International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 11, No. 1, March 2020, pp. 505~514
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v11.i1.pp505-514

Improvement of protection relay with a single phase auto-reclosing mechanism based on artificial neural network

Zozan Saadallah Hussain[1], Ahmed J. Ali[2], Ahmed A. Allu[3], Rakan Khalil Antar[4]
[1,3] Technical Institute, Northern Technical University, Iraq
[2,4] Technical College, Northern Technical University, Iraq

Article Info

Article history:

Received Mar 26, 2019
Revised Jul 8, 2019
Accepted Oct 22, 2019

Keywords:

Artificial neural network
Fault classification
Matlab\Simulink prog.
Power system
Single phase auto-reclosure

ABSTRACT

This paper presents a developed logical tripping scheme to improve conventional protection performance. Adaptive single pole auto-reclosure (ASPAR) system is proposed that considers, automatically tripping and reclosing of a multi-shot independent pole technique of a circuit breaker at a predetermined sequence, which can be used to boost the synchronization of the power grid under the transient fault conditions. Moreover, the ASPAR can be utilized to enhance the electrical system stability and reliability at the same operating conditions. Based on the three-phase system, the Artificial neural network (ANN) in this work has been done in order to diagnose and detect healthy and faulted phases. The proposed ANN-fault classifier method consists of the logic gates, router circuits, timers, and positive and negative sequence analyses circuit. In addition, it is used to give the ability to recognize a fault type, which by training on the sequence angle values and coordination of the transmission line. Three-phase overhead transmission line including the proposed ASPAR is built in MATLAB\SIMULINK environment. Thus the performance ANN-fault classified is tested under different fault conditions. Simulation results show that the proposed ASPAR based on ANN is accurate and well performance. Whereas resultant tripping and reclosing signals of ASPAR are successfully provided that enhances the circuit breaker mechanism under these operating condition.

Corresponding Author:

Zozan Saadallah Hussain,
Technical Institute,
Northern Technical University,
Mosul, Iraq,
Email: zozan.hussian@gmail.com

1. INTRODUCTION

Detection and classification of faults occurred at transmission lines are considered an important factor in correctly, safely and reliable operation of protection relays. Intelligent technologies had been widely used in various areas of electrical power applications that require a consciously monitoring to ensure the reliability of the system to equip consumers with uninterrupted power [1]. Different types of these methods have been handled to detect and identify the transient and permanent faults that occur because of external influences such as natural disasters or due to increase loads more than the capacity of the generation system. A fuzzy systems technique was used to detect and classify faults because of it has a great ability to analyze the changes that occur in the elements of the power system at the instant of occurring failure [2-3]. However, this technique suffers from the problem of selecting the type of membership functions of the controller, which had been solved by using intelligent neural networks. It is function is to decide and choose the shape, number, and type of these functions [4].

Conventional Neural Network is a suitable tool used in the applications of power system. Artificial Neural Network algorithm (ANN) is applied accurately to identify and classify different types of grid faults. An algorithm of the Marquardt Levenberg type employed with double circuit structure. Three-phase voltages and six-line currents are used as input patterns for ANN. It can be used to detect and classify all line-to-ground fault types, which occurred in three phases of both transmission line circuits which resulting in breakdown the insulator [5-10]. The mutual effect problem that occurs in double circuit power system transmission lines causes inaccurate operation of the traditional protection device. CNN has been trained to overcome this problem depending on current magnitudes at sending end to detect faults [11-12]. To overcome this problem and detect the fault types, it is important to realize the fault resistance and harmonics contained in the fundament component of line currents. Have a deep knowledge about the fault resistance and harmonics contained in the fundament component of line currents. Another neural network structure called a radial based function algorithm with three-phase currents as an input was introduced to give an indication about fault location. Two separate neural networks are used, the first model for line-ground faults while the other for phase angle faults [13].

A single-phase auto reclosure SPAR based on adaptive technique used to distinguish between required time for extinguishing the arc and nature of fault that occurred on the transmission line. Thus, to avert any adverse effects of conventional SPAR due to these transients, it is important to improve the conventional SPAR technique [14-15]. Moreover, this technique is convenient for supply continuity of a transmission system during and after a transient fault and since power can be transmitted through the remaining healthy two phases even during dead time, thereby increasing of transmission power capacity and the maximum transmission power is restricted by system stability. Also, various methods have been presented for transient stability improvement of the recent power systems [16]. A wavelet transform approach has been used to discriminate the stability of power system enhanced in both uncompensated and compensated systems [17]. Also wavelet based on Clarke's transformation is used to obtain the fault current as a new algorithm for fault location and classification [18]. While in [19], discrete wavelet transform method and Fast Fourier Transform algorithm are compared to detect the fault location of double circuit transmission line. A fuzzy logic method was used to improve the performance of traditional auto reclosure. It is used to detect and classify symmetrical and unsymmetrical faults at single and double circuit transmission lines. This type of intelligent classifier discriminates faults based on angles between positive and negative sequence components [20].

