Support vector machine based fault section identification and fault classification scheme in six phase transmission line

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ABSTRACT

The higher complexity of a six phase transmission system (SPTS) construction and the large number of possible faults makes the protection task challenging. Moreover, the reverse & forward path faults in SPTS cannot be detected by traditional relay as it becomes under-reach. In this paper, a support vector machine (SVM) method including Haar wavelets for SPTS fault section identification and fault classification is focused. The positive-sequence component phase angle and currents at middle two buses are used to formulate a suggested method. Feasibility of suggested SVM is tested with a 138 kV, 300 km, 60 Hz, SPTS in MATLAB based Simulink platform. Several major parameters including far end and near end location conditions are taken to investigate the reach setting and accuracy of proposed SVM. This relaying method can detect the existence of fault in reverse & forward path in 1 ms time.

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1. INTRODUCTION

Electricity has become the universal driver for social economic developments. Due to urban growth as well as constraints on right-of-way, there are limits on installing latest transmission line. Recently, six phase transmission system (SPTS) is being employed to improve the transmission reliability and capacity [1], [2]. SPTS must be equipped with the relays to ensure continuous monitoring for detect faults. Thus, SPTS is restored to the normal condition and power supply is reconnected for load costumers in the lowest possible time leading to high reliability. A considerable amount of literature required to study with the complication of a fault section identification and fault classification method. To ensure accurate and faster detection of SPTS disturbances, different monitoring schemes have been presented by researchers.

Researchers over the world wide have widely studied [3], [4] different features of SPTS viz. lower audible noise levels, decreased radio interference levels, lesser corona, reduced conductor surface gradient, higher efficiency, good voltage regulation, thermal loading capacity and better surge impedance loading. Some recent papers reveal that SPTS performs excellently in obtaining a high power transmission capacity. Published fault statistics [5]-[7] clearly divulge that a majority of SPTS faults are shunt faults. In the past decade many researchers focused many methodologies for fault location in a SPTS. Researchers made a work on fuzzy method to get the faulty location [8], [9] for a SPTS. Further, a research work [10], [11] has been done with real-time validation for solving fault issues in SPTS by Sunil K *et al.* Another scheme by Ebha *et al.* [12], [13] implemented artificial neural network to predict the faults in SPTS.

Section identification/discrimination/directional relaying and classification have been a hot topic for few decades. Researchers have exerted much effort over the years exploring relaying and classification [14]-[17]. Additionally, various challenges have been reviewed in SPTS with relaying and classification [18], [19]. Although the aforesaid schemes, remarkably, contributed in the directional relaying, the emergence of new structures along with complexity of SPTS has necessitated the usage of intelligent techniques in the directional relaying. A suitable and straightforward method based on support vector machine (SVM) with relaying and classification in [20]-[25] for directional relaying. It is observed from literature survey that no paper exploited the directional relaying in SPTS using SVM. In this context, a maiden attempt has been done in this paper to present a SVM as SPTS faulted line discrimination and faulty phase identification issues. The main aims of this paper are: i) Studying the faults in three sections, ii) Developing of SVM-based for directional relaying and classification methods in SPTSA smaller amount computing work, iv) Detection of the faults unambiguously, and v) Enhancement of reach setting and accuracy.

The article starts with introduction followed by the review of current research work is presented. Next, it gives the SPTS details. After that, it develops the SVM model and it's designing. Sequentially, the experimental results are presented and the concluding remarks are provided.

2. SYSTEM STUDIED

The proposed support vector machine (SVM) based protection relaying has been implemented for a SPTS referring to the Springdale-McCalmont 138 kV, 60 Hz line of 300 km length is shown in Figure 1. The source impedances of sending terminal and receiving terminal are 2.02 + j9.03 Ω and 4 + j17.88 Ω, respectively. The circuit of SPTS is implemented in MATLAB based Simulink platform using distributed parameter lines and its details are shown in Table 1. The specifications of the SPTS have been adopted in this work for simulating. Phase angle of positive-sequence component, zero-sequence component and Haar wavelet currents in SPTS during faulty condition in section-1 are in illustrated Figures 2-4, respectively. The outline of suggested SVM-based directional relaying and classification schemes for shunt faults is exemplified in Figure 5.

