International Journal of Pure and Applied Mathematics
Volume 120 No. 5 2018, 885-893
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

Classification of Shunt Faults in Six Phase Transmission Line using k-Nearest Neighbor Algorithm

A Naresh Kumar[1], M Chakravarthy[2], Ch Sanjay[3]

[1]Department of Electrical and Electronics Engineering, Institute of Aeronautical Engineering, Hyderabad, India
[2]Department of Electrical and Electronics Engineering, Vasavi College of Engineering, Hyderabad, India
[3]Department of Mechanical Engineering, GITAM University, Hyderabad, India

E-Mail: ankamnaresh29@gmail.com[1]

Abstract: This paper presents a method for classification of shunt faults in six phase transmission (SPT) line using k-nearest neighbor (k-NN) approach. A 138 kV SPT line of 68 km length has been simulated using Simulink® and Simpowersystems® toolbox of MATLAB® software. The fundamental component of current signals measured at source location is used as input to k-NN network. The effect of variation in fault distance location and fault inception angle has been investigated on the performance of the proposed protection approach. The simulation results of k-NN based fault classifier show that the proposed approach correctly classifies all types of shunt faults within half cycle time. It validates the accuracy and suitability of the proposed approach.

Keywords – Fault Classification, k-Nearest Neighbor, Shunt faults, Six Phase Transmission Lines.

I. Introduction

Recent times have witnessed an increase in the demand of electrical energy. To facilitate the growing energy demand, it is vital to enhance the power handling capability of existing transmission lines. Due to the constraints of land availability, infrastructure and several environmental problems, multiphase transmission line is an alternative scheme for increasing power handling capability of overhead transmission line. In recent times, the multiphase transmission system has emerged as the viable transmission alternative to attain efficient utilization of rights of way and increased transmission capability to meet growing power demand. Among the multiphase transmission lines, SPT is the most promising alternative for transferring more power with the existing structure of a three phase double circuit line.

Preliminary works on the design and implementation have disclosed the feasibility of a SPT line [1–9]. To maintain the stability of the power system under all operating conditions, it is needed to develop an adequate protection network which protects the system by isolating only the portion of transmission line that is faulty, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic approach in clearing system faults. Thus, it is essential to build up a fast reliable and complete protection system for various shunt faults. There are 120 numbers of possible fault combinations in a SPT line, which is much more as compared to 11 numbers in a three phase transmission line. Therefore, the complexity of protection system for a SPT line is more as compared to a three phase transmission line. Different faults likely to occur on a SPT system have been analyzed in various papers using unsymmetrical components, symmetrical components and phase coordinates approach [10–12].

In Ref [13, 14], different classification schemes for shunt faults have been demonstrated using the currents and voltages on one end of transmission line. Some protection strategies use only the fault currents [15, 16]. Shunt fault classification as an input of fundamental component of currents in transmission line has been widely studied [17]. As reported in the literature [18, 19, 20, 21] many fault classification procedures were addressed particularly for SPT lines. Some of the above-mentioned methods did not provide the classification of shunt fault in SPT line, which took up to half cycle. Fault classification using k-NN in three phase circuit lines are discussed in [22]. The purpose of this paper is to design an efficient shunt fault classification methodology in SPT line considering k-NN and fundamental frequency component of currents. Indeed, the core idea of this work is to improve accuracy of classification. Thus, an improved k-NN scheme for fault classification in SPT line is proposed in this paper.

We organized the rest of our paper as follows. Section II demonstrates the SPT line configuration, modeling and simulation of shunt faults. Section III illustrates the k-NN approach for classifying shunt faults. Section IV explains the simulation results for classifying shunt fault cases. Our conclusion is presented in Section V.

II. Simulation of SPT Transmission Line

A single line diagram of the SPT power network is shown in Fig. 1. The network consists of a 138 kV, 60 Hz transmission line of length 68 km. The line is fed from sources at both the sending end and receiving end with two loads of 250 MW and 100 MVAR at receiving end. The short-circuit capacity of sources at both the ends and their X/R ratio are 1250 MVA and 10, respectively. Basic system description and line configuration data of SPT line used in the present work are detailed in Table. 1. The SPT line model is implemented and simulated using Simulink and Simpowersystems toolbox of MATLAB. The six-phase current Ia, Ib, Ic, Id, Ie, If waveforms of corresponding phases during a shunt fault in phase ‘‘c’’ at 40 km from the relaying point and at fault inception angle 90 ^{o} are shown in Fig. 2. The recorded instantaneous six current input signals were sampled at a sampling frequency of 1200 Hz and further processed by simple 2nd-order low-pass Butter worth filter with cut-off frequency of 480 Hz. One full cycle discrete Fourier transform has been used herein to process the time series currents and the fundamental component of six phase currents has been calculated using discrete Fourier block set of MATLAB® software. The k-NN algorithm employs the fundamental components of six phase currents at one terminal of the line only.

