Wavelet-Based Fuzzy logics for Recognition of Faults at Nha Be Power Substation of the Vietnam power system

Bon Nhan Nguyen, Thanh Phan Nguyen, Trieu Ngoc To, Khanh Van Nguyen, Toan Duc, Vang Quoc Le

***Abstract*—This paper presents a new study of power system transient fault recognition using Wavelet Multi-Resolution Analysis (MRA) technique integrated with Fuzzy logic. The proposed method requires less number of features as compared to conventional approach for the identification. The feature ex-tracted through the wavelet is input by a fuzzy logic for the classification of events. After training the neural network, the weight obtained is used to classify the Power Quality (PQ) and Faults problems. These techniques are applied to recognize different faults in the supply voltage of the Southern Vietnam power system at NHABE substation. The research results prove the techniques can be used to detect and classify a wide range of power different faults occurring in power systems with a high accurate ratio. The simulation results possess significant improvement over existing methods in signal detection and classification**

***Keywords*—Wavelet Technique, Fuzzy logic system, Power system Transient, Multi-Resolution Analysis**

I. Introduction

A short circuit happens in the power grid, which causes a significant change in the system variables such as over current, over voltage, power factor, impedances, frequency, over or under power and power and current direction. Digital Signal Processing has been a vital role in analysis and control power systems, with an increased importance at present in the context of smart grid development [1-7]. The work performed in this research is focused on a new fault recognition using a wavelet-based technique and an artificial neural network. The task of recognition and assessment of these faults with good accuracy therefore is part of a comprehensive effort in improving the grid performance. The paper includes 5 sections, in which section 1 is the introduction, section 2 is with the identification of transient phenomena using Multi-Resolution Analysis (MRA) technique. Section 3 is about a proposed method based on Fuzzy Logics and Wavelet technique. Section 4 is the application of the developed methods in recognizing voltage disturbances in a part of Southern Vietnam power system. The conclusion is in section 5.

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II. APPLICATION OF DWT TECHNIQUE AND EXPRIMENTAL RESULTS

A. Multi-Resolution Analysis technique

The first main characteristic in DWT is the Multi-Resolution Analysis (MRA) technique that can decompose the original signal into several other signals with different levels (scales) of resolution. From these decomposed signals, the original time-domain signal can be recovered without losing any information.

The recursive mathematical representation of the MRA is as follows [2]:

$$u_J = w_{J+1} \oplus u_{J+1} = w_{J+1} \oplus w_{J+2} \oplus \cdots \oplus w_{J+n} \oplus u_{J+n} \quad (1)$$

In (1):

u_{J+1}: approximated version of the given signal at scale J+1
w_{J+1}: detailed version that displays all transient phenomena of the given signal at scale J+1.

$\oplus$: denotes a summation of two decomposed signals.
N : is the decomposition level.

B. Detailed Energy Distribution

$$\frac{1}{N}\sum_{k=1}^{N}(x[k])^2 = \frac{1}{N}\sum_{k=1}^{N}|u_J[k]|^2 + \sum_{j=1}^{J}\left(\frac{1}{N}\sum_{k=1}^{N}|w_j[k]|^2\right) \quad (2)$$

In (2):

x[k]: discrete input; k = 1…N.

u_j [k]: approximation version of the given signal at scale j.

w_j [k]: detailed version that displays all transient phenomena of the given signal at scale j.

The first term on the right of (2) denotes the average power of the approximated version of the decomposed signal, while the second term denotes that of the detailed version of the decomposed signal. The second term giving the energy distribution features of the detailed version of distorted signal will be employed to extract the features of power disturbance.

As seen in (2), the energy of the distorted signal can be partitioned at different resolution levels in different ways depending on the power-quality problem. Therefore, the coefficient of the detailed version at each resolution level will be examined to extract the features of the distorted signal for classifying different power-quality problems. The process can be represented mathematically by [2]:

$$P_j = \frac{1}{N}\sum_{k=1}^{N}\left|w[k]\right|^2 = \frac{\left\|w_j\right\|^2}{N} \tag{3}$$

Energy is normalized [1]:

$$P_j^D = \left(P_j\right)^{1/2} \tag{4}$$

In this paper, a 13-level decomposition of each discrete distorted signal will be performed to obtain the detailed version coefficients $w_1 \sim w_{13}$. Simultaneously, with formulas (3)-(4), each detailed energy distribution ($P_1^D \sim P_{13}^D$) can be obtained.

