Fault Type Classification of 150 kV Transmission Line using Wavelet Multi-Resolution Analysis Method

Novizon¹, Nurfi Syahri¹, Silvia Wulandari¹, Tesya Uldira Septiyeni¹ and Rahadian Asneli Putri¹

¹Department of Electrical Engineering, Engineering Faculty of Universitas Andalas, Padang 25163, Indonesia

INTRODUCTION

The human population is increasing day by day. Therefore, the need for energy in daily life is also increasing. Electricity is one of the basic needs for the survival of every human being which causes the demand for electrical energy to increase. The increasing demand for electrical energy requires more generation and distribution of electricity. In general, the electric power system is divided into four parts, namely, generation, transmission, distribution and load. Of all these, the transmission and distribution system plays a major role and it is like the heart of the entire power system. However, frequent disturbances also occur in the transmission and distribution system, this will jeopardize of the overall power system security.

The transmission system consists of two types, namely overhead and underground cables. The overhead line is more widely used than the underground cable because it has several advantages. The air transmission line (overhead) will be affected by atmospheric conditions which cause the possibility of more disturbances [1]. Faults in overhead lines are classified into two types, namely open conductor faults (series) and short circuit faults (shunts). Series faults are also classified into two types, namely one-conductor open fault and two-conductor open fault.

The most common disturbance in the transmission line is short circuit (shunt) which is classified into two types, namely asymmetrical and three phase symmetrical faults, the most dangerous fault. Asymmetrical faults are phase to ground, phase to phase, and two phases to ground. The most common faults that occur in transmission line are phase to ground fault. The fault analysis can be divided into three parts, namely the faults detection, the classification of the fault and the fault location.

The analysis of fault type classification is an important part in the fault analysis [2]. There are several methods to determine the type of fault. These methods include the wavelet method [3,4,5], artificial neural networks [6,7,8], fuzzy logic [9,10,11], wavelet-neural network [12], wavelet-fuzzy [13], and neuro-fuzzy [14,15]. The kind of wavelet method is used to identification of fault types in this study, namely the wavelet multi-resolution analysis method. The multi-resolution analysis is a function to analyze signals at different frequencies with different resolutions [19,20,21]. In this research, fault classification is determined using multy resolution analysis. The 150 kV transmission line is used in this work. Phase to ground fault, two phase faults, three

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The data used in this research is transmission line data from the Maninjau Hydroelectric Power Plant (PLT) to Palu. The data can be seen in Table 1 and the single line of transmission system can be seen in Fig. 5.

Table 1. Transmission line data

| No. | Specification          | Data                        |
|-----|------------------------|-----------------------------|
| 1   | System Voltage         | 151 kV                      |
| 2   | Nominal Current        | 645 A                       |
| 3   | Line Length            | 90.7 km                     |
| 4   | Conductor Type         | HAWK                        |
| 5   | Conductor Cross Area   | 240 mm²                     |
| 6   | Nominal Voltage        | 240 V/km                    |
| 7   | Average Power          | 2.15 MW                     |
| 8   | Impedance              | 1.793 Ω/km                  |
| 9   | Negative Sequence      | 0.117 Ω/km                  |

The single line of transmission electrical system of West Sumatera can be seen in Fig. 2.

The fault type classification algorithm can be proposed based on the Multi-resolution Analysis (MRA) [25]. The MRA is one of the best tools for analyzing signals at different frequencies with different resolutions [24]. Mathematically, the wavelet energy can be expressed as Eq. 3 and Eq. 4.

\[
E_m = \sum_{i=1}^{M} |\psi_m^i(t)|^2
\]

\[
E_t = \sum_{i=1}^{N} |\phi_t^i(t)|^2
\]

The fault type classification algorithm can be proposed based on the Multi-resolution wavelet transform at different levels. According to Parseval's theorem, the total energy of the transient signal can be decomposed at different resolutions at the high frequencies of a signal. As good frequency and poor time resolution at the low frequencies. Therefore, the MRA is designed to provide good time and poor frequency resolution at the low frequencies and good frequency and poor time resolution at the high frequencies as well.