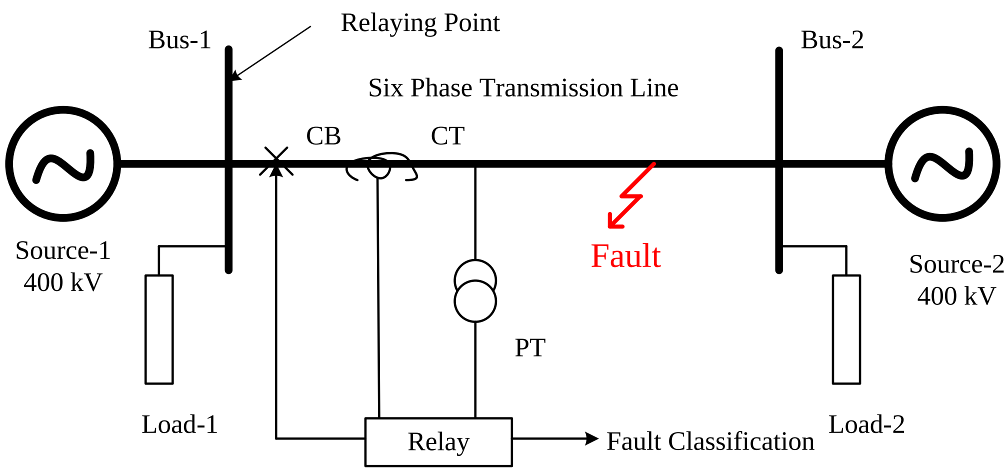

Fig.1. Power System Network considered

Table.1. Basic system description data

Parameter	Units	Nominal Values
Nominal Source Voltage	[kV]	138
Base Voltage	[kV]	138

Base Power	[MVA]	100
Frequency	[Hz]	60
Earth Resistivity	[Ω-m]	100
Line Length	[km]	68
Short Circuit Capacity	[MVA]	1250
X/R Ratio of the Source	-	10
Load at Bus	[kW]	100
	[kVAR]	100

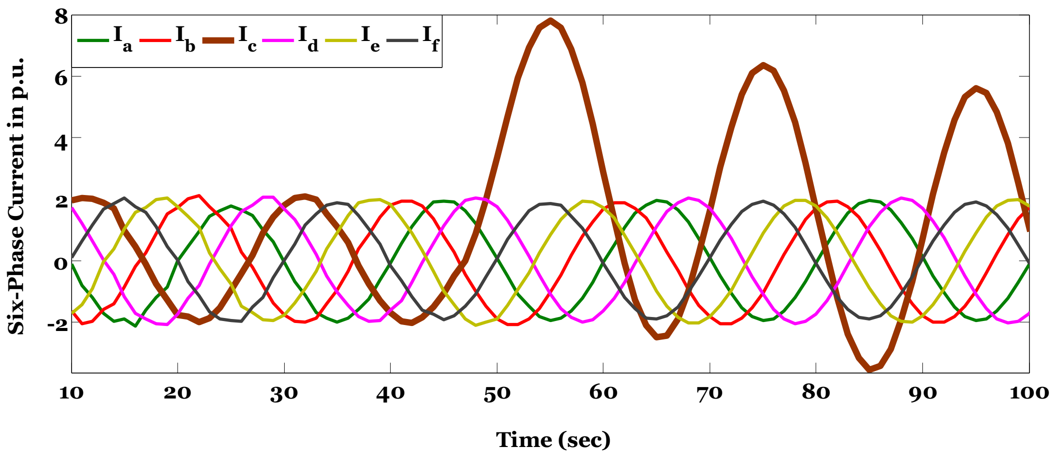

Fig.2. Six phase currents during shunt fault

III. Designing of k-NN Network

The k-NN algorithm is a nonparametric classification method that can achieve high classification accuracy in problems with non-normal and unknown distributions. For a particular sample, k closest points between the data and the sample are found. Usually, the Euclidean distance is used, where one point's components are utilized to compare with the components of another point. The basis of k-NN algorithm is a data matrix that consists of N rows and M columns. Parameters N and M are the number of data points and dimension of each data point, respectively. Using the data matrix, a query point is provided and the closest k points are searched within this data matrix that is the closest to this query point. In general, the Euclidean distance between the query and the rest of the points in the data matrix is calculated. After this operation, N Euclidean distances which symbolize the distances between the query with each corresponding point in the data set are achieved. Then, the k nearest points to the query can be simply searched by sorting the distances in ascending order and retrieving those k points that have the smallest distance between the data set and query.

