevention algorithm compares the measured current value to a preset value. If the value of the input current is greater than the present value, as confirmed via simulation, it is supplied in the ANN functional fitting training in MATLAB to find an improved ideal relay operation time. As a result, the ANN values acquired can be utilized to generate a new time setting for the relay operation as well as anticipate the more likely timing of the relay operation. When an overcurrent condition is detected, the protection algorithm transmits a signal to the breaker, which in turn cuts off the protected circuit.

5. MATERIALS AND METHOD

The data for this study was obtained from a Swedish company for a three-phase model of a 100-kilometer-long overhead electricity transmission line (Terco Company). The Terco-prototype of a transmission line, as illustrated in Figure 3, was used in this investigation; Table 1 shows the data of the line used. The multipurpose relay model is evaluated under various fault conditions. A Terco (MV2221) transmission line was used in the scheme of protection's design, and the MATLAB/Simulink environment was used for the implementation.

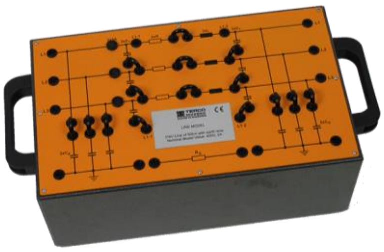

Figure 3. Terco-prototype of transmission line (MV2221 line model)

Table 1. The Specifications of Terco-prototype of transmission line

Parameters	Terco company
Lounge of transmission lines.	100 Km
Voltage	230 kV
Ability	110 MVA
Resistance	2.20 ohm
Inductance	25 mH
Capacitance	4 uF
Dimensions	410×245×160 mm
Weight	10 kg

6. RESEARCH METHOD

MATLAB provides an appealing environment with hundreds of dependable and efficient built-in algorithms. These functions aid in the solution of a wide range of mathematical problems, including linear systems, matrix algebra, nonlinear systems, differential equations, and many other sorts of electrical machine-related technical solutions. Figure 4 shows the modeling circuit for over-current relay protection.

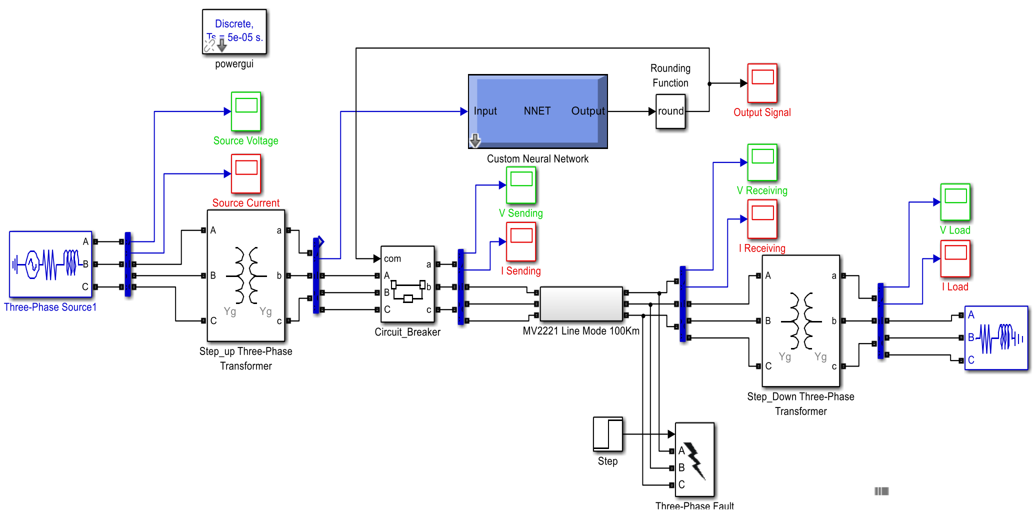

Figure 4. Over current relay protection circuit modeling

7. ANN TECHNIQUES

The ANN is seen as a machine that functions similarly to the human brain. It possesses learning, capacity, and generalization qualities [21]. It may also be characterized as a group of artificial neurons that rely on a set of separate mathematics models for information processing, which are based on a relationship method of computing [22]. The most significant component of this method is its ability to grasp and understand the model's behavior through prolonged data training, resulting in satisfactory and desirable outputs. As a result, the ANNs algorithm is used to identify the different types of faults [23], [24]. ANNs methods were trained with a range of parameters, and the suggested relay-based ANNs were trained with "nntool". The number of output neurons was decided by the goal number, the number of neurons in the input layer, on the other hand, was determined by the number of training samples. Finally, the number of hidden neurons within the hidden layer was calculated through trial and error [25]. The internal structure of the proposed ANN is illustrated in Figure 5.

