Engineering Science and Technology, an International Journal xxx (2016) xxx–xxx

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: www.elsevier.com/locate/jestch

Full Length Article

Support vector machine based fault classification and location of a long transmission line

Papia Ray [a,*], Debani Prasad Mishra [b]

[a] Department of Electrical Engineering, Veer Surendra Sai University of Technology, Burla, Odisha, India
[b] Department of Electrical and Electronics Engineering, International Institute of Information Technology, Bhubaneswar, Odisha, India

ARTICLE INFO

Article history:
Received 28 December 2015
Revised 19 March 2016
Accepted 4 April 2016
Available online xxxx

Keywords:
Fault classification
Feature selection
Fault location
Support vector machine
Wavelet packet transform
Transmission line

ABSTRACT

This paper investigates support vector machine based fault type and distance estimation scheme in a long transmission line. The planned technique uses post fault single cycle current waveform and pre-processing of the samples is done by wavelet packet transform. Energy and entropy are obtained from the decomposed coefficients and feature matrix is prepared. Then the redundant features from the matrix are taken out by the forward feature selection method and normalized. Test and train data are developed by taking into consideration variables of a simulation situation like fault type, resistance path, inception angle, and distance. In this paper 10 different types of short circuit fault are analyzed. The test data are examined by support vector machine whose parameters are optimized by particle swarm optimization method. The anticipated method is checked on a 400 kV, 300 km long transmission line with voltage source at both the ends. Two cases were examined with the proposed method. The first one is fault very near to both the source end (front and rear) and the second one is support vector machine with and without optimized parameter. Simulation result indicates that the anticipated method for fault classification gives high accuracy (99.21%) and least fault distance estimation error (<0.21%) for all discussed cases. In order to verify the accuracy of the proposed method, a comparison is carried out with methods published by other researchers. Separate investigation is also carried out with the transmission line placing thyristor controlled series capacitor in the middle and applying the same proposed method. It is observed from the test results of the thyristor controlled series capacitor based transmission line model that fault classification gives a high accuracy of 98.36% and absolute fault location error is >0.29%.

1. Introduction

Progress of a country is measured by per capita consumption of electric energy. Protection engineers find it difficult to maintain uninterrupted electric power to the end users due to the presence of fault in a transmission line [1]. Generally the reason for the transmission line fault is hard to discover, so it is very important to build up a fault analyzer that can examine the type of the fault and estimate the fault distance quickly and accurately. Fault occurrence takes place when conductors touch each other or the ground [2], and are classified in a three phase system as:

- Single line-to-ground fault (SLG).
- Line-to-line fault (LL).
- Double line-to-ground fault (LLG).
- Triple line fault (LLL).

After the occurrence of a fault, restoration of power supply is possible only when the maintenance crew finishes the repair work. If failure of power supply is elongated then it leads to line outage, economic losses and wastage of time and energy of maintenance workers. So it is required to classify and locate the fault quickly and correctly, otherwise the whole transmission line has to be examined by the maintenance worker in order to find the exact fault position.

In the recent past, many researchers have investigated in a long transmission line following fault location and classification techniques [3]

- Impedance measurement based technique.
- Traveling wave phenomenon based technique.
- Artificial Intelligence based technique.

* Corresponding author.
E-mail addresses: papia_ray@yahoo.co.in (P. Ray), debani@iiit-bh.ac.in (D.P. Mishra).

Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2016.04.001
2215-0986/

Nomenclature

List of symbols

V	volts
I	current
$x(t)$	signal
$\bar{x}$	mean value of current signal
t	time (s)
E	energy
EN	entropy
c	cost parameter of support vector machine
g	gamma parameter of support vector machine
f	fitness value of particle swarm optimization
$y(k)$	discrete samples
$e(w)$	evaluation function of forward feature selection method
w	inertia weight in the case of particle swarm optimization
c1, c2	acceleration constant in case of particle swarm optimization
wmin, wmax	initial and final values of weighting coefficients in case of particle swarm optimization method
E_s	voltage source at the sending end of the transmission line
E_r	voltage source at the receiving end of the transmission line
R_f	fault resistance (in ohms)
θ	fault inception angle (in degree)
e	error
F_s	sampling frequency (in Hertz)