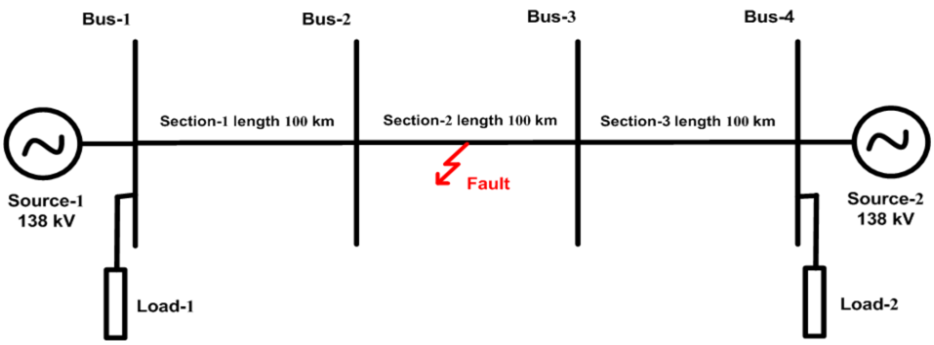

Figure 1. SPTS

Table 1. SPTS parameter values

Parameter	Units	Values
Number of Circuits	-	1
Number of Sections	-	3
Number of Phases	-	6
Source Voltage	[kV]	138
Base Power	[MVA]	120
Frequency	[Hz]	60
Earth Resistivity	[Ω-m]	150
Line Length	[km]	300
Short Circuit Capacity [MVA]	-	1350
Source X/R Ratio	-	9
Load at Bus	[kW]	120
	[kVAR]	120

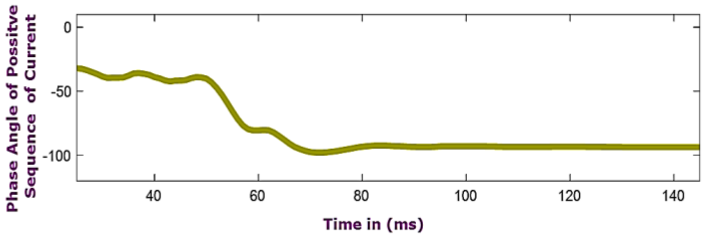

Figure 2. Phase angle of positive sequence component in SPTS during faulty condition

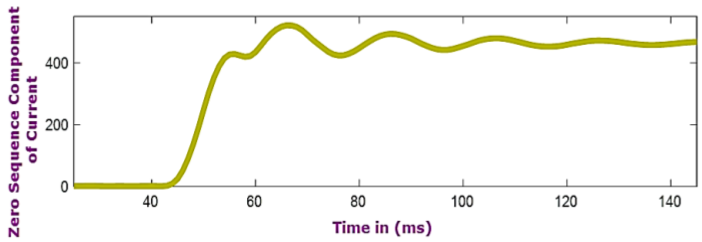

Figure 3. Zero sequence component of current of SPTS during faulty condition

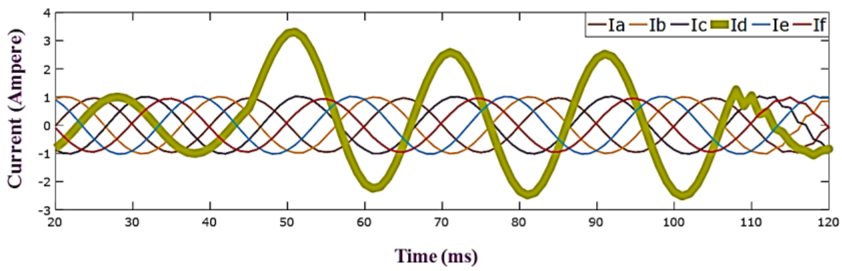

Figure 4. Haar wavelet currents of SPTS during faulty condition

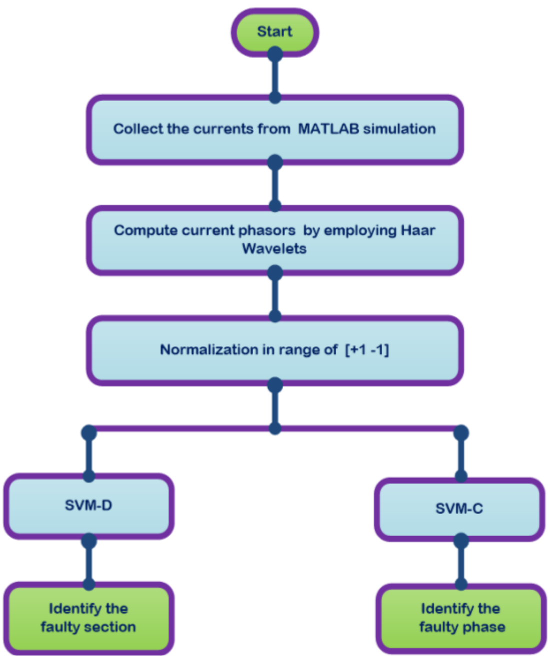

Figure 5. Flow of proposed work

3. TECHNIQUE USED

The support vector machine (SVM) is developed from the theory of statistical learning concepts in late 1960 s. Recently, SVM has emerged as a popular tool for solving the regression and classification problems. It deals primarily with two class classification issues. A hyperplane or linear line is built as decision boundary between feature data sets of two-classes for classification. The nearest feature data points to the hyperplane are known as support vectors. The two class data point with the separating linear line is depicted in Figure 6. Meanwhile, support vector regression can be employed to determine a function which approximates the mapping function from an input domain to another domain of real values based on training data set while maintaining all main features that exemplify the maximum margin method. In this section, linear support vector machine based technique for classification of shunt faults in a SPTS is discussed.