Back-propagation is the most widely used and effective method for generating multilayer feed-forward networks. Backpropagation learning is divided into two stages: forward and backward. During the forward phase, the input signals pass across the network layer, finally creating a response at the network's output. When an actual answer differs from the anticipated (target) response, error signals are generated and sent backward through the network. The network's free parameters are modified during the backward phase of operation to reduce the sum of squared errors. Back-propagation learning has been used successfully to solve a wide range of challenging problems [26]. The output layer was connected to the hidden layers, as seen in Figure 6. Figures 7 and 8 illustrate the performance and state plot of the trained ANN. Figure 9 illustrates the regression performance plot.

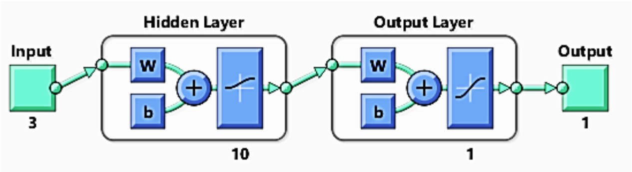

Figure 5. Internal structure of the proposed ANN

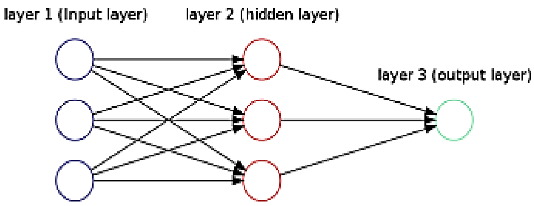

Figure 6. ANN's internal architecture

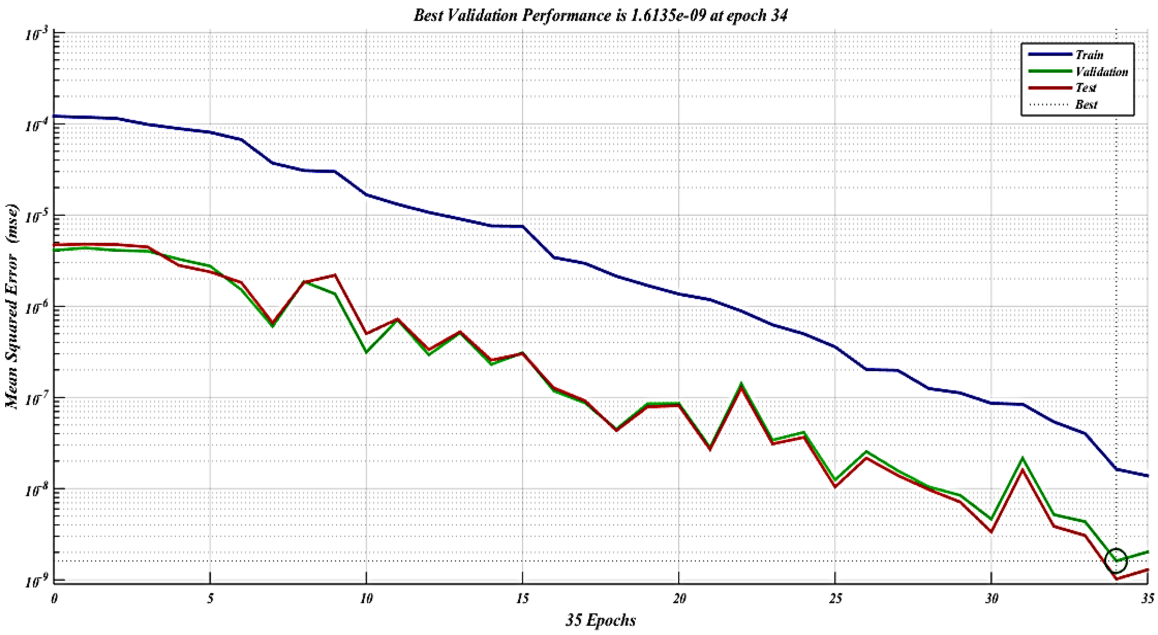

Figure 7. The effectiveness plot of the trained ANN

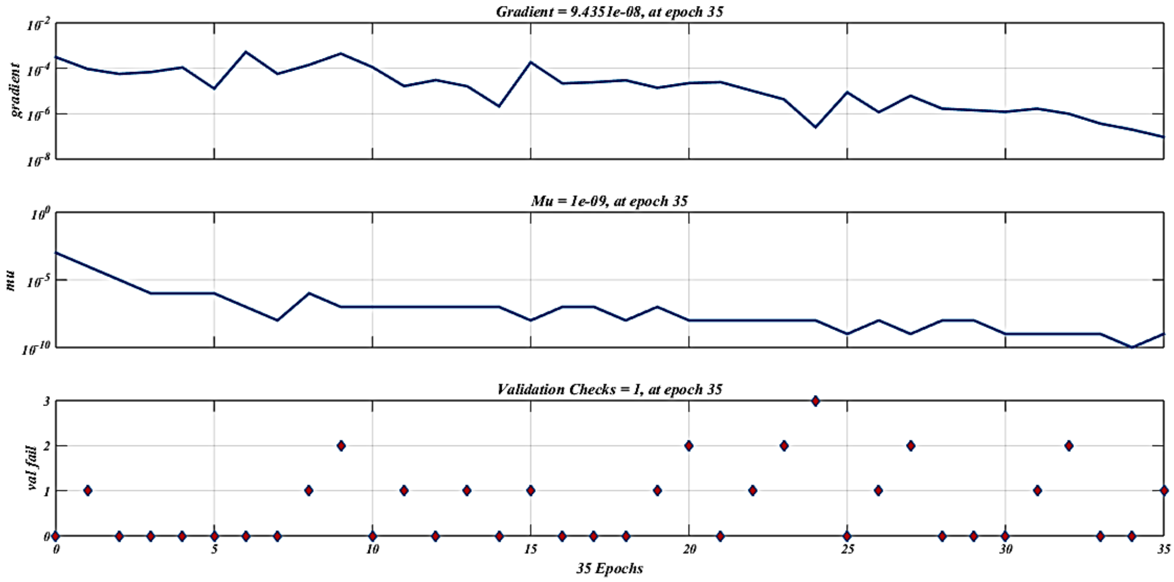

Figure 8. State plot of the trained ANN

