FAULT LOCATION ALGORITHM BASED ON ANN FOR SINGLE LINE-TO-GROUND FAULT IN MV DISTRIBUTION SYSTEM

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LIST OF ABBREVIATIONS

DC	Direct Current
AC	Alternating Current
CT	Current Transformers
SLG	Single line-to-ground fault
LL	Line-to-Line faults
DLG	Double Line-to-Ground
LLL	Balanced three phase faults
MV	Medium Voltage
EMTP-ATP	Electromagnetic Transient Program-Alternative Transient Program
DWF	Discrete Wavelet Wilter
FIR	Finite Impulse Response
DFT	Discrete Fourier Transform
GPS	Global Positioning System
GPRS	General Packet Radio Service
AI	Artificial Intelligence
ANN	Artificial Neural Networks
NN	Neural Network
LCC	Line / Cable
COG	Coefficient Of Grounding
TL	Transmission Line
FFT	Fast Furrier Transfer
$\|A\|$	Magnitude of Current Signal
$\|A\|_{FFT}$	FFT Magnitude of Current Signal
F	Fault
V	Voltage

V_{L-L}	Voltage line-to-line
V_{L-N}	Voltage line-to-neutral
I	Current
R	Resistance
L	Inductor
Hz	Hertz
Ω	Ohm
%	Percentage

Algoritma Lokasi Berdasarkan Rangkaian Neural Buatan Untuk Kerosakan Talian Ke Bumi Dalam Sistem Voltan Pengagihan Sederhana

ABSTRAK

Projek ini khusus untuk mengesan dan mencari kerosakan talian tunggal ke bumi yang berlaku pada talian penghantaran di jaringan-jaringan voltan sederhana. Kerosakan talian tunggal kebumi adalah yang paling biasa berlaku berbanding kerosakan lain. Untuk mengesan dan mencari lokasi kerosakan tunggal fasa kebumi di rangkaian-rangkaian voltan sederhana, algoritma mencari lokasi kecacatan berasaskan rangkaian neural buatan telah dibangunkan untuk mencapai matlamat ini. Pada mulanya, rangkaian voltan sederhana ini direka bentuk dengan menggunakan Program Fana Elektromagnet-Program Fana Alternatif (EMTP-ATP) mengikut suatu rangkaian sebenar (IEEE 34 penyuap). Selepas itu rangkaian disimulasi dengan mensimulasi pelbagai kerosakan di lokasi-lokasi yang berbeza. Tambahan lagi, suatu rintangan bumi telah diubah dan semua data yang telah digunakan, direkodkan untuk membangunkan algoritma lokasi kerosakan berasaskan rangkaian neural buatan. Isyarat kerosakan diukur dalam program EMTP tersebut. Juga, isyarat yang diperolehi telah dianalisa dengan menggunakan Penjelmaan Fourier Pantas dalam MATLAB untuk mengira tiga domain tertinggi yang pertama. 150 kecacatan telah disimulasikan pada rangkaian-rangkaian voltan sederhana untuk menjana isyarat arus kerosakan. Data telah dikumpul, diukur dan isyarat dianalisis. Data telah dilatih dan diuji dalam rangkaian neural di MATLAB untuk membangunkan algoritma. Algoritma yang dibangunkan dapat menganggarkan lokasi kecacatan tunggal talian kebumi yang disimulasikan di jaringan-jaringan voltan sederhana. Dari perbandingan di antara semua kecacatan lokasi yang disimulasikan dan semua lokasi yang dikesan dalam algoritma lokasi kerosakan yang dibangunkan, didapati bahawa jumlah ralat di antara mereka adalah kecil dan ralat tersebut kurang dari 0.7 km. Kemudian, berdasarkan algoritma yang dibangunkan, litar Simulink dijana dan diuji untuk mengesan kerosakan tunggal talian kebumi yang mungkin berlaku di rangkaian voltan sedrehana tersebut di masa hadapan.