In this paper, a conventional auto-reclosure with the adaptive SPAR system is improved depending on ANN to enhance transient stability. The ANN-fault classifier method that employed for line fault is implemented to be able to recognize different fault types. In case of the line to ground fault, here the resultant tripping signals is only assigned to faulted phase. In meanwhile, the power flows in other two healthy phases under the transient fault conditions. Considering that, it is a potential issue to improve the transient stability of the power system. That can be achieved by avoiding unnecessary tripping signals to the healthy phase circuit breaker. The proposed algorithm is simulated and tested with three-phase electrical power system using MATLAB/Simulink.

2. POWER SYSTEM SIMULATION

The power system is designed, simulated and modeled by Matlab\Simulink to estimate faulted lines, and protect transmission line through trip/auto-reclosing the fault based on ANN technique. The study system consists of a (500 kV) overhead transmission line as a single circuit. The parameters of line specimens (R, L, and C per km) are defined in positive and zero-sequence components. A Synchronous generator is connected to the transmission grid through a 13.8 kV/500 kV (Δ/Y_g) transformer as illustrated in Figure 1. In order to test different faults at the power system, a 3-phase fault block is allied at the transmission line to simulate faults along the line.

Different faults such as phase-to ground (AG), phase-to-phase (AB), phase-to-phase to ground (ABG) and three phases-to-ground faults (ABCG) are tested. Line voltages and currents signals are used as inputs of the protection system, which consists of definite time over current relay (DTOCR), positive, negative and zero sequence calculation, faults classifier using ANN, and ASPAR system of the multi-shot independent pole mechanism blocks as shown in Figure 1.

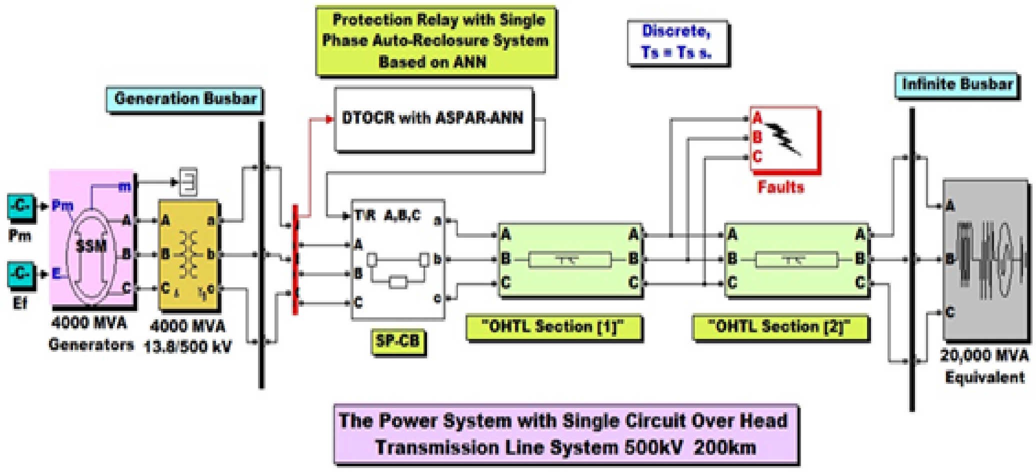


Figure1. Electrical power system model

In this work, a characteristic of the conventional definite time over-current relay is utilized to detect the fault occurrences. The conventional fault detection based on this relay gives tripping and reclosing signals to all poles of the circuit breaker. That is only achieved apart from selecting a pole of the circuit breaker that belongs to healthy or faulted phases. However, the proposed ASPAR based on ANN is employed to specify the tripling single required for a curtain pole of the circuit breaker. This can allow isolating only the faulted phases. Otherwise, unnecessary tripling singles are blocked from sending to other circuit breaker poles of the healthy phases.