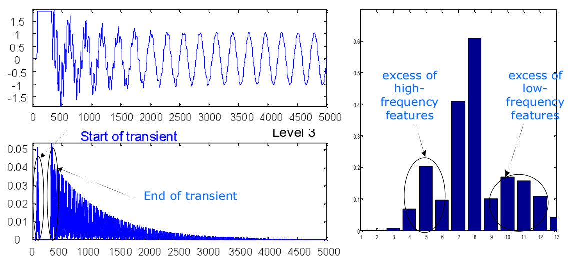

Figure 1. DWT and energy distribution diagram of capacitor switching.

Employing the DWT technique to analyze the energy of the distorted signals, in terms of its time and amplitude, is presented in [4].

Figure 1 shows specific analysis results of capacitor switching signal, which show the duration of the disturbance, and the corresponding energy distribution levels in terms of frequency spectrum.

III. FUZZY LOGIC SYSTEM

Fuzzify inputs resolve all fuzzy statements in the antecedent to a degree of membership between 0 and 1. If there is only one part to the antecedent, this is the degree of support for the rule.

Applying fuzzy operator to multiple part antecedents. If there are multiple parts to the antecedent, apply fuzzy logic operators and resolve the antecedent to a single number between 0 and 1. This is the degree of support for the rule.

Implication method uses the degree of support for the entire rule to shape the output fuzzy set. The consequent of a fuzzy rule assigns an entire fuzzy set to the output. This fuzzy set is represented by a membership function that is chosen to indicate the qualities of the consequent.

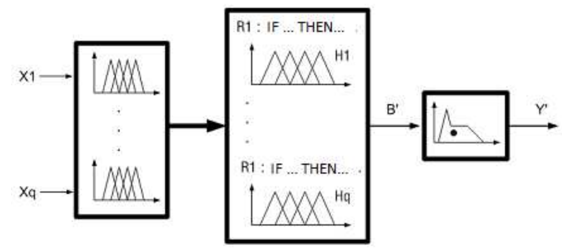

Figure 2. Fuzzy System Model for Transient Phenomena Recognition at NHABE Substation.

Time FIS has two properties: YES and NO; Amplitude FIS has six properties of faults; Output FIS gives the results; and 22 rules classifies 8 voltage faults.

Fuzzy Logic System has the following characteristics: implementation time is of 0.90 (s), outputs are types of faults. These are showed in figure 2,3,4,5.

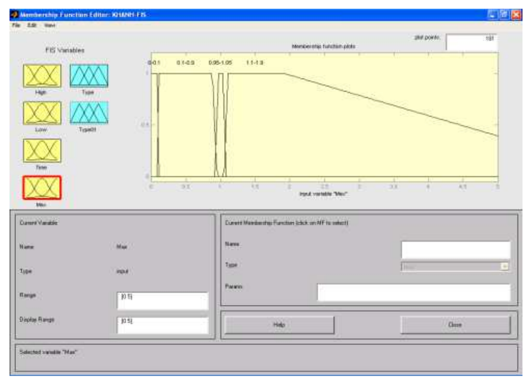

Figure 3. Amplitude FIS Membership.

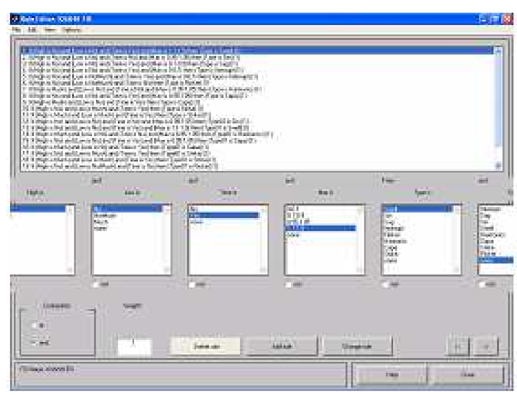

Figure 4. Amplitude FIS Membership.