Fault Location Algorithm Based on ANN for Single Line-To-Ground Fault in MV Distribution System

ABSTRACT

This project was focused to detect and locate the single line-to-ground (SLG) fault which occurs on transmission lines in MV networks. SLG fault is the most common compared to other faults. To detect and locate single-phase ground faults on MV networks, the ANN based fault location algorithm was developed to achieve this objective. In beginning, the MV network was designed by using Electromagnetic Transient Program-Alternative Transient Program (EMTP-ATP) according to a real network (IEEE 34 feeder). After that the network was simulated by creating faults at different locations. In addition, an earth resistance were changed and all the data which was used, is recorded to develop the ANN based FL algorithm. The fault current signal was measured in the EMTP program. Also, were analyzed captured signals by using the Fast Fourier Transform (FFT) in MATLAB to calculate the highest first three domains. 150 fault locations were simulated on the MV network to generate fault currents. The data is gathered from simulated fault currents. The data was trained and tested in the neural network in MATLAB to develop the algorithm. The developed algorithm is able to estimate a location for SLG faults which were simulated on the MV network. From a comparison between all location faults which were simulated and all locations which were detected in the developed FL algorithm it was found that the total error between them was small and the error is less than 0.72 km. Then based on the developed algorithm, the Simulink circuit was generated and tested to detect a SLG fault which may occur in the MV network in a future.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The electrical power industry is a main part of any country. Typically, there are three parts for any power system: generation, transmission, and distribution. All of them are essential for the entire power system. In recent years, the power system is increasingly developed. The transmission lines are longer and longer. The voltage level on transmission line is also higher and higher. However, the faults of the transmission lines are difficult to avoid. Those faults imperil the safety and the reliability of the power system. The longer the power failure, the greater the damage caused. Therefore, quickly locating the fault location and retrieving power supply are desired by all utilities. In order to fix the fault swiftly, detecting the accurate location of fault is the key. Consequently, the estimation of fault location in the transmission line is very important to electric engineers and utilities.

The fault occurs in electrical network due to a variety of different factors as lightning ionizing air, wires blowing together in the wind, animals or plants coming such in contact with the wires, and salt spray or pollution on insulators (Singh, M., Panigrahi, B. K., et al. 2011).

Two types of faults which occur on any transmission lines: unbalanced fault and balanced fault, which are also known as asymmetrical and symmetrical fault, respectively. Generally the faults that occur on the electrical power network are unbalanced faults.

1.2 Single Line to Ground Fault

Single line to ground fault exceedingly common compare with all others types of shunt fault. There are four types from shunt fault which occur on three-phase transmission line.

- Single line-to-ground faults (SLG)
- Line-to-line faults (LL)
- Balanced three-phase faults (LLL)
- Double line-to-ground (DLG) faults

Figure 1.1 shows how the current flows in circuit when these faults occur. Power systems have been in working for more than hundred years now. Cumulative expertise shows that all faults are not evenly probable. Single line-to-ground (SLG) faults happen the most. Whilst the least frequent is the three-phase fault (LLL) fault due to simultaneous short circuit between all the three lines, as shown in Table 1.

