An Algorithm for Fault Detection and Identification of Iraqi Distribution Network Using Wavelet-Neural Network Technique

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Abstract:-

Power system restoration plays an important role in power system due to the incident of a fault. This paper presents an algorithm to diagnosis and identify the fault in power system distribution regarding the significant of system reliability and fault occurrence time. This algorithm performs a hybrid wavelet-neural network for an Iraqi distribution feeder. The wavelet transform structure was used as an integrate input to the neural network. The simulation results of a selected feeder at Baghdad city is used to validate the application of the proposed algorithm. From the obtained results it was clear that using the proposed algorithm give a fast and accurate method for fault detection and identification of the Iraqi distribution power system.

Keywords: - Iraqi distribution system; fault detection ;fault identification; neural and wavelet network.

INTRODUCTION

Power systems are prompted to many disturbances due to faults, environmental and operation problems. The main goal of fault diagnosis and identification is to observe and control the power system to obtain the stability of the electrical supply with a reduction of losses [2,10]. The currents and voltages during faults are calculated by using the fault analysis methods. Then, the protection of the power system can be set up. The effect of faults in all levels of power system is studied [1]. A fault should be detected in order to monitor and control the system for a stable source. That's can be obtained by implementing an algorithm to estimate the phasors of current and voltage, and impedance. The type of the fault is varied by using the impedance rule base. The fault location is calculated using current compensation technique and geographic information system (GIS) [7]. Now, some distribution system described a fuzzy logic system and wavelet analysis designed for fault diagnosis [4,5,6,8,9,11]. Others explained the neural network for faults detection and diagnosition [3].

In this work, a hybrid system of wavelet – neural network is presented for fault detection and classification of Iraqi distribution power system. Ten types of faults (three single line to ground, three line to line, three line to line to ground and one three line fault) have been designed to detect.

I. POWER SYSTEM DETECTION AND IDENTIFICATION

A. Wavelet Fault Detection

Wavelet analysis is capable to detect promptly changes that are used in analyzing transient signals. Therefore, it is consider as a preferable technique for fault detection in power system within a quick time and good accuracy. In addition, the wavelet transform based fault detection is used in order to overcome the problems relating to the short time Fourier transform that performs fixed windows for all frequencies which gives poor resolution. A set of basic functions is considered for wavelet analysis instead of expanded in terms of trigometric polynomials. In order to study a signal, it must be transformed to wavelet transform [4].

The analyzing methods of the wavelet transform are continuous wavelet transform (CWT) and Discrete Wavelet Transform (DWT). In a DWT, the scales and position of the wavelet functions are changed in discrete steps. In this paper, the DWT was considered. The DWT is an application of the wavelet transform using a discerete set of the wavelet scales and translation adapting some defined rules. The DWT propose enough information for both analysis and synthesis of the original signal, with a big reduction in the calculation time. So the DWT is applied in a straightforward manner, therefore, it is considered much easier than the CWT.

In this work, the fault is identified using the coefficients of the discrete wavelet transform. First, the unfaulted waveforms are excluded, then the faulted waveforms sent to the neural network for fault classification.

Consider a function that satisfying the following conditions:

$$\int_{-\infty}^{\infty} |\psi(t)|^2 \, dt < \infty \qquad (1)$$

$$c_\psi = 2\pi \int_{-\infty}^{\infty} \frac{|\Psi(\omega)|^2}{|\omega|} d\omega < \infty \qquad (2)$$

$$s(t) = \frac{1}{c_\psi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} S(b,a)\psi_{a,b}(t) \frac{dadb}{a^2}. \qquad (3)$$

$$S(b,a) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} \psi^{'}(\frac{t-b}{a}) s(t) dt \qquad (4)$$

Where $\psi^{'}$ is the complex conjugate of ψ.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}} \psi(\frac{t-b}{a}) \qquad (5)$$

The function $\psi_{a,b}(t)$ is shifted by b.

The gravity of the fault can be obtained by calculating the fault indexing parameter that are based on wavelet coefficients where the wavelet transform coefficients are similar to the scaled wavelet.

Wavelet functions are analyzed using Daubachies, Morlet, Symlet, Meyer, and Harr wavelets. The simplest type of function is the Haar wavelet compared with morlet and Meyer wavelet. However, it is not continuous and its Fourier transform deteriorates relating to bad frequency localization. The scaling function $\varphi(t)$ of the Daubechies wavelet is given below:

$$\varphi(t) = \sqrt{2}\sum h(n)\varphi(2t-n) \qquad (6)$$

$$\psi(t) = \sqrt{2}\sum g(n)\varphi(2t-n) \qquad (7)$$

where

$$g(n) = (-1)^n h(1-n) \qquad (8)$$

Where *g(n)* represents the mother wavelet while *h(n)* represents the signal. The discrete fourier transform (DFT) of the signal *h(n)* provides the frequency components that present in the signal.