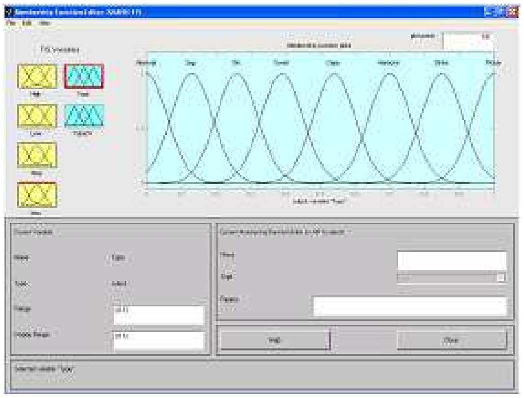

Figure 5. Amplitude FIS Membership.

IV. APPLICATION IN SOUTHERN POWER SYSTEM OF VIETNAM

This proposed method above is applied at 500kV NHABE substation in the Southern power system of Vietnam on Figure 3, with the assessment of power system transient phenomena. There are eight disturbance types at NHABE Substation. In Figures 3, 4, 5 are shown respectively simulated parameter. In Figures 7, 8, 9 are shown respectively short-cirtcuit fault voltages, energy distribution diagram of voltages by MRA. Fault resistances are changed for different values of 0, 2, 5, 10, 20, 100 Ω. Fault positions on a transmission line are varied (10%, 30%, 50%, 70%, 90%).

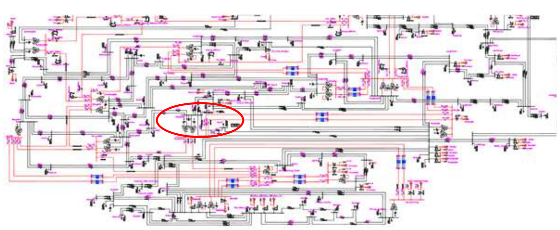

Figure 6. A location scheme for 500kV NHA BE power substation of Southern Vietnam power system (an ellipse figure).

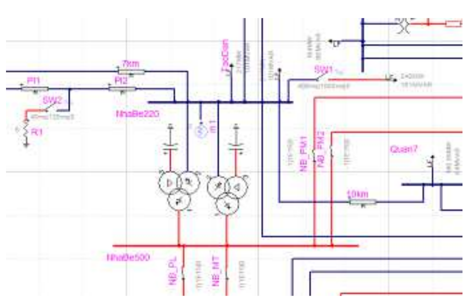

Figure 7. Nha Be – Sai Gon 1 transmission lines faults at NHABE substation.

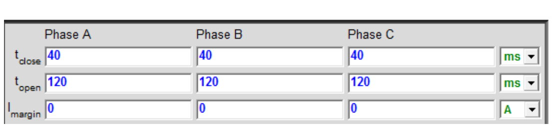

Figure 8. A time parameter

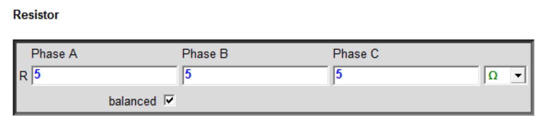

Figure 9. A Resistor parameter

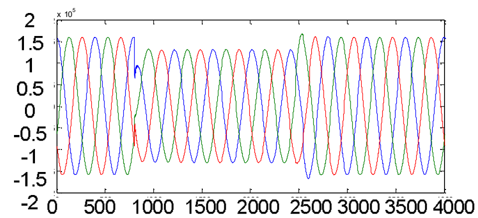

Figure 10. 220kV voltages at Nha Be – Sai Gon 1 transmission lines faults.

The accurate ratios of signal recognitions are presented on Table 1.