The k-NN fault classification network is designed for classifying different types of shunt faults. K-NN network consists of two different k-NN networks: k-NN-P and k-NN-G. The k-NN-P module is designed to identify the faulty phases, whereas k-NN-G recognizes whether the fault loop involves ground or not. Training patterns used for designing the k-NN-P modules are fundamental component of currents. Corresponding targets for different faulted phases are assigned as 0-No fault and 1-faulty phase. The k-NN-G module is designed by taking zero sequence components of current signals as input. From the zero sequence components, 10 post-fault samples are taken from each case. Corresponding targets are set as “0” for no fault, “1”for ground faults. Training performance is checked by varying the value of k for both k-NN-P and k-NN-G module as shown in Table 2 and 3, respectively. Highest training accuracy for k-NN-P and k-NN-G modules is obtained with k = 2, thus k = 2 is chosen for k-NN-P and k-NN-G modules as their nearest neighbors.

IV. Results and Discussions

Testing is required to check the performance of proposed k-NN based fault classifier. The proposed k-NN based fault classifier is tested using testing data set considering all types of shunt fault with variation in fault location from 1 km to 67 km and fault inception angle between 0° to 360°. Total 120 fault cases are simulated and tested. After testing the proposed k-NN based fault classifier, it has been found that the proposed approach is able to classify all types of shunt faults correctly i.e. an accuracy of 100%. The accuracy is computed using equation (1) in faulty classification.

$$\text{Accuracy} = \frac{\text{Number of test samples correcly classified}}{\text{Number of test samples}} \times 100 \quad \ldots(1)$$

Table. 2. Test results of k-NN classifier for different fault inception angles.

Fault type	Fault Inception Angle	Output of k-NN-based fault classifier						
		A	B	C	D	E	F	G
B-G	0°	0	1.01	0	0	0	0	1
CF-G	40°	0	0	1	0	0	1	1
ABC-G	60°	0.99	1	1	0	0	0	1
ABCE-G	120°	1	0.99	0.99	0	1	0	0.99
ABCDE-G	170°	0.99	1	1	0.99	0.98	0	1

ABCDEF-G	320°	1	0.81	0.94	1	0.94	1	0.95
DE	30°	0	0	0	0.99	1	0	0
DEF	80°	0	0	0	1	1	0.99	0
CDEF	270°	0	0	1	1	1	1	0
BCDEF	300°	0	0.99	0.99	1	0.99	0.99	0
ABCDEF	310°	1	1	1	0.99	1	1	0

Table. 3. Test results of k-NN classifier for different fault locations

Fault type	Location in km	Output of k-NN-based fault classifier						
		A	B	C	D	E	F	G
A-G	3	1	0	0	0	0	0	1
AB-G	5	1	1	0	0	0	0	1
BCD-G	12	0	1	1	0.99	0	0	1
ABCD-G	25	1	1	1	1	0	0	0.97
ABCDE-G	36	1	0.99	1	1	0.99	0	1
ABCDEF-G	45	1	1	0.99	1	1	1	1
BC	45	0	1	1	0	0	0	0
BCD	52	0	1	1	1	0	0	0
ABDE	64	0.99	1	0	0.99	1	0	0
ABCDE	86	1	1	1	1	1	0	0
ABCDEF	96	0.99	1	1	0.99	1	1	0

V. Conclusion

This paper proposes an accurate approach for classification of shunt faults in SPT line based k-NN. Various types of shunt fault, under varying fault conditions such as location of fault from source point (1 km to 67 km) and fault inception angle (0° to 360°) have been investigated. The approach employs the fundamental components of six phase currents of the line at one end only. The performance of the proposed scheme has been investigated by a number of offline tests. The test results confirm the suitability of proposed approach.

References

1. Barnes H.C, Barthold L. O, High Phase Order Transmission, *Electra*, 24, (1973),139–153.

2. Stewart J.R, Wilson D.D. High Phase Order Transmission–a Feasibility Analysis Part-I Steady State Considerations, *IEEE Transactions Power Apparatus and Systems*, 97, No.6, (1978), 2300–2307.

3. Nanda SP, Tiwari SN, Singh LP. Fault Analysis on Six Phase System, *Electrical Power System Research*, 4, (1981), 201–211.