3. ARTIFICIAL NEURAL NETWORK STRUCTURE

ANN is considers one of the common methods used to detect and distinguish different types of faults occurred on power system. This due characteristic of ANN where they do not need a wide information base about faults compare with classification methods. ANN consists of many layers and each of them contains several neurons, which are interconnected to each other. A system structure choosing depends on the categorization problem that contains fault samples [21]. Detection of faults is nonlinear process, therefore it require to a nonlinear solver like ANN to handle it. ANN has the ability to deal with any incomplete mathematical problems like missed or corrupted data. In addition, it can solve any mathematical matter without requirements for approximation the model. All of mentioned above make ANN is the preferred way to treat the faults of transmission line over other methods. Also, it displays a good fault location and classification in case of existence resistance of the faults and variation of power system factors. Therefore ANN is widely used in power system applications [22-23]. Then it is designed to detect and classify the fault depending on the following steps [24]:

a) Training the ANN system, depending on the proper data.
b) Choice the suitable ANN structure for a given implementation.
c) Training the ANN.
d) Appraisal of the trained ANN using test patterns until its accomplishment is cogent.

3.1. Training of ANN Based Fault Classifier Scheme

The algorithm of Back Propagation Algorithm (BPA) is central to much current work on learning in neural networks. This learning rule, also known as a Generalized Delta Rule, then it gives a description for varying the weights in any feed-forward system. In BPA case, a supervised learning is used as the network will be trained using the data created from the simulation model of transmission. Various neural network architecture, training algorithms and transfer functions were studied to decide upon the final neural network model for fault detection system [25]. Also it has been proven is the preferred learning method among others due to it is simple structure, very fast NN training process and easy to implement in different learning applications like speech recognition, detection and classification of faults, image processing and adaptive control [26].

The neural nets used in this study are trained by the BPA proposed by Rumelhart. At the beginning of the training process the generated weights are selected randomly and the output signal is calculated using equation 1 as shown below. At the end of this sage, the error signal (difference between output and target signals) for all iteration is taken into consideration where it sent backward to the weights, and the learning process will continue until the error value equal to acceptable value depending on the actual problem. The data received from outer environment (or other neurons) are transferred to the neurons in the hidden layer(s) through weights which adjust using the summation function and then uses an activation function; it is used to express the ANN, which consist of basically the input data to the network, some hidden layers and an output layer are connected to form it as shown in Figure 2. [13]. The weights of neuron are (W_1, W_2, .., W_N) are used to calculate the value of input parameters X , where X=(X_1, X_2, …, X_N) . Then the output (y) = (Y_1, Y_2, …, Y_N) of each neuron is calculated by equation 1. They are trained in order to implement a specific mission by adjusting both weight and base of the neurons for all layers [23].

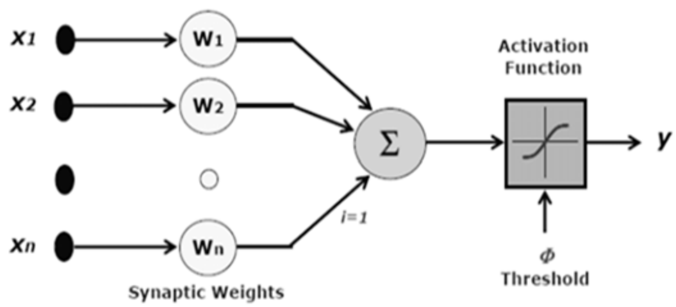


Figure 2. Perceptron representation

$$y = \sum_{i=1}^{n} w_i . x_i - b_k \quad (1)$$

Where (b_k) known as a threshold or bias value, where the neurons produce an output if y is greater than zero. If the number of neurons and hidden layers increase, the detection and classification features of ANN will rise, and then are updated continuously through training process of the neural network. Several procedures (algorithms) had been established to train neural network according to type of problem [24].

In current work, the detection and classification of line-ground faults is implemented by using ANN-fault classifier in a 500 kV transmission line. A feed-forward with back propagation learning algorithm had been used as a fault detector and classifier. As illustrate in Figure 3, the ANN scheme depended on inputs angles are (Ang_A , Ang_B, Ang_C) relative to phase (A, B, C) respectively, which are calculated from 3-phase sequence analyzer circuit. These angles based on zero, positive, and negative sequence components are calculated using the following equations [26].

$$I_{a1} = I_a + a \, . I_b + a^2 I_c \quad (2)$$

$$I_{a2} = I_a + a^2 . I_b + a . I_c \quad (3)$$

$$Angle - A = \left| I_{a1} - I_{a2} \right| \quad (4)$$

$$Angle - B = \left| a^2 I_{a1} - a . I_{a2} \right| \quad (5)$$

$$Angle - C = \left| a . I_{a1} - a^2 .. I_{a2} \right| \quad (6)$$

The results of these relations are shown in the in Table 1. The symbol (a) is ($a = 1\angle 120°$) and (I_{a1} and I_{a2}) represent the positive and negative sequence components of the currents after fault refer to phase "a".

