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156 PRZEGL A D ELEKTROTECHNICZNY, ISSN 0033-2097, R. 90 NR 11/2014 Makmur SAINI1,2, Abdullah Asuhaimi Bin MOHD ZIN1, Mohd Wazir Bin MUSTAFA 1, Ahmad Rizal SULTAN1,2 1Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru 2Politeknik Negeri Ujung Pandang, South Sulawesi, Indonesia 90245 An accurate fault detection and location on transmission line using wavelet based on Clarke□s transformation Abstract. This paper presents accurate fault detection and location using wavelet based on Clarke□s transformation.

This study was done using Clarke□s transformation method to convert current phase (three phase) signal into a two-phase current alpha and beta (current m ode). The proposed method introduced the mode current to transform the signal using discrete wavelet transform (DWT) and was utilized to obtain th e wavelet transform coefficients. Analysis was also conducted for other mother wavelets. The most accurate parent was wavelet Db8, with the fastest time of detection and the smallest error, whereas the largest error was found in Coil4 parent wavelet.

The result for proposed method was compar ed with Db4, Sym4, Coil4 and Db8 and found to be very accurate Streszczenie. W artykule opisano dok ladn a metod e wykrywania awarii w sieciach przesy lowych bazuj a ca na falkowej transformacie Clarka. Sygna l tr□jfazowy jest przekszta lcany do postaci dwufazowej Za najbardziej si e do tego celu nadaja ca uznano falk e Db8 z najszybszym czasem wykrywania i najlepsz a dok ladno s cia . Wyniki por□wnano z innymi typami falek.

Dokl adna metoda lokalizacji awarii w sieciach przesy l owych bazuj a ca na wykorzystaniu transformaty falkowej Clarka Keywords: Wavelet Transformation; Fault location; Fault detection; Clarke□s Transformation.

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S l owa kluczowe: wykrywanie i lokalizacja awarii, transformata falkowa, transformata Clarka.
doi:10.12915/pe.2014.11.42 Introduction Fault detection and determination of the location of short circuit transmission lines have become a growing concern. There are two commonly used methods to determine the location of the fault in accordance with standard IEEE Std C37.114. 2004 [1].

The first method is based on a frequency component, and the second is based on signal interference at high frequencies where the wave theory is ignored and a shorter sampling window is used [2]. The determination of wave theory for intrusion detection was introduced by Dommel and Michess [3], where transient voltage waveform and current waveform were used to describe the graph pattern and detect fault location respectively. C.Y.Evrenosoglu and A.Abur [4] developed a circuit defining the technical relationship between the arrival of peak measurement of, the forward and backward traveling waves which were used to predict the travel time of a transient signal transmitter (source signal) to the point affected by the fault.

Wave theory is categorized under graphic patterns [5]-[7]. These are described based on the voltage and current waveform, in the form of a brief relationship between the arrival of the peak value at the measurement point of forward and backward waves. A new approach to detect and determine fault location is introduced in this paper. It is based on Clarke□s transformation which basically transforms a three-phase system into a two-phase system [8,9].

The results of this transformation are then tr ansformed into wavelet transformation. Wavelet transformation is a technique used to solve signal problem, based on t he development of Fourier's transformation. [10].The basic functions used in wavelet transform have band pass characteristics that make mapping similar to the mapping in the form function of time and frequency [11]. The wavelet transformation analyzes not only the frequency as in Fourier's traditional method, but also include sudden disturbances such as a transient disturbance.

The wavelets generate waves and disrupt the signal frequency [12]. There are many advantages of applying a wavelet in an electric power system as mentioned in many references [13,14]. These papers present an overview comparison of Fourier; short-time Fourier and wavelet transformation, which are examples of t he application of wavelet transformation to analyze the transient power system.

In this paper, PSCAD/EMTDC [15] is used to obtain the transient signal interference from transmission lines using MATLAB, which is used to perform Clarke□s transformation. Overview of Clarke□s and wavelet transformation. A. Clarke□s Transformation. Clarke's transformation, also referred to as (a□) transformation, is a mathematical transformation to simplify the analysis of a series of three phases (a, b, c). It is a two- phase circuit (a□ 0) stationery and conceptually very similar to the (dqo) transformation.