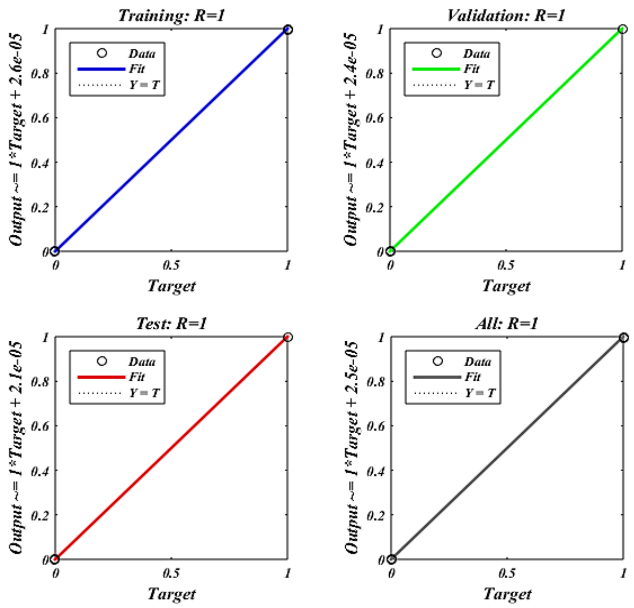

Figure 9. Regression performance plot

8. DISCUSS THE RESULT

8.1. Normal operation

In the power system's normal operation, if the current value is less than the reference current (setting current), the trip signal is not sent to a circuit breaker (C.B.). Figure 10 represents the output signal of the intelligent relay without faults, where a value of one means there is no fault and a value of zero means there is a fault. Figure 11 shows the current in the transmission line with no faults.

8.2. Fault situation

In the power system's fault situation, if there is a fault in one of the lines with ground, the fault current becomes very high compared to the reference current (setting current). In this case, the trip signal is sent to the C.B. after 4.4 ms, which is very fast. Figure 12 represents the output signal of the intelligent relay with faults, where a value of one means there is no fault and a value of zero means there is a fault. Figure 13 depicts the transmission line current with one line faulted to ground. Figure 14 depicts the transmission line current with tow line faults to ground. Figure 15 illustrate the transmission line current with faults on three lines to ground.