Table. Typical values of ANN angles during detection and reclaim time at different fault types

Fault Type	ANN Angles During Detection Time			ANN Angles During Reclaim Time		
	Angle (A)	Angle (B)	Angle (C)	Angle (A)	Angle (B)	Angle (C)
a-g	38	158	82	121	1	119
b-g	82	38	158	119	121	1
c-g	158	82	38	1	119	121
a-b	40	80	160	120	120	0
a-c	80	160	40	120	0	120
b-c	160	40	80	0	120	120
a-b-c	67	53	173	20	140	100
Hearlty	31	151	89	26	146	94

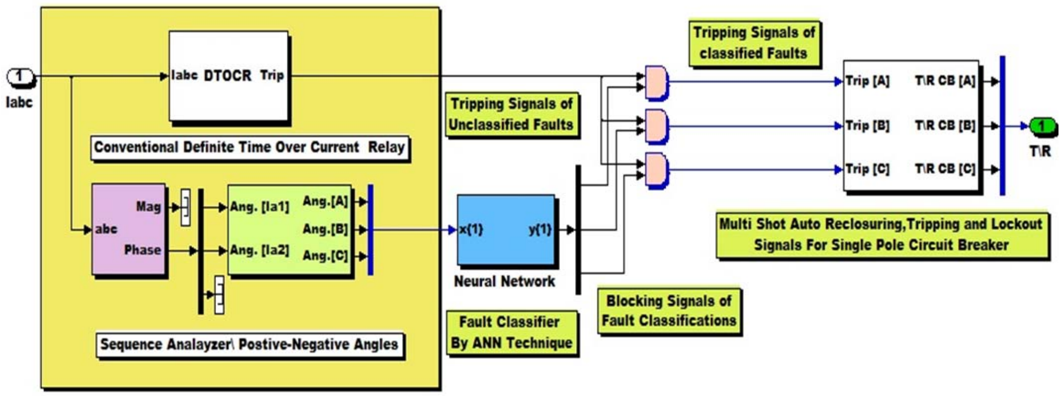


Figure 3. Simulation scheme of ANN-based fault classifier utilizing MATLAB/SIMULINK program

4. PRINCIPLE OF THE PROPOSED NEW LOGIC ASPAR WITH MULTI-SHOT SCHEME

Majority of the faults that occur on the overhead transmission line are transient in nature. These faults are caused by the breakdown of air surrounding the insulator due to abnormal transient over-voltages or by passing of objects near or through lines (birds, vines, tree branches etc.). These situations result in arcing faults can be extinguished by energizing simultaneous opening of circuit breaker (C.B) on both ends of the line or on one end of the line. Since the cause of transient faults disappears after a short time, the C.B can be reclosed the moment the arc in fault has been extinguished and the path has regained its dielectric strength [14]. Hence, auto-reclosing is attempted for the purpose of restoring the transmission line to service and suitable in improving the continuity of service. Further benefits of auto-reclosing are [27]:

- Improvements in transient stability.
- Improvements in system reliability.
- Minimizing of switches over voltage.
- Minimizing of shaft torsional vibration of bulky thermal units.
- Minimized unsuccessful reclosing using variable dead time.

When three-phase auto-reclosing is applied to single circuit interconnections between two power systems, the three phases are tripped whether single-phase fault or multi-phase fault are occurring this may cause the two systems to drift apart in phase. If only the faulty phase tripped, synchronizing power can still be interchanged through the healthy phases, also shorter dead time can be set in this mode when compared to the single phase auto-reclose. Therefore, it is not necessary to interrupt services on the other two phases [27].

In this research ASPAR method has been proposed to automatically operate the C.B according to a predetermined sequence of open and close operations; which consist of the 3-phases auto reclosing. Each unit of the auto-reclosing circuit operates independently on the other two phases for tripping and reclosing mechanism as shown in Figure 4, which is the simplified scheme logic for the single-pole auto-reclosure.

The logical elements include S-R flip-flops, AND, NAND, NOR, Time delay, dead time block for each shot, and counter for the three-shot auto-reclosure after that design resets if reclosure is successful within the chosen number of shots. When a fault occurs on a transmission line, the single pole auto-reclosure at each end open to separate the faulted line, remain open for a specified time (delay time)) then. If the transmission line fault has cleared, then the ASPAR remains closed and the transmission system returns to its pre-fault condition. If the fault still exists, then in this case the ASPAR is designed to have up to three open-close operations and after these a final open operation to lock out the all three poles of the circuit breaker. The counting mechanisms register processes of the phase or earth fault units which can also be initiated by externally controlled devices when appropriate communication means are available.