Impedance measurement based technique mainly depends on fundamental frequency current and voltages. This method is simple and cheap, but gives erroneous results for huge value of the fault resistance [4]. Estimation of fault type and distance with impedance based technique in a transmission line is discussed in [5–10]. In these schemes, single ended impedance measurement is used to estimate fault distance in a long transmission line. The simulation results of these schemes show that due to large fault resistance, estimation of fault type and distance error becomes more. In a transmission line for estimation of fault type and distance, the relationship between forward and backward waves travelling is the main theory behind travelling wave technique which has attracted widespread attention nowadays. These techniques estimate different type of fault and find the high impedance fault in the transmission line almost accurately, but the sampling rate required is quite high (above 1 MHz) which is hard to implement in practical field [11,12]. Travelling wave based distance evaluation and fault classification in a long transmission line is reported in [13–16]. In order to analyze the fault, these schemes are based on correlation method to find the time difference between forward and backward wave. The methods discussed in [13–16] gives less error for fault classification and distance evaluation, however, they show the same pattern for fault near and at the far end of the transmission line due to which it becomes quite difficult to identify and locate the fault.

Nowadays, researchers are giving more emphasis on artificial intelligence based fault classification and distance estimation skills such as neural network, fuzzy logic etc. because of its accuracy, self adaptiveness and robustness to parameter variations. Fault classification with fuzzy logic technique in a long transmission line is reported in [17–20]. These schemes use wavelet transform (WT) of the current signal to provide unseen fault data to the fuzzy logic system for fault classification. In these schemes simple computational process is used, however the fault classification error reported is quite large due to changes in simulation condition. Artificial neural network (ANN) is discussed in [21–28] for long transmission line fault classification and distance evaluation. These schemes [21–28] use wavelet transform or wavelet packet transform (WPT) to extract distinctive features like energy and entropy from acquiring signals of voltage and current which are further used in ANN for fault location and classification . The simulation results show good accuracy, however the training time is quite large due to which the task becomes quite complex and lethargic. In the scheme [29] fault classification and location in a high voltage power transmission line is proposed by using wavelet transform and support vector machine whereas in our proposed method, fault classification and location in a high voltage power transmission line is discussed by using wavelet packet transform and particle swarm optimization based support vector machine in combination with forward feature selection method. By using wavelet packet transform more number of features and better resolution is achieved. In scheme [29] one terminal current and voltage signal is analyzed and wavelet entropy criterion is applied to reduce the size of feature vectors whereas in our proposed method one terminal current signal is analyzed and wavelet energy and entropy is applied for pre-processing. Further in the proposed method, forward feature selection method is used to remove redundant features and to enhance the accuracy. It was observed from scheme [29] that fault classification accuracy was 99% and maximum fault location error was 0.74% whereas the proposed method in this paper says fault classification accuracy is 99.21% and fault location error is >0.21%.

Fault location of a transmission line using stationary wavelet transform in combination with determinant function feature (DFF), support vector machine (SVM) and support vector regression (SVR) is discussed in [30]. The scheme in [30] uses single end measurement and DFF to extract features. Also filtering is used in the scheme [30] to remove noise and decaying DC offset. Simulation results of [30] show fault location error to be less, however the instrumentation associated with it is quite complex. Fault detection, classification and location for transmission system with multigenerators applying discrete orthogonal stockwell transform is reported in [31]. In this scheme [31], synchronized current measurements from both ends of the transmission line is taken for fault analysis purpose. Also in the scheme [31] energy is extracted as feature from the acquired signal and SVM is used as fault locator. However the algorithm is quite complex and parameters of SVM are not optimized which leads to errors in fault analysis.

This paper mainly focuses on two hybrid methodologies for estimation of fault type and distance in a long transmission line. The proposed method uses one cycle waveform of current which is extracted from the sending terminal of the power system transmission line under study for fault classification and location. Thereafter current samples are pre-processed by wavelet packet transform and characteristics (also termed as features) like energy and entropy are extracted from them. The best feature subset of the whole feature matrix is then selected by forward feature selection technique during training. The data for training is generated by considering a variety of simulation condition like type of fault, fault resistance, fault distance and fault inception angle. Further the feature set is scaled between [−1,+1] which is then fed to the support vector machine (SVM) for training the data and to