The wave signal analyzer is a very useful application for the transformation. Clarke□s transformation is one of the transformation matrices, which correspond to three-phase transmission lines. A three-phase current that has a digital representation is assumed to have the form [16] (1) where T is the sampling period. Equation (1) can be re-formed into the following matrix form (2) = (x (3) = 1 0 v v (x) Therefore, the above components can be formed into matrix form [17, 18] (4) = i =C = 1 0 v v x) PRZEGL A D ELEKTROTECHNICZNY, ISSN 0033-2097, R. 90 NR 11/2014 157 where C is the famous transformation introduced by Edith Clarke [19].

Wavelet Transformation Wavelet transformation is a refinement of the Fourier transformation, where the wa velet transform allows placement time as a frequency component within the given different signal. Sort Time Fourier Transforms is another improvement of the Fourier transform [20, 21], which uses a fixed amount of the modulation window. This is because a narrow window gives bad time resolution.

Therefore, the Fourier transform is only suitable for the information signal frequency as it does not change according to time. Continuous Wavelet Transformation. Continuous Wavelet Transformation (CWT) is used to calculate the convolution of a signal from a modulation signal, with a window at any time to any desired scale. By giving a wave function f (t), the CWT can be calculated as follows [22, 23]. (5) CWT(f,a,b)= v f f *)dt where a and b are the constants and constant scale transnational, CWT (f, a, b) is the continuous wavelet transform of a coefficient, and f is wavelet functions which value are not real but just for simplification purposes only.

The selection of the parent wavelet will be adapted to the needs of the wavelet coefficients. Discrete Wavelet Transformation Discrete Wavelet Transformation (DWT) is considered relatively easy to implement compared to CWT. The coefficient of the discrete wavelet transformation of a wave can be obtained by applying the DWT as given by equation (6) [24, 25]. DWT(f.m.k)= ? * (6) where the parameters a and b in equation (6) are replaced as , and where k and m are positive integer variables.

From just a few samples of WTC taken, the implementation of DWT decomposition is essentially based on a Mallat algorithm [26,27]. (i) Fig..1. Bewley Lattice diagram of the transmission line The proposed Algorithm The simulations were performed using PSCAD, and the simulation results were obtained from the fault current signal. The steps performed in this study were: (ii) Finding the input to the Clarke transformation, wavelet transformation, and the signal flow of PSCAD converted into m.files (*. M) and then c onverting this in to mat. Files (*mat).with a sampling rate of and a frequency dependence of 0.5 Hz 1 MHz.

(iii) Determining the data stream interference, where the signal was transformed by using the Clarke transformation to convert the transient signals into basic current signal (Mode). (iv) Transforming mode current signals again by using DWT and WTC, which was the generated coefficient and then squared to be in order to obtain the maximum signal amplitude to determine the timing of the interruption.

Processing the ground mode and aerial mode (WTC)2 using the Bewley Lattice diagram [28] of the initial wave to determine the fault location as shown in Fig. 1. If (7) = and (8) = Then (9) x = km where - Time fault from bus A , - Time fault from bus B; x - Calculated distance of fault location; L - Distance transmission line; V - Propagation velocity ;d - Estimation of the distance of fault location. To determine the distance from the fault location from Bus A ? = To determine the distance from the fault location from Bus B ? = Error (10) = / (x) 100% The flowchart of the algorithm used in this study is. shown in Fig. 2 Fig. 2.

Flowchart of fault detection and fault location 158 PRZEGL A D ELEKTROTECHNICZNY, ISSN 0033-2097, R. 90 NR 11/2014 Fig. 3. Single line of the system under study using PSCAD/EMTDC Simulation model. The system under study is shown in Fig. 3. It consists of 150 kV transmission line 100 km in length. Two sources are connected at both sides of the transmission line edges. The system was performed using PSCAD/EMTDC software. Transmission data: Sequence Impedance ohm/km Positive and negative = 0.03574 + j 0.5776 Zero = 0.36315 +j 1.32.647 Source Bus A Z1 = Z2 = Z0 = 30.20 + j 52.32 Ohm Source Bus B Z1 = Z2 = Z0 = 6.25 + j 35.45 Ohm Fault Starting = 0.22 seconds Duration in fault = 0.15

Seconds Fault resistance ( ) = 2 ohm Type Conductor = Chukar , diameter = 1.602 inch [29] The position of the tower and the distance between the conductors were taken into account to achieve system accuracy. The conductor types used for this simulation were obtained using propagation velocity = v = 299939.4321 km/seconds. Case 1: Single line to ground fault (AG), 10 km from bus A and 90 km from bus B In the transient signals in Fig. 4(a). the interference was measured from Bus A.