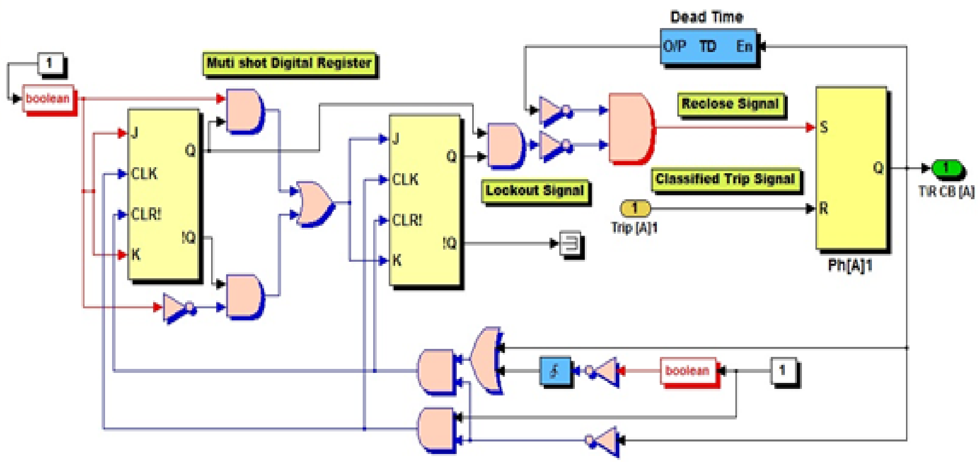
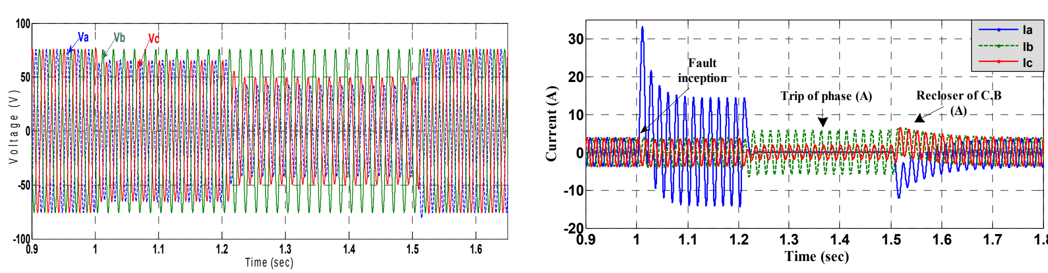


Figure 4. Single-shot auto-reclose scheme for transient and permanent faults

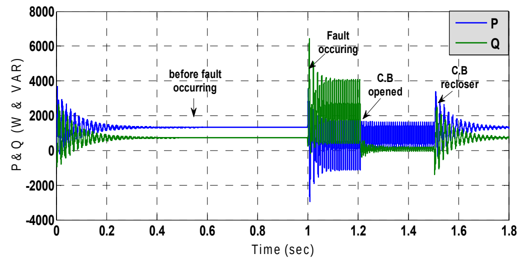
5. SIMULATION AND RESULTS

The tripping/reclosing system and the proposed ANN-based fault classifier/detector at different faults are simulated to investigate the ability of this scheme for fault type detection, tripping the faulted phase and after the fault extinguish the faulted phase auto-reclosure.

A phase-to-ground (AG) fault is applied at time =1sec from the start of the simulation. After the fault start, the current in respective phase (A) will increase and the protection system detects the fault based on the ANN-fault classifier at the faulted phase (A). Then, the opening signal is sent to the C.B of phase (A) at t = 1.2 sec and after this time the faulted phase (A) is opened and the C.B of phase (A) is opened and the C.B of phase (A) is reclosed at t = 1.5sec. The waveforms of 3-phase (currents, voltages, active power, and reactive power) during fault situation is shown in Figure 5. There is an obvious distortion in the current and voltage waveforms in phase A when the secondary arc extinguishes. It can be observed from Figure 5(3) that unbalance operational condition leads to a fluctuation in the active and reactive powers during the fault occurrence. The operation of tripping/reclosing of auto-reclosure at the single line-to-ground before and after fault occurring are dissipated in Figure 6.