The detection methods can be divided into the formulation of the one line distribution system feeder, and the wavelet transform is applied to the different types of faults in addition to the normal condition. However, the proposed model does not cancel the noise. The model topology is based on the current waveform that are obtained from the current transducer and processed by data acquisition system. After calculation of fault indexing parameters, the decision can be obtained.

To explain the scenario of the proposed topology, the current waveform usually contains the fundamental component and harmonics that are exist even when the fault occurs. The unfaulted component in the current waveform is predicted and it can be develop a fault component whenever the fault occurred. In result, the faulted component can be estimated by eliminating the unfaulted components. Equation (7) expressed the approximation coefficients and detail coefficients in each level using Daubechies wavelet. The test feeder distribution system is loaded to obtain the three phase current samples at the time of unfaulted as well as faulty conditions. These currents signal are taken from the data acquisition system, a detailed coefficients using wavelet analysis and power spectral density of each component is calculated in order to estimate fault severity. As illustrated previously, according to the calculation of power spectral density and fault indexing parameters of coefficients, the decision on the faulty and unfaulty system then can be obtained.

B. Neural Network Fault Identification

Power system fault identification is designed using a neural network. Three layers are produced which are input layer, hidden layer and an output layer. A suitable weight for the neural network is selected in order to achieve the desired target. The training algorithm is based on back propagation strategy [3]. The structure of the neural network is shown in **Fig.1**.

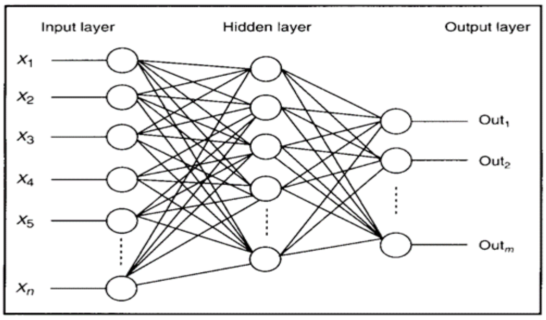

Fig. 1 structure of neural network

To complete the design of the neural network, a number of neurons for each layer should be selected. Therefore, 2 neurons for both the output and the hidden while a 3 neurons for the input layer are executed in this work. Each neuron has its own weight.

The input layer represents the three sequence components, zero, positive and negative are represented by I_{ao}, I_{a1} and I_{a2} respectively for phase a. The angles of the phase a is 0^o and angle of phases b and c are 120^o as obtained by the equations:

$$\begin{aligned} ang\_A &= \left| ang(I_{a1}) - ang(I_{a2}) \right| = 0^o \\ ang\_B &= \left| ang(I_{b1}) - ang(I_{b2}) \right| = 120^o \quad (9) \\ ang\_C &= \left| ang(I_{C1}) - ang(I_{C2}) \right| = 120^o \end{aligned}$$

The output layer represents the fault types.

II. ORGANIZATION OF THE PROPOSED ALGORITHM

The organization of the proposed methodologies is illustrated by the flow chart shown in **Fig. 2.** The initial values of the data and parameters were obtained by building and implementing two programs (Newton Raphson load flow analysis and short circuit analysis) with a Matlab environment. According to the obtained results, the values of currents and voltages are used to detect the occurrence of fault with a wavelet transform and these normal values will be regard as normal values to train the neural network. From the short circuit analysis it can be diagnosis the fault type. There are ten types of fault (three single line to ground, three line to line, three line to line to ground and one three line fault) is considered in this work.

The normal current waveform is taken from the test feeder (selected area of Baghdad city), then it was sampled of 10 kHz and normalized to process in Matlab. Fault indexing parameters are calculated with the wavelet coefficients using power spectral density. These values of fault indexing parameters are saved in order to test the algorithm for fault conditions. To identify the fault type with a neural network algorithm can be done by comparing the normal values of currents and voltages with a faulted one.