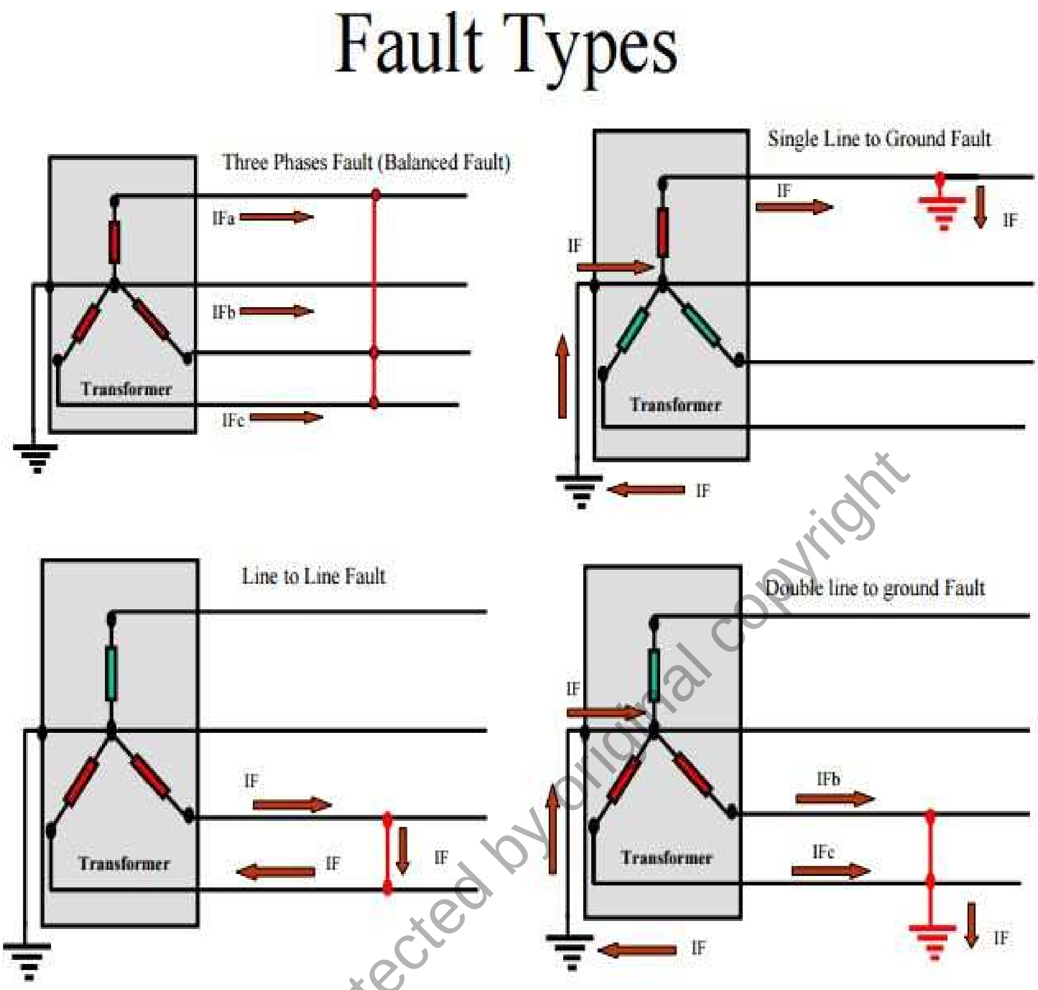

Figure 1.1 How the Current Flows in Circuit When These Faults Occur

(A. M. Baseer, et al. 2013).

Table 1: Probability of Fault Occurrence (A. M. Baseer, et al. 2013)

Type fault	Probability of occurrence (%)	Severity
L-G	70 - 80	Lowest
L-L	8 - 10	Lower
L-L-G	5 - 7	Higher
L-L-L	2 - 3	Highest

Single phase to earth faults in MV network is the most common from other faults in power distribution networks about 50% to 80% of the faults are of this type. In 2010, a fault statistic studied by utility company in Dresden Germany shows that 75% of all faults are single line to earth faults (Mohd Adzman , et al. 2014). Also, above 80% of the faults were measured involved only one phase either in connect with ground or with the neutral (Shimaa Barakat , et al. 2014).

1.3 Problem Statement

This project focuses on the single line-to-ground faults that occurs in MV network system. Previously, the conventional method for detecting fault location is by searching along the line by using the fault locating equipment which could be time consuming. The main problem is when the SLG fault occurred in the medium voltage network; the voltage decreases while the current increases and effects on the whole network system.

Therefore, the fault must be detected and selected its location exactly in the network to be cleared. The sensitivity and accuracy of the equipment for detecting the fault location in the network is very important in the system. Because the fault might exceed to be three-phase to ground fault and the problem will be bigger than single line to ground fault. For that reason, this project will design medium voltage (MV) network and develop fault locating algorithm to detect the fault and select the line location in the shortest time to be repaired and restored to the network as soon as possible.