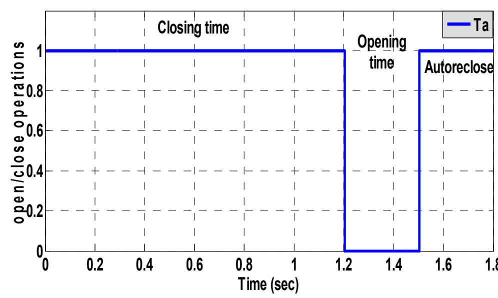


(a) (b)

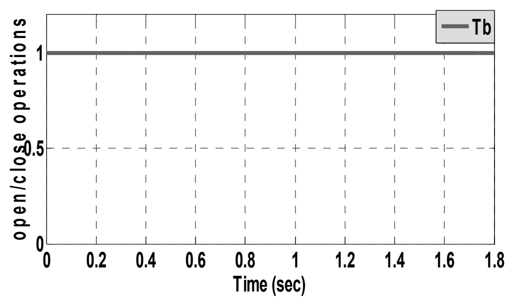


(c)

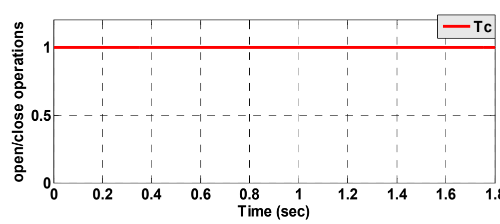
Figure 5. Simulation results of a single phase-to ground fault (AG) at generation busbar for 3-phase waveforms: (a) Voltages, (b) Currents and (c) Active and reactive transmission power before after the fault clearing (fault inception time 1sec)



(a)



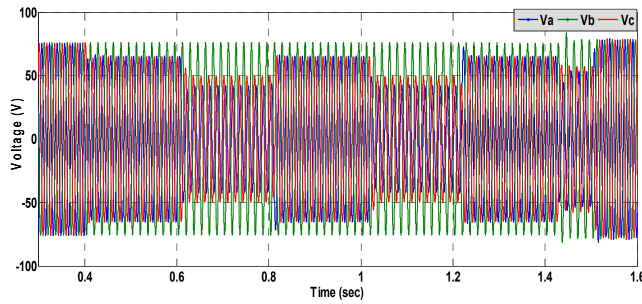
(b)



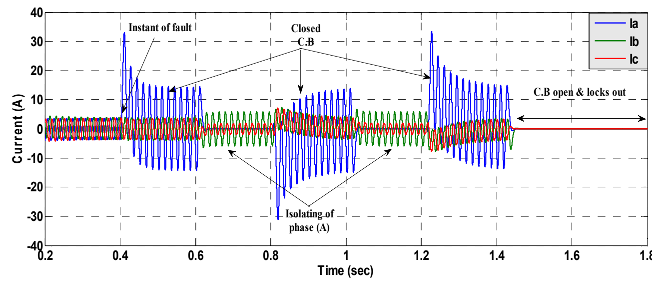
(c)

Figure 6. Sequences of open/ reclosure operation for C.B in 3-phases at single-phase-to ground fault (AG): (a) Phase A, (b) Phase B and (c) Phase C

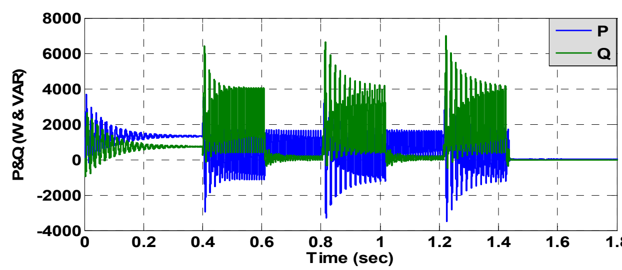
In the case of the permanent fault, it is considered that the single line to ground fault occurs in the phase A and at t = 0.4 sec. It demonstrates that a permanent fault is cleared at t = 0.6 sec, the auto-reclosure on the faulted line is opened at t = 0.6s, and the C.B is reclosed at t = 0.8 s. while the fault is staying after closing the faulted phase. Therefore, the C.B is reopened at 1 s and the C.B is reclosed at t=1.2s. In Figure 7, the performance of three-phase voltages, currents and active and reactive power is shown under the line–to-ground fault of the permanent condition. The resultant tripping and reclosing signals diagnosed by the proposed ASPAS is illustrated in Figure 8. In this case, it can be noted that the all poles of the C.B are locked out after third tripping signals.



(a)

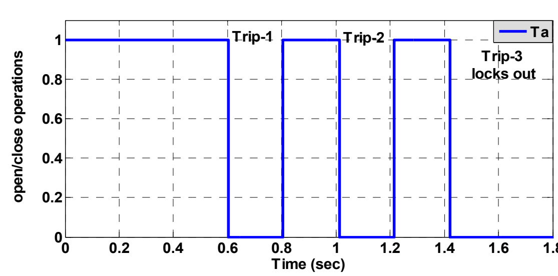


(b)

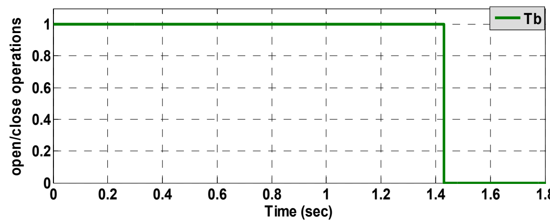


(c)