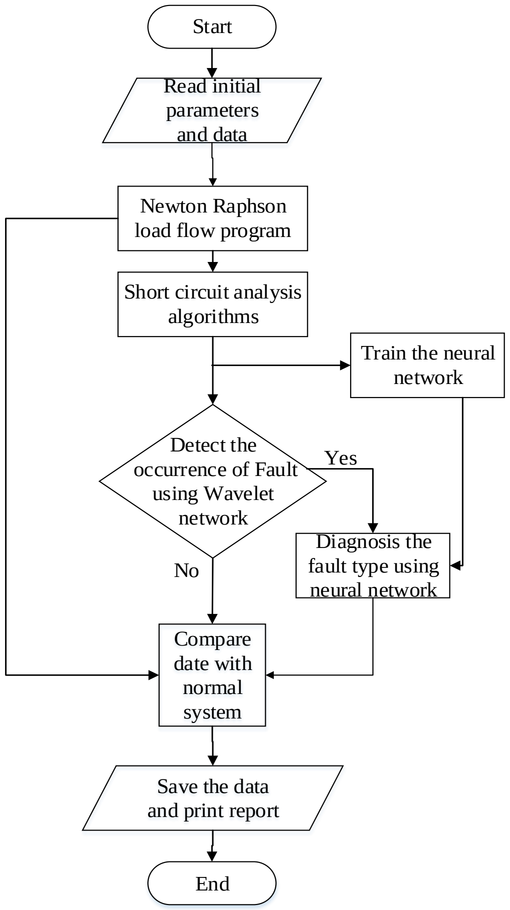

Fig.2 the flow chart of power system fault detection and diagnosis

III. SIMULATION RESULTS AND ANALYSIS

To proposed methodologies was applied on Alrostomya feeder system which is located at the Alresafa side of Baghdad city. **Fig. 3** shows the one line diagram of the feeder. The data of the system under consideration are given in appendix A.

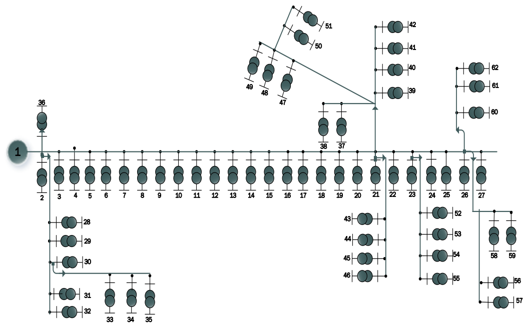

Fig.3 ALROSTOMYA FEEDER TEST SYSTEM

The system was analyzed for all types of faults at all nodes in order to confirm the ability of the short circuit analysis program. The total feeder data and short circuit analysis results for all possible cases were saved to be used to verify the occurrence of the fault.

Single line to ground, line to line and double line to ground faults frequently occurred in power distribution system, therefore, they are demonstrated in this paper on two nodes (node 60 and node 28) of the considered feeder as samples of the results to verify the algorithm.

Fig.4 displays the diagram of Alrostomya test feeder when that fault occurred on node 60. **Fig. 5** shows the current waveforms that obtained when single line to ground (LG) fault occurred on phase (a). **Fig. 6** shows the current waveform that obtained when double line to ground (LLG) fault.

Fig. 7 shows the diagram of Alrostomya test feeder when the fault is occurred at node 28. Line to line fault has been considered to be analyzed. **Fig. 8** shows the current waveform for line to line fault.

Briefly, the detection time with the wavelet algorithm during different types of fault is given in Table 1.