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\]

\[
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\]

Finally, waveform decomposition at the desired level is obtained by repeating the same process. The complete detail and approximation coefficients are obtained at level 1 (D1 and A1). The approximation coefficient is as Eq. (2).

\[
\psi_m(t) = \sum_{n=-\infty}^{\infty} c_m n \phi_{m,n}(t)
\]

\[
\phi_t(t) = \sum_{n=-\infty}^{\infty} d_t n \psi_{t,n}(t)
\]

The mother wavelet in that equation become as Eq. (2).

\[
\psi_m(t) = \sqrt{\frac{a_0}{b_0}} \psi_m \left( \frac{t-b_0}{a_0} \right)
\]

\[
\phi_t(t) = \sqrt{\frac{a_0}{b_0}} \phi_t \left( \frac{t-b_0}{a_0} \right)
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\]

The multi-resolution analysis method is used to classify the types of disturbances that occur in the transmission line by comparing the average value of the approximation coefficients of each phase [27]. The approximation coefficient is obtained along the decomposition process or signal line. Mathematically, to determine the average value of the approximation coefficient, the approximation coefficient is as Eq. (2).

\[
\frac{m_{av}}{n} = \frac{m_{av}}{n} = \frac{m_{av}}{n} = \frac{m_{av}}{n}
\]

\[
\frac{M_{av}}{n} = \sum_{n=1}^{N} \frac{m_{av}}{n}
\]

The mother wavelet in that equation become as Eq. (2).
METHOD

The method to classify the types of fault using wavelet multi-resolution analysis can be explained using flowchart. Fig. 3 explains the steps of fault classifying type using wavelet multi-resolution analysis. Fault is classified into five types of fault, they are phase to ground fault, two phase fault, two phase ground fault, three phase symmetrical fault and lightning fault [29]. All fault types are analyzed using MRA method based on approximation value comes from wavelet analysis.

RESULTS AND DISCUSSION

The phase fault ground fault is modeled in ATP software with a distance of fault is 45.5 km from bus 1 that is Power Plant Maninjau.

The bus 1 is position where the measurement point is used. The fault impedance is 1 ohm. The complete model for phase to ground fault in Sumbar transmission line can be seen in Fig. 4.
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Table 2 shows that the classification results for 1-phase ground faults with faults in phases A, B and C for fault distance 45.5 km meet the classification requirements according to the multi-resolution analysis method. From the results of this classification, it can be said that for phase to ground with distance variations, the percentage of success is 100%.

CONCLUSIONS

All model components that is used in the simulation of this study have been successfully build and work well according to research needs. From the analysis of the simulation results and calculations, based on the wavelet multi-resolution analysis method is used in classifying the type of faults, the average value of the approximation coefficient is obtained. This approximation coefficient is used as parameter by MRA to classify the type fault. All types of faults which is analyzed in this study met the classification requirements using the MRA method. In other words, the simulation of the classification of the type of fault met 100% successfully.

Table 2. Results of Fault Type in Phases AB, Phases BC and Phases AC with Various Distance

| Fault Impedance | Fault Distance | Fault Type | MA1 | MB1 | MC1 | MRA Criterion | Analysis | Fault Classification |
|-----------------|----------------|------------|-----|-----|-----|----------------|----------|-----------------------|
| 1 Ω             | 45.5km         | AG         | -   | -   | -   | [MA1]≈[MB1]   | agree    | Phase to ground fault |
|                 |                | BG         | 9566| 18734| 9492| [MB1]≈[MC1]   | agree    | Phase to ground fault |
|                 |                | CG         | 7402| 7475 | 17076| [MA1]≈[MC1]   | agree    | Phase to ground fault |
| 10 Ω            |                | AG         | -   | -   | 13419| [MA1]≈[MC1]   | agree    | Phase to ground fault |
|                 |                | BG         | 6361| 11930| 6287| [MB1]≈[MC1]   | agree    | Phase to ground fault |
|                 |                | CG         | 7192| 7266 | 16437| [MA1]≈[MC1]   | agree    | Phase to ground fault |
| 20 Ω            |                | AG         | -   | -   | 10910| [MA1]≈[MC1]   | agree    | Phase to ground fault |
|                 |                | BG         | 4124| 7290 | 4050| [MB1]≈[MC1]   | agree    | Phase to ground fault |
|                 |                | CG         | 6712| 6786 | 15195| [MA1]≈[MB1]   | agree    | Phase to ground fault |

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