1.4 Objective

The objectives of this project are:

a) Design a typical MV network using Electro Magnetic Transient Program (EMTP/ATP).
b) Simulate a single line to ground fault in medium voltage (MV) network and analyze a captured earth fault signal using signal processing techniques.
c) Develop a fault location algorithm of single line to ground fault in medium voltage (MV) network based on ANN method.
d) Generate a Simulink circuit based on developed ANN model to locate the actual fault location.

1.5 Scope of Research

The scope of this project is to simulate a single line to ground fault on solidly grounded MV network. The MV network was designed using ATP/EMTP program .The properties of fault signals are studied and collected these data are later used to develop a fault locating algorithm. In addition, Simulink circuit is generated after the data was tested using ANN model in order to locate the actual fault in the network.

1.6 Organization of the Thesis

The rest of this thesis are orderly organized into four chapters. **Chapter 2** presents an overview of the concerning studies. **Chapter 3** fundamentally discusses the methodology of this project, which comprise design MV network at different types of load and simulate many faults on this network and set out in block diagrams. **Chapter 4** shows how the data was collected and tested after simulating the fault to develop ANN algorithm to locate the actual fault when occurs on network. **Chapter 5** concludes the research methodology, results and the future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this thesis the research work is related on developing fault location methods for earth fault that happens in distribution network transmission lines. Single line-to-ground fault is the most common problem in power distribution network. Several researchers and engineers had study this problem in their research and adopted varies methods for locating the fault.

There are three steps to locate a single line-to-ground fault location: the first one is faulted line selection, fault section determination and determining the fault point (Jing, et al., 2009). There are some achievements were made for the first two parts, but the effective solutions at the last part is not acquired yet. So, how to accurately locate a single phase to ground fault is still a research focus. Due to the characteristics of the single phase to ground fault in distribution network, this chapter introduces and present several methods that were used to analyze the fault and determine the fault location.

2.2 Wavelet Method

When a single line-to-ground fault happens, the fault path inductance of the fault line comprises a series of collected positive, negative and zero inductance. The inductance fault is described as follows (Lehtonen et al., 1992):

$$L_f = \frac{1}{3}\left(L_{1,p}L_{1,n}L_{1,0}\right).l \qquad (2.1)$$

In which l signifies the fault distance and $L_{1,p}, L_{1,n}, L_{1,0}$ signify the inductance per unit length of positive, negative and zero sequence systems. A fault location algorithm instituted on wavelet transform was presented by Hänninen et al., (2001) to appreciate the fault path inductance of the fault line length by utilizing the transient signal. According to (Hanninen et al., 2001), the fault path inductance can be estimated based on the following equation:

$$L_f = \frac{1}{w} imag\left[\frac{U_w(K\Delta t, f)}{I_w(K\Delta t, f)}\right] \qquad (2.2)$$

In which $U\omega$ and $I\omega$ denote the congregation wavelet coefficients of current and voltage while ω denotes the angular frequency. According to (Hanninen et al., 1999), the initial algorithm searches for the maximum wavelet coefficient of the current includes amplitude, frequency and the location of the wavelet. This frequency uses several time which the equivalent fault inductance can be calculated. The 2 ms inductance, corresponding to 10 sub estimates, is then measured with the smallest standard deviation. The average value of the inductance, calculated in this interval is finally used to define the fault distance. In the study conducted by (Imris et al., 2006), it is discovered that researcher deals with an earth fault in sub transmission networks. Their research relates to transient-based ground fault location by employing charge transient.(Imris et al., 2006) further proposed the use of discrete wavelet filter (DWF), the FIR filter with the Gaussian wavelet and amplitude correction in filtering specific coefficient of transient component. Instead of using DWT in many frequency scales, DWF only uses a single scale where the transient is of interest. However, the method still requires a pre-processing technique to locate the specific transient frequency. This is done by using discrete Fourier Transform (DFT). The equation of DWF is illustrated below:

$$DWF[n] = \frac{2}{\alpha\sqrt{2\pi\delta}} \sum_n x[n].\, e^{-\left(\frac{((n-b)/a)^2}{2\delta^2}\right)+jw_0(n-b)/a} \quad (2.3)$$

In which x[n] which indicates a discrete function of the samples is a scaling factor while b is the translation of $\delta = \sqrt{3/2}, \omega 0 = 5.336\, rads - 1$ and n is an integer variable parameter which represents discrete time. In Equation (2.3), the scaling factor is calculated from sampling frequency (fs) and the filtered frequency of the charge transient (fc) $as\ a = fs/fc$ (Imris et al., 2006).