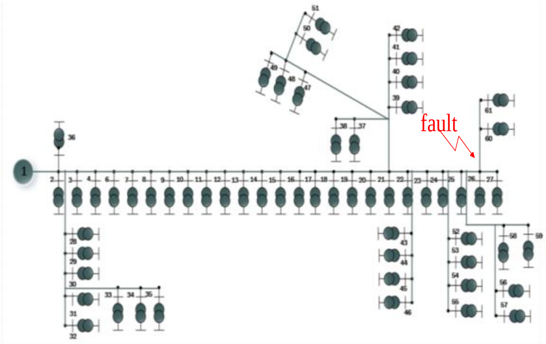

Fig. 4 Alrostomya Feeder test diagram system in Baghdad-Iraq fault at node 60

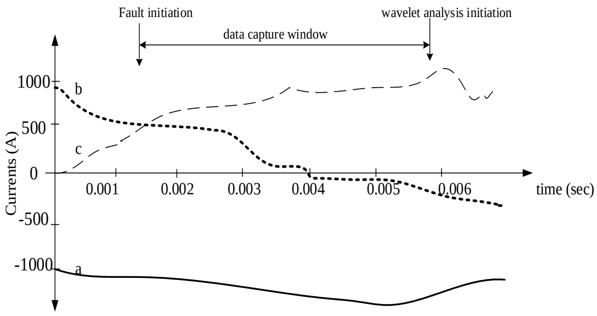

Fig. 5 current waveform obtained when fault occurred on phase a to ground

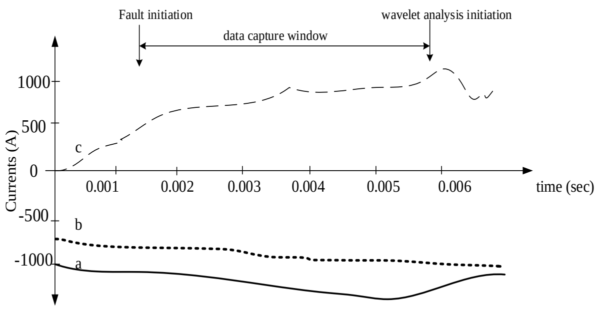

Fig. 6 the current waveform during phase a and phase b to ground fault.

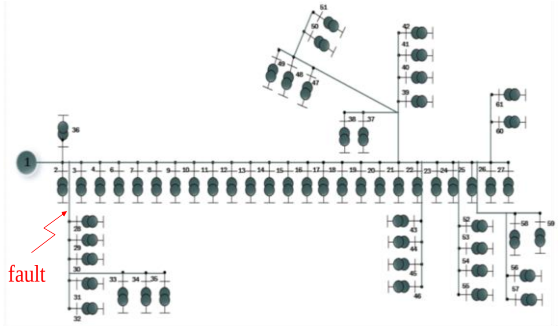

Fig. 7 Alrostomya Feeder test diagram system in Baghdad-Iraq fault at node 28

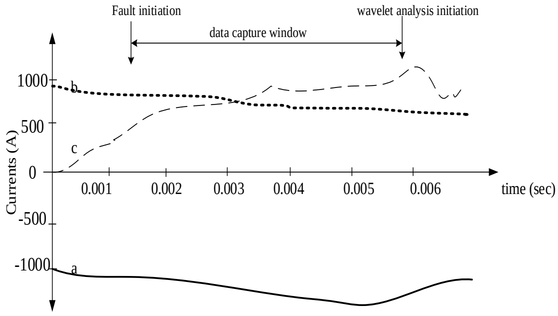

Fig. 8 the current waveform of three phases during line to line fault.

Table. 1 the execution time of detection

Case study	Fault types	Detection time (sec)
Fault at node 60	LG	0.281702
	LLG	0.107503
Fault at node 28	LL	0.110631

IV. CONCLUSIONS

An efficient algorithm was proposed using hybrid wavelet - neural networks to detect and identify the fault that implemented on Alrostomya test feeder of Iraqi power system distribution. The work develops a fast and accurate system. It was very clear that the execution time of detection by using wavelet network is quite promising. A power spectral density is used to calculate the wavelet coefficients due to a good indication and can estimate the fault component easily as well as it can predict the fault at early stage. Also, the artificial neural method is a very efficient and accurate approach to identify the occurring faults in the distribution system.