4. Tiwari SN, Six-Phase (Multi-phase) Power System: Some Aspects of Modeling and Fault Analysis, *Electrical Power System Research*, 6, (1983), 193–202.

5. Stewart JR, Grant IS, High Phase Order - Ready for Application, *IEEE Transactions on Power Apparatus and Systems*, 101, No. 6, (1982), 1757–1764.

6. Tiaras N, Singh LP, Mathematical Modelling and Analysis of Multi Phase Systems, *IEEE Transactions on Power Apparatus and Systems*, 101, No.6, (1982), 1784–1793.

7. Stewart JR, Kallaur E, Grant IS, Economics of EHV High Phase Order Transmission, *IEEE Transactions on Power Apparatus and Systems*, 103, No.6, (1984), 3386–3392.

8. Wilson DD, Stewart JR. Switching Surge Characteristics of Six-Phase Transmission Lines, *IEEE Transaction on Power Apparatus and Systems*, PAS-103, No.11, (1984), 3393–3401.

9. Tiwari SN, Singh GK, Multi-Phase Transmission Research-A Survey, *Electrical Power System Research*, 24, (1992), 207–215.

10. Bhatt NB, Venkata SS, Guyker WC, Booth WH, Six-Phase (Multi-Phase) Power Transmission System: Fault Analysis, *IEEE Transactions on Power Apparatus and Systems*, 96, No. 3, (1977), 758–767.

11. Venkata SS, Guyker WC, Kondragunta J, Saini NK, Stanek EK, 138-kV, Six Phase Transmission System: Fault Analysis, *IEEE Transaction on Power Apparatus and systems*, 101, No. 5, (1982), 1203–1216.

12. Onogi Y, Isaka K, Chiba A, Okumoto Y, A Method of Suppressing Fault Currents and Improving the Ground Level Electric Field in a Novel Six-Phase Transmission System, *IEEE Transactions on Power Apparatus and Systems*, 102, No. 4, (1983), 870–879.

13. Sami Ekici, Support Vector Machines for Classification and Locating Faults on Transmission Lines, *Applied Soft Computing*, 12, No. 6, (2012), 1650-1658.

14. Soumyadip Jana, Sudipta Nath, Aritra Dasgupta, Transmission Line Fault Classification Based on Wavelet Entropy and Neural Network, *International Journal of Electrical Engineering and Technology*, 3, No. 2, (2012).

15. Simi P Valsan, K Shanti Swarup, High Speed Fault Classification in Power Lines: Theory and FPGA Based Implementation, *IEEE Trans. Industrial Electronics*, 6, No.5, (2009), 1793-1800.

16. L.N. Tripaty, P.K. Dash, S.R. Samantary, A New Cross- Differential Protection Scheme for Parallel Transmission Lines Including UPFC, *IEEE Trans. Power Delivery*, 29, No.4, (2014), 1822-1830.

17. Jain A, Thoke. A. S, Patel R.N, Modi P.K, Classification and Location of Single Line to Ground Faults in Double Circuit Transmission Lines using Artificial Neural Networks, *International Journal of Power and Energy Conversion*, 2, No. 2, (2010), 109-125.

18. Ebha Koley, Khushaboo Verma, Subhojit Ghosh, An Improved Fault Detection Classification and Fault Location Scheme Based on Wavelet Transform and Artificial Neural Networks for Six Phase Transmission Line using Single End Data only, *Springer Plus*, (2015).

19. A. Naresh Kumar, Chakravarthy M, Simultaneous Fault Classification and Localization Scheme in Six Phase Transmission Line using Artificial Neural Networks, *Journal of Advanced Research in Dynamical & Control Systems*, 10, No. 3, (2018), 342-349.

20. Ebha Koley, Anamika Jain, A.S. Thoke, Abhinav Jain, Detection and Classification of Faults on Six Phase Transmission Line using ANN", *International Conference on Computer & Communication Technology*, Allahabad, India, (2011), 100 - 103.

21. A. Naresh Kumar, Chakravarthy, M, Fuzzy Inference System Based Distance Estimation Approach for Multi Location and Transforming Phase to Ground Faults in Six Phase Transmission Line, *International Journal of Computational Intelligence Systems*, 11, No. 1, (2018), 757–769.

22. Anamika Yadav, Aleena Swetapadma, Fault Analysis in Three Phase Transmission Lines Using k-Nearest Neighbor Algorithm, *International Conference on Advances in Electronics Computers and Communications*, Bangalore, India, (2014), 1 - 5.