2.3 Fourier Transform Method

An algorithm based on Fourier transforms method was suggested by (Igel, et al., 1990). Solve the line impedance in the frequency domain is the basic idea for FFT. In event first order line model, the resistance of the fault line length is obtained as the imaginary part of the impedance calculated from the corresponding frequency spectrum identical of currents and voltages of the faulty phase (Igel, et al., 1990). The distance to earth fault location is calculated as follows:

$$Z = \frac{\underline{U}_{(\omega)}}{\underline{I}_{(\omega)}} \quad (2.4)$$

$$l = \frac{3\text{Im}(\underline{Z}_{(w)})}{\left(L_{1,0}(w) + 2L_{1,p}(w)\right)w} \tag{2.5}$$

Where, l , $\text{distance single line} - \text{to} - \text{gruond fault location}$, $\underline{Z}(\omega), \underline{U}(\omega)$ and $\underline{I}(\omega)$ are the frequency (ω) component of impedance, measured voltage and current, $L_{1,0}$ and $L_{1,P}$, are the inductance per unit length of zero- and positive-sequence per length of the faulty line. As explained in (Igel, et al., 1990), the fault distance is calculated as a weighted average of the rating made for the dominating frequencies in the spectrum. Likewise a higher order model, which authorize for the phase to earth capacitances, is offered in (Igel, et al., 1990).

2.4 Differential Equation Method

The network ability to model through a simple first order model of a RL-circuit in an ground fault in electrical power network .The current and voltage signals for fault phase as the following relation (Phadke, et al., 2009):

$$u_{(t)} = R \,.\, i_{(t)} + L\frac{d_i}{d_t} \tag{2.6}$$

Where $u_{(t)}$, $i_{(t)}$, R and L are the voltage, current, resistance and the inductance of the faulty phase, respectively. According to (Phadke, et al., 2009), the differentiation is sensitive to higher frequency noise and can be solved by using above equation is done by using the integration technique. With samples of voltage and current signal, inductance L is calculated by using three equally spaced pairs of voltage and current using trapezoidal rule as follows:

$$L = \frac{\Delta t}{2}\frac{((i_{k+1} + i_k)(u_{k+2} + u_k) - (i_{k+2} + i_{k+1})(u_{k+1} + u_k))}{((i_{k+1} + i_k)(i_{k+2} - i_{k+1})_{-}(i_{k+2} + i_{k+1})(i_{k+1} - i_k))} \tag{2.7}$$

An earth fault transient signal has been applied to the differential equation method by (Schegner, et al., 1989). The total length of the time window was 16 to 24 samples, with a sampling frequency of 10 kHz. Differential-equation algorithms work according to theory for all the voltage and current components which state Equation (2.7). The preferable result is, however, obtained if all the other frequencies are first distilled out, exclude the charge transient (Lehtonen, et al., 1992).

2.5 Impedance Method

This method assumes that the transmission line is uniform in which the fault loop impedance could be calculated in accordance to the value of the current and voltage that were obtained during the fault. The length of the line is proportional to the impedance. Thus, the distance that measures between the device installed point to fault point is investigated finally as a result (Ge et al., 1993).

The line parameters affect the precision of the fault location in the distribution network. This research puts the malfunction location zone which also denotes the single line based on double end impedance method without data synchronization. It also depends on the analysis of the fundamental knowledge of the location of fault as mentioned by (Li et al., 2011).

It also derives from the measured rang equation of the SPG fault in the distributing network. In actual fact, there are two steps that need to be taken when employing this method. Firstly, both proper frequency sinusoidal signal and resistor sensation are applied on the line. This is followed by the measurement conditions of initial and terminal points of the transmission line and also some of the electrical extents