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Appendix A

Table. A Node data and Line data for test feeder

V = 11 KV P.F. = 0.8							
LINE DATA							
Node data			11kV Feeder data				
	Node No.	Trans. Rating (kVA)	Feeder section	Kind of feeder	Length (km)	R (Ω)	X (Ω)
Main Feeder	2	-	s.s-2	3×150 UGC	2.133	0.29464	0.230703
	3	400	2-3	Al-95	0.1	0.04184	0.044302
	4	250	3-4	Al-95	0.216	0.03146	0.03331
	5	250	4-5	Al-95	0.216	0.06795	0.07194
	6	250	5-6	Al-95	0.15	0.06795	0.07194
	7	250	6-7	Al-95	0.15	0.04719	0.049965
	8	250	7-8	Al-95	0.066	0.04719	0.049965
	9	250	8-9	Al-95	0.466	0.020763	0.021984
	10	250	9-10	Al-95	0.266	0.146603	0.155224
	11	250	10-11	Al-95	0.233	0.083683	0.088604
	12	250	11-12	Al-95	0.183	0.073301	0.077612
	13	250	12-13	Al-95	0.3	0.05757	0.06095
	14	250	13-14	Al-95	0.133	0.09438	0.09993
	15	250	14-15	Al-95	0.066	0.041841	0.044302
	16	250	15-16	Al-95	0.266	0.020763	0.02198
	17	250	16-17	Al-95	0.5	0.020763	0.02198
	18	250	17-18	Al-95	0.4	0.1573	0.16655
	19	250	18-19	Al-95	0.166	0.12584	0.13324
	20	250	19-20	Al-95	0.3	0.052223	0.055294
	21	250	20-21	Al-95	0.5	0.09438	0.09993
	22	250	21-22	Al-95	0.15	0.17303	0.183205
	23	250	22-23	Al-95	0.166	0.036493	0.038639
	24	630	23-24	Al-95	2.1	0.18876	0.19986
	25	250	24-25	Al-95	2.3	0.026111	0.027647
	26	400	25-26	Al-95	0.15	0.16768	0.177542
	27	250	26-27	Al-95	0.3	0.262061	0.277472
Lateral 1	28	630	2-28	Al-95	0.416	0.34718	0.28633
	29	250	28-29	Al-95	0.233	0.04719	0.049965
	30	250	29-30	Al-95	0.3	0.09438	0.088604
	31	250	30-31	Al-95	0.1	0.130873	0.138569
	32	250	31-32	Al-95	0.766	0.073301	0.077612
sub Lateral 1	33	250	30-33	Al-95	0.433	0.09438	0.09993
	34	250	33-34	Al-95	0.2	0.03146	0.03331
	35	250	34-35	Al-95	0.65	0.240983	0.255154
Lateral 2	36	250	2-36	Al-95	0.2	0.28426	0.21971
Lateral 3	37	250	21-37	Al-95	0.333	0.136221	0.144232

	53	400		52-53	Al-95	0.266	0.146603	0.155224
	54	250		53-54	Al-95	0.8333	0.083683	0.088605
	55	400		54-55	Al-95	1.033	0.262061	0.277472
Lateral 8	56	250		26-56	Al-95	0.1666	0.324981	0.344092
	57	250		56-57	Al-95	0.583	0.052223	0.055294
Lateral 9	58	630		26-58	Al-95	0.3	0.183411	0.194197
	59	250		58-59	Al-95	1.4	0.09438	0.09993
	60	250		26-60	Al-95	1.166	0.44044	0.46634
	61	400		60-61	Al-95	1.6	0.366823	0.388394
	38	250		37-38	Al-95	0.65	0.06292	0.06662
Lateral 4	39	630		21-39	Al-95	0.55	0.20449	0.216515
	40	400		39-40	Al-95	0.116	0.06292	0.06662
	41	250		40-41	Al-95	0.6	0.104762	0.110922
	42	400		41-42	Al-95	0.083	0.20449	0.216515
Lateral 5	43	250		22-43	Al-95	0.533	0.17303	0.183205
	44	250		43-44	Al-95	0.833	0.115143	0.121914
	45	250		44-45	Al-95	0.55	0.115143	0.121914
	46	250		45-46	Al-95	0.366	0.12584	0.13324
Lateral 6	47	630		21-47	Al-95	0.366	0.1573	0.16655
	48	400		47-48	Al-95	0.4	0.04719	0.049965
	49	250		48-49	Al-95	0.766	0.036493	0.038639
Sub lateral2	50	250		48-50	Al-95	0.6	0.240983	0.255154
	51	250		50-51	Al-95	0.766	0.18876	0.19986

خوارزمية كشف وتمييز الاعطال في منظومة التوزيع العراقية باستخدام تقنية الشبكات العصبية والمويجات

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الخلاصة

اعادة العمل للشبكة الكهربائية بعد حدوث خطأ وباسرع وقت ممكن تعتبر من الامور المهمة للشبكة الكهربائية. يقدم هذا البحث خوارزمية لتشخيص وتحديد العطل في نظام التوزيع الكهربائي مع الاخذ بنظر الاعتبار وثوقية المنظومة وزمن حدوث الخطأ . هذه الخوارزمية المركبة من مويجات – الشبكة العصبية وقد طبقت على مغذي في شبكة التوزيع الكهربائية العراقية. ان هيكل تحويل المويجات استخدم كمدخلات للشبكة العصبية. نتائج المحاكاة لمغذي محدد في مدينة بغداد استخدم للتحقق من تطبيق الخوارزمية المقترحة. اوضحت النتائج ان استخدام الخوارزمية المقترحة تعطي طريقة سريعة ودقيقة في اكتشاف وتحديد الاخطاء لنظام التوزيع الكهربائي العراقي.

الكلمات المفتاحية:- منظومة التوزيع، اكتشاف الاعطال، تمييز الاعطال، الشبكات العصبية والمويجات