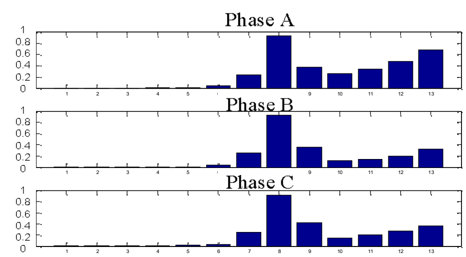

Figure 11. 13 wavelet levels of energy distribution diagram of fault current waves.

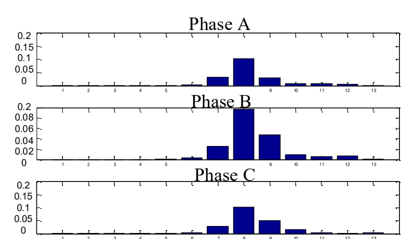

Figure 12. 13 wavelet levels of energy distribution diagram of fault voltage waves.

In Table 1 , test samples are given to Fuzzy system model to regconize. There are 160 test samples in which resistors are changed in values (0, 3, 15, 30, 70, 100 Ω) and Fault positions on a transmission line are varied (20%, 40%, 60%, 80%). The accurate ratio is about 86%. This is oppurtunity to apply wavelet technique in Vietnam power system. However this research needs to continue to improve the accuracy rate and more disturbance types for real- time identification capabilities.

In Table 2 gives more detailed results. This work proposes Wavelet-MRA based featured selection technique. The input features are selected based on 13 energy levels of detail coefficients of the signals. From the table it is inferred that Fuzzy system model with less number of features give high classification rate with less training time and testing time.

Figure 13 and Figure 14 are performances the results of two different fault categories. These results are shown on the table 1. The recognition system diagram is showed on Figure 2 which classify seven fault types.

TABLE I. ACCURATE RATIO RESULTS OF FAULT RECOGNITION

No	**Fault types**	**Accurate Ratio**
1	220kV Nha Be – Sai Gon lines	19/20
2	Nha Be – District 7 lines	19/20
3	Nha Be – Nhon Trach lines	19/20
4	Nha Be – Phu My lines	19/20
5	Load Switchings	10/10
6	Harmonics	9/10
7	Interruptions	10/10
	Total	**96.2%**

TABLE II. RECOGNITION RESULTS

Test samples	110
Accurate sample	105
Accurate rate	96.2%
Test time (s)	0.01

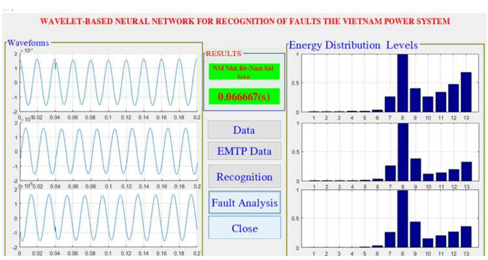

Figure 13. Identification of short-circuit of 220kV Nha Be – Nam Sai Gon power transmission line.

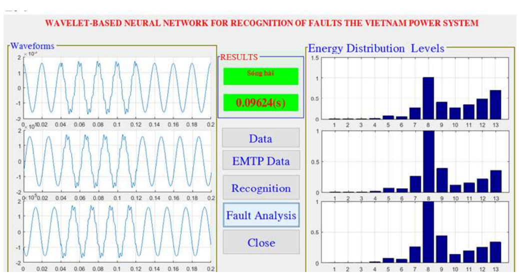

Figure 14. Recognition of harmonic fault at 500kV NHABE bus.

V. CONCLUSION

In this work, the application of wavelet transform combined with Fuzzy system model, to detect and classify various faults, is presented. Recognition of wide range of power system disturbances can be done at 500kV NHABE power substation. Some contributions of the research of power system transients can be listed:

- Detection of starting time and duration of disturbance transients.
- Recognition of different types of capacitor bank switching.
- Identification and classification of power system disturbances with a high accurate ratio.

These contributions above have been applied at NHABE Substation in Southern power system of Vietnam with a high accuracy. The proposed method stands as an evident that it can be implemented in real time applications.

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