The fault current was obtained from a bus as far as 10 km, with disorder type. = 2.699 kA, = 0.53388 kA and = 0.7556 kA. Fig. 4(b). shows a mode signal graph with the application of a current signal that was obtained using Clarke□s transformation, with = 1.484 kA, = 0.5518 kA and = 1.216 kA from bus A to the point of interruption of 10 km. Fig. 4(b). shows that, there was a signal waveform Io, which was assumed to occur due to ground fault. Fig. 4(c). shows the graph (WTC) 2 in the ground mode.

The results of the wavelet transformation value did not indicate zero, meaning that the ground fault occurred in the first peak which is 0.22004 seconds. Fig. 4 (d). shows (WTC) 2 in which the peak occurred in aerial mode (WTC) 2 at equal to 0.22004 seconds . (a) Current waveform signal original (b). Current mode waveform from Clarke's transformation (c). Ground mode for wavelet mother Sym4 (d). Aerial mode for wavelet mother Sym4 Fig. 4. Single line to ground fault (AG) 10 km from bus A for case 1 Fig. 5(a).

presents the transient interference signals, measured from Bus B, obtained from the bus fault current interruption that was located 90 km from bus B, with = 2.340 kA, = 0.352 kA and = 0.5579 kA. Fig.. (5b). shows a graph of the signal mode Clarke transformation , with signal = 0.930 kA, = 0.358 from bus B to the point of interruption which occurred at 90 km at = 0.4712 kA is obtained. It was assumed that there was interference on the ground fault type. Fig..

5(c) shows the graph (WTC) 2 in the ground mode, where in the results of the wavelet transformation mode at ground zero, the value did not indicate zero, meaning the ground fault occurred in the first peak at 0.22032 seconds. In Fig.. 5(d). the graphs show the (WTC) 2 in Aerial mode, in which the peak occurred in (WTC) 2 which is = 0.22031 seconds (a). Original signal of current waveform PRZEGL A D ELEKTROTECHNICZNY, ISSN 0033-2097, R. 90 NR 11/2014 159 (b). Current mode waveform from Clarke□s transformation (c).

Ground mode for wavelet mother Sym4 (d). Aerial mode for wavelet mother Sym4 Fig.. 5. Single line to ground fault (AG) 90 km from bus B for case 1 Case 2 : Line to line fault (AB), 25 km from bus A and 75 km from Bus B In Fig. 6(a). the graph shows the transient interference signals measured from bus A, where the fault current was obtained from bus A to a point where the fault was located 25 km from bus A with . = 1.608 kA, ==1.73533 kA and = 0.3542 kA. Fig. 6(b) s hows a graph of the obtained mode signal current with = 1.607 kA, = 1.193 kA and = 0 kA to the disturbance point of the bus located 25 km away. Fig. 6(b) shows that the current Io produced no signal.

Therefore, it can be concluded that the above disorder was a type of ungrounded fault. Fig. 6(c) shows the graph (WTC)2 on ground mode. The results of the wavelet transformation mode showed the ground zero value, meaning that this type of fault was ungrounded. Fig. 6(d) shows (WTC)2 in Aerial mode where the peak occurred in (WTC)2 at = 0.22009 seconds. (a). Original signal of current waveform (b). Current mode waveform from Clarke's transformation (c). Ground mode for wavelet mother Db8 (d). Aerial mode for wavelet mother Db8 Fig 6.

Line to line fault (AB) 25 km from bus A for case 2 Fig. 7(a) signifies the transi ent signal interference graph measured from bus B, obtained from the bus fault current interruption to point B for 75 km with = 2.654 kA, ==1.4733 kA and = 0.5468 kA. Fig.7(b) shows a graph of the signal mode with a current of = 0.2654 kA, = 0.6473 kA and = 0 on bus B to the point of disorder at 75 km. Fig. 7(b).

shows that the current = 0, thus suggesting that the disorder was a dist urbance at the ungrounded fault. Fig. 7 (c). shows the graph (WTC)2 in ground mode. The results of wavelet transformation mode showed ground zero value, which means that this was an ungrounded fault. Fig. 7(d)..shows (WTC)2 in aerial mode in which the peak occurred at (WTC)2 at = 0.22026 seconds. (a). original signal of Current waveform (b). Current mode waveform from Clarke's transformation (c). Ground mode for wavelet mother Db8 (d). Aerial mode for wavelet mother Db8 Fig. 7.