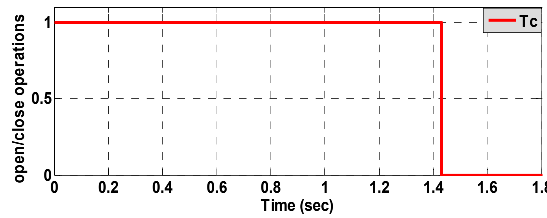
Figure 7. Simulation results of a single line–to-ground fault (AG) at generation busbar with 3-shots auto-reclosure in case permanent fault for 3-phase waveforms: (a) Voltages, (b) Currents and (c) Active and reactive transmission power before after the fault occurring (fault inception time



(a)



(b)



(c)

Figure 8. Sequences of open/ reclosure operation for C.B in 3-phases at (AG) fault with 3-shots auto-reclosure in case permanent fault (1) Phase A, (2) Phase (B) and (3) Phase (C)

6. CONCLUSION

In this paper, a new scheme multi shot 3-phase tripping and reclosing system has been designed for system stability. Also, ANN is trained and tested based on Back Propagation to detect fault per phase. As a whole, the suggested approach has been modeled in Matlab/Simulink program and based on the analyzing fundamental 3-phase currents at the generation bus-bar during the period between the occurrence and the clearance of the fault. The obtained results on a simulated system show that the ANN fault classifier technique is accurate, effective, and correctly classifies the fault. In addition, it is able to make correct trip decision under different faults. This means that ANN can be used as an effective means in the design of auto-reclosure schemes. Also, it shows that auto-reclosure scheme have benefits such as transient stability enhancement, faster reclosure after transient fault clearance, minimizing power system oscillation through good reclosure time, tripping all phases and lockout in the case of a permanent fault, and a reduction in system equipment damage under a permanent fault.

REFERENCES

[1] Mayadevi N, ey. al., "A Review on Expert System Applications in Power Plants," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 4, No. 1, pp. 116~126, February 2014.

[2] Arckarakit Chaithanakulwat, "Track the maximum power of a photovoltaic to control a cascade five-level inverter a single-phase grid-connected with a fuzzy logic control," *International Journal of Power Electronics and Drive System (IJPEDS)*, Vol. 10, No. 4, pp. 1863~1874, December 2019.

[3] Ahmed J. Ali, Ziyad K. Farej, and Nashwan S. Sultan, "Performance evaluation of a hybrid fuzzy logic controller based on genetic algorithm for three phase induction motor drive," *International Journal of Power Electronics and Drive System (IJPEDS)*, Vol. 10, No. 1, pp. 117~127, March 2019.

[4] Azriyenni and Mohd Wazir Mustafa, "Application of ANFIS for Distance Relay Protection in Transmission Line," *International Journal of Electrical and Computer Engineering (IJECE),* Vol. 5, No. 6, pp. 1311~1318, December 2015.

[5] N. K. Singh and S. S. Badge, "A Novel Fault Detection and Classification Technique for Double Circuit Transmission Line Using Artificial Neural Network," *International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)*, Kannur, pp. 1338-1342, 2017.

[6] Anamika Jain, A. S. Thoke, and R. N. Patel, "Classification of Single Line to Ground Faults on Double Circuit Transmission Line using ANN," *International Journal of Computer and Electrical Engineering*, Vol. 1, No. 2, pp. 1793-8163, June 2009.

[7] G. Venu Madhav and Y. P. Obulesu, "A New Hybrid Artificial Neural Network Based Control of Doubly Fed Induction Generator," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 5, No. 3, pp. 379~390, June 2015.

[8] N. F. Fadzail and S. Mat Zali, "Fault detection and classification in wind turbine by using artificial neural network," *International Journal of Power Electronics and Drive System (IJPEDS)*, Vol. 10, No. 3, pp. 1687~1693, Sep 2019.

[9] Amrinder Kaur, Yadwinder Singh Brar, and Leena G.3, "Fault detection in power transformers using random neural networks," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 9, No. 1, pp. 78~84, February 2019.

[10] Olalekan Kabiru Kareem, et. al., "Power distribution system fault monitoring device for supply networks in Nigeria," *International Journal of Electrical and Computer Engineering (IJECE,),* Vol. 9, No. 4, pp. 2803~2812, August 2019.

[11] Ankush K. and Lumesh K. S., "An Accurate Fault Detection and Classification Algorithm for Double Circuit Transmission Lines Using Artificial Neural Network," *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, Vol. 5, Issue VI, No. , pp. 2060 -2065, June 2017.