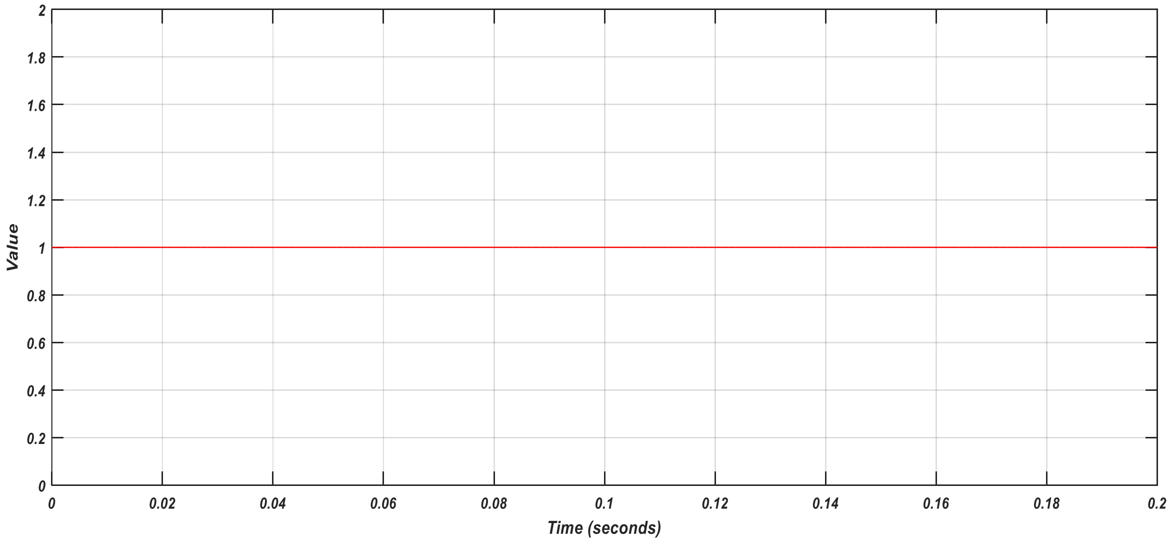

Figure 10. Output signal of the intelligent relay without faults

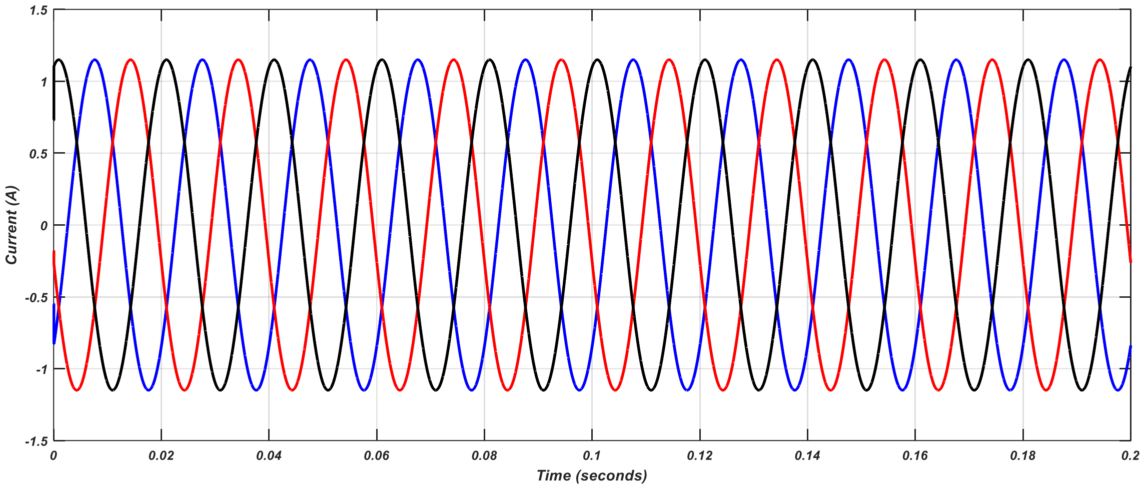

Figure 11. Current of the transmission line with no faults

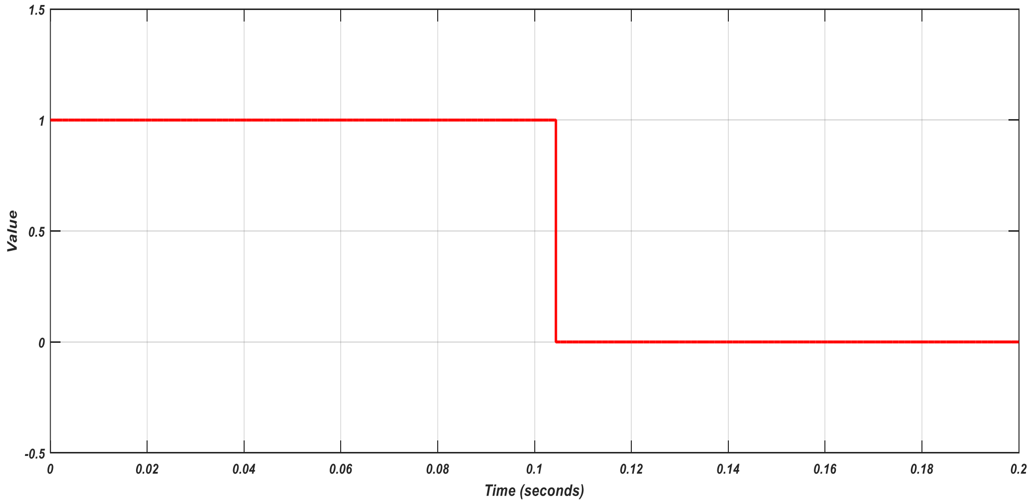

Figure 12. Output signal of the intelligent relay without faults

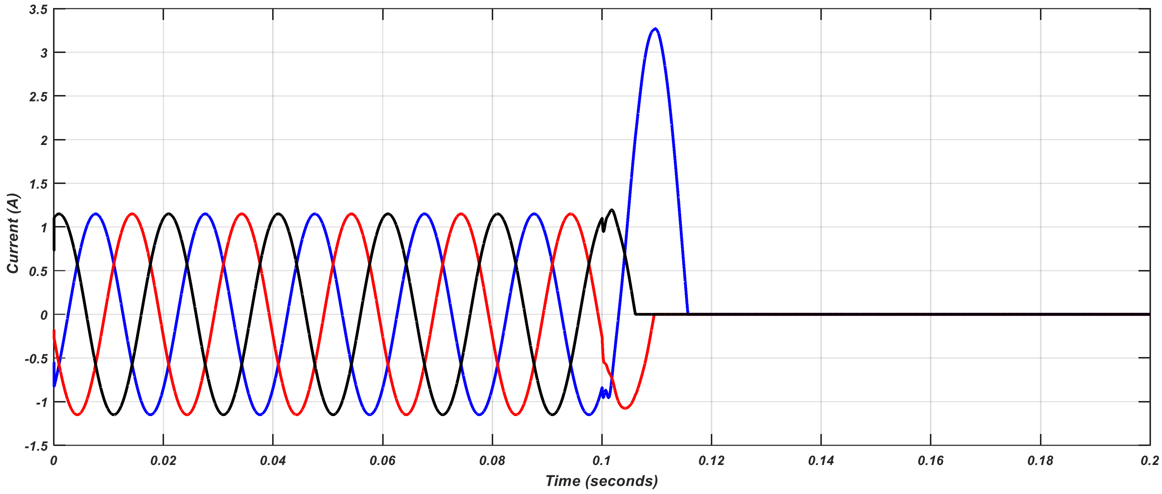

Figure 13. Transmission line current with faults on one line to ground

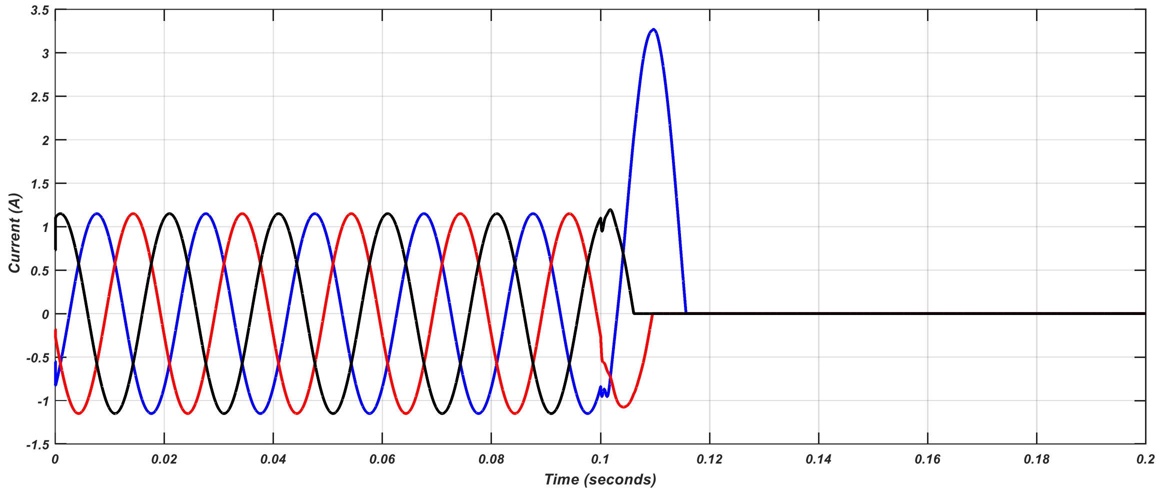

Figure 14. Transmission line current with faults on two lines to ground

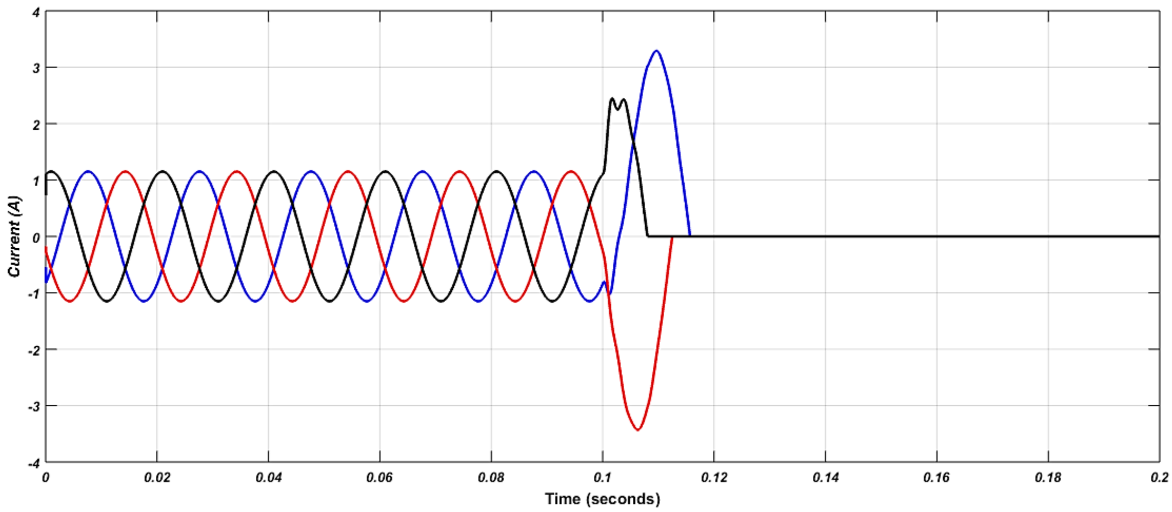

Figure 15. Transmission line current with faults on three lines to ground

9. CONCLUSION

In the MATLAB environment, the ANN structure represented the overcurrent relay properties. A new overcurrent protection algorithm for transmission line faults was used to simulate a 100-km transmission line (Terco type) in MATLAB/Simulink with actual parameters. Furthermore, transmission line currents with defects on lines 1, 2, and 3 to ground were investigated. The results indicate that when no faults occur and the current is normal, the current value is less than the reference current, and the trip signal is not transmitted to a circuit breaker (C.B.). The results show that if a fault occurs in one, two, or three of the grounding lines, the fault current becomes quite high in comparison to the reference current (setting current). After 4.4 ms, the trip signal is forwarded to a circuit breaker (C.B.). This very short time gives great importance and reliability to protecting the electrical equipment in the electric power system. According to the simulation findings, the proposed overcurrent relay is a good solution. The dependability, security, and speed of operation of the ANN-based overcurrent relay appears to be promising for power system protection. The results suggest that the proposed technique yields considerable outcomes. Furthermore, ANN output reduces miscoordination time and speeds up relay operation time, while the time between the open circuit breaker and the trip signal is very short. That means the intelligent relay used gave good results.

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