Line to line fault AB locatedat 75 km from bus B for case 2 160 PRZEGL A D ELEKTROTECHNICZNY, ISSN 0033-2097, R. 90 NR 11/2014 Discussion and Result Fig. 8 shows that the f ault detection column Db4 had a long-time duration of 0.00018 seconds for time fault detection, while Sym4 and Coif4 have similar time for fault detection of about 0.000165 seconds. Db8 had a better time for fault detection compared to others at about 0.00016 seconds.

The percentage of error in fault location for different type of mother wavelet is shown in Table 1. shows more detailed results, includin g the error calculation of the single line to ground fault. This shows that Db4, Sym4 and Db8 had the same percentage error for the distance of 10 km and 90 km of the transmissi on line, whereas at 25 km, Db8 had a better performance than the rest. In contrast, for 75 km transmission line, Db4 and Sym4 had less percentage error than Db8 Fig..8. Fault time detection (second .

The percentage calculation of the error fault line to line to the ground fault shows that at 10 km and 90 km, long transmission lines Db4, Sym4 and Db8 had the same percentage of error. Conversely, at 25 km and 75 km, the percentage error of Sym4 and Db8 were less compared with Db4 and Coif4 since Coif4 had a major percentage of error in all cases. This indicates that the proposed algorithm for fault classification is accurate and precise.

Conclusion When transformed into a wavelet, the determination of fault location using the Clarke transformation was very accurate, with an error of less than 2%. This was true even at a distance of 50 km, with an average error of 0.258% which was achieved for the time of bus A to the point of disturbance for the time achieved by bus B. From the above results, Db8 was found to be the best compared with other mother wavelets, with the fastest detection time at 0.00016 seconds and produced the smallest error in all types of interference. Meanwhile, the largest percentage error was produced by the mother wavelet Coif4. . Table 1.

Percentage error in Fault Location for different type of Mother Wavelet, = 2 Ohm and fault inception angle = 0 (degree) Acknowledgment The authors would like to express their gratitude to Universiti Teknologi Malaysia, The State Polytechnic of Ujung Pandang, PT. PLN (Persero) of South Sulawesi and the Government of South Sulawesi Indonesia for providing the financial and technical support for this research. REFERENCES [1] IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines, IEEE Std C37.114, (2004) [2] Magnago F.H.,

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Fault location on double-circuit transmission line not requiring line Type Of Fault Actual Point of Fault (km) Db4 Coif4 Syms4 Db8 Calcul ated point of Fault (km) Error =(x- d)/L *100% Calcul ated point of Fault (km) Error = (x-d)/L *100% Calculat ed point of Fault (km) Error = (x-d)/L *100% Calculate d point of Fault (km) Error = (x-d)/L *100% LG (AG) 10 9.51 0.419 12.52 2.051 9.51 0.419 9.51 0.419 25 24.51 0.495 26.01 1.001 24.51 0.495 24.51 0.495 75 74.45 0.258 73.99 1.005 74.45 0.258 75.49 0.495 90 90.49 0.492 88.99 1.080 90.49 0.492 90.49 0.492 LL (AB) 10 9.51 0.419 11.01 1.001 9.51 0.419 9.51 0.419 25 24.51 0.495 26.01

1.001 24.51 0.495 24.51 0.495 75 75.49 0.495 73.99 1.001 75.49 0.495 75.49 0.495 90 90.45 0.492 86.69 1.307 90.49 0.492 90.49 0.492 LLG (BCG) 10 9.51 0.419 10.86 0.857 9.51 0.419 9.51 0.419 25 26.01 1.001 26.01 1.005 24.51 0.495 24.51 0.495 75 73.99 1.001 73.85 1.155 75.49 0.495 75.49 0.495 90 90.49 0.492 88.99 1.007 90.49 0.492 90.49 0.492 LLL (ABC) 10 9.51 0.419 11.01 1.008 8.76 1.242 9.51 0.419 25 26.01 1.001 26.01 1.001 24.51 0.495 24.51 0.495 75 73.99 1.001 73.99 1.001 75.49 0.495 74.49 0.495 90 89.74 0.258 88.88 1.007 90.49 0.492 90.49 0.492 PRZEGL A D ELEKTROTECHNICZNY, ISSN 0033-2097, R. 90 NR 11/2014 161 parameters, Przeglad Elektotechniczny, R.

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