[12] Anamika Jain, A. S. Thoke, and R. N. Patel, "Fault Classification of Double Circuit Transmission Line Using Artificial Neural Network," *World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering*, Vol. 2, No. 10, pp. 2363-2368, 2008.

[13] Preeti Gupta and R. N. Mahanty, "Artificial Neural Network based Fault Classifier and Locator for Transmission Line Protection," *Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, Vol. 11, Issue 1 Ver. I, PP. 41-53, (Jan – Feb) 2016.

[14] H. Meyar-Naimi, S. Hasanzadeh, and M. Sanaye-Pasand, "Discrimination of Arcing Faults on Overhead Transmission lines for Single-Pole Autoreclosure," *Int. Transactions on Electrical Energy Systems*, vol. 23, No. 8, pp. 1523–1535, 2013.

[15] M. Khodadadi, M. R. Noori, and S. M. Shahrtash, "A Non Communication Adaptive Single-Pole Autoreclosure Scheme Based on The Acusum Algorithm," *IEEE Trans. Power Del*., vol. 28, No. 4, pp. 2526–2533, October 2013.

[16] Zaid H. Al-Tameemi, Hayder H. Enawi, Karrar M. Al-Anbar, and Hussam M. Almukhtar, "Transient Stability Improvement of the Power Systems," *Indonesian Journal of Electrical Engineering and Computer Science*, Vol. 12, No. 3, pp. 916–923, December 2018.

[17] Avagaddi Prasad and J. Belwin Edward, "Application of Wavelet Technique for Fault Classification in Transmission Systems," *Procedia Computer Science*, pp.78–83, 2016.

[18] Makmur Saini, A. A. Mohd Zin, M. W. Mustafa, A. R. Sultan, and Rusdi Nur, "Algorithm for Fault Location and Classification on Parallel Transmission Line using Wavelet based on Clarke’s Transformation," *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 8, No. 2, pp. 699-710, April 2018.

[19] Abdul Hadi Bin Mustapha, R. Hamdan, F. H. Mohd Noh, N. A. Zambri, M. H. A. Jalil, Marlia Morsin, and M.F. Basar, "Fault Location Identification of Double Circuit Transmission Line Using Discrete Wavelet Transform," *Indonesian Journal of Electrical Engineering and Computer Science*, Vol. 15, No. 3, pp. 1356-1365, September 2019.

[20] Ali, A. J., Allu A. A., and Antar R. K., "Fuzzy Logic Technique Based Single Phase Autoreclosing Protection System of a Double Circuit Transmission Line," *Proceedings of International Conference on Electrical, Communication, Computer, Power, andControl Engineering*, pp. 31–36, 2013.

[21] Hagh M.T., Razi K., and Taghizadeh H., "Fault Classification and Location of Power Transmission Lines Using Artificial Neural Network," *Conf. Proc. IPEC*, Vol. 1–3, pp. 1109–1114, 2007.

[22] Pranav. D. Raval, "ANN based Classification and Location of Faults in EHV Transmission Line," *Proceedings of the International MultiConference of Engineers and Computer Scientists*, Hong Kong, Vol. I, ISBN: 978-988-98671-8-8, pp. 19–21, March 2008.

[23] S. K. Padhy, B. K. Panigrahi, P. K. Ray, A. K. Satpathy, R. P. Nanda and A. Nayak, "Classification of Faults in a Transmission Line using Artificial Neural Network," *International Conference on Information Technology (ICIT)*, Bhubaneswar, India, pp. 239-243, 2018.

[24] Avagaddi Prasad, J. Belwin Edward, and K. Ravi, "A Review on Fault Classification Methodologies in Power Transmission systems: Part—I," *Journal of Electrical Systems and Information Technology*, pp. 48-60, May 2018.

[25] N. Saravanan and A. Rathinam, "A Comparitive Study on ANN Based Fault Location and Classification Technique for Double Circuit Transmission Line," *Fourth International Conference on Computational Intelligence and Communication Networks*, pp. 824-830, Nov 2012.

[26] Murari Mohan Saha, Jan Izykowski, and Eugeniusz Rosolowski, "Fault Location on Power Networks,” *Wroclaw University of Technology, Springer London Dordrecht Heidelberg New York*, ISSN 1612-1287 e-ISSN 1860-4676, DOI 10.1007/978-1-84882-886-5, 2010.

[27] S. Jamali and A. Parham, "New Approach to Adaptive Single Pole Auto-reclosing of Power Transmission Lines," *Published in IET Generation, Transmission & Distribution*, Vol. 4, Issue 1, pp. 115–122 , April 2010.