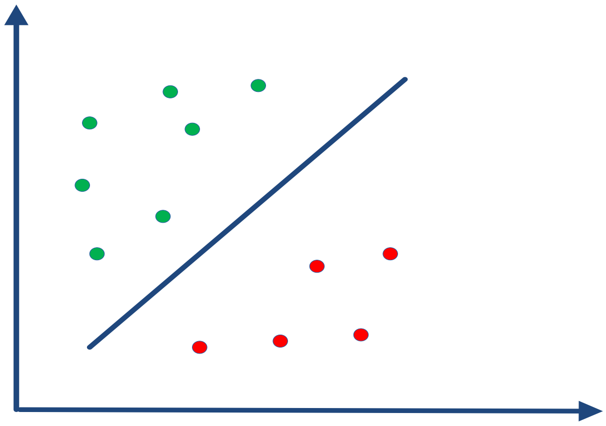

Figure 6. Linear SVM

For the protection two SVM have been designed namely SVM-D and SVM-C to identify the fault section identification and fault classification, respectively. The positive-sequence component phase angle and Haar wavelet currents is used to study the faults in a SPTS. The obtained samples of the currents and positive-sequence component phase angle are classified into large range of frequencies using Haar wavelets. After that, from the 3rd level coefficients are extracted. The total number feature sets are 184 features. Additionally, to scale feature sets, normalization is completed between -1 and +1 therefore it can appropriately be compared. The feature data is then created for training as well as testing process considering different of simulated conditions viz. fault types, fault section, the fault resistance, fault instant, and fault distance.

Few features cannot predict the output perfectly from the total feature data set. Consequently the prediction accuracy decreases. Thus to enhance the accuracy, redundant feature data are removed from total feature sets by employing forward feature selection method during training. Employing feature selection technique, the total feature sets to be given to the SVM is decreased, which in turn makes it fast and simplifies the process. The optimal feature data set with the testing data are then given to the trained SVM-D and SVM-C technique for prediction purpose. The output of SVM is either '0' or '1' denoting healthy phase or faulted phase. For each of these faults, samples of the positive-sequence component phase angle for full cycle duration have been given at the input side of SVM. The SVM-D resultant output indicates whether the corresponding section is involved with fault or not. The SVM-C resultant output indicates whether the corresponding phase is involved with fault or not.

4. RESULTS AND DISCUSSION

The developed support vector machine (SVM) solutions have been tested thoroughly with the help of MATLAB program. When there is healthy, the output of both SVM-D and SVM-C will be 0 values. If faults occur, the SVM-D response starts adjusting to 1, 2, and 3 depending on the section 1, section 2 and section 3 faults, respectively and SVM-C response starts adjusting to 1 during SPTS faults. The enactment of SVM-D and SVM-C for shunt faults with changing numerous fault locations, numerous fault resistances and numerous fault types is summarized. The SVM-D and SVM-C responses for all cases in Table 2 and the reach setting and accuracy of these cases are above 99.986%. It is evident that the SVM method provides satisfactory enactment of faulted line discrimination, and faulty phase identification for all the samples.

Table 2 SVM-D and SVM-C results for all cases

Parameter Varied	Type	L (km)	FIA (°)	R (Ω)	Section	SVM-D	SVM-C						
							A	B	C	D	E	F	G
Fault type is changing and L, FIA, R and Section are fixed	Ag	21	45	10	1	1	1	0	0	0	0	0	1
	Eg	21	45	10	1	1	0	0	0	0	1	0	1
	DFg	21	45	10	1	1	0	0	0	1	0	1	1
	ABg	21	45	10	1	1	1	1	0	0	0	0	1
	ABCg	21	45	10	1	1	1	1	1	0	0	0	1
	ABCDg	21	45	10	1	1	1	1	1	1	0	0	1
	ABCDEg	21	45	10	1	1	1	1	1	1	1	0	1
	ABCDEFg	21	45	10	1	1	1	1	1	1	1	1	1
L is changing and Fault type, FIA, R and Section are fixed	CD	12	90	30	2	2	0	0	1	1	0	0	0
	CD	26	90	30	2	2	0	0	1	1	0	0	0
	CD	34	90	30	2	2	0	0	1	1	0	0	0
	CD	56	90	30	2	2	0	0	1	1	0	0	0
	CD	61	90	30	2	2	0	0	1	1	0	0	0
	CD	75	90	30	2	2	0	0	1	1	0	0	0
	CD	86	90	30	2	2	0	0	1	1	0	0	0
	CD	93	90	30	2	2	0	0	1	1	0	0	0
FIA is changing and Fault type , L, R and Section are fixed	BFg	74	5	40	3	3	0	1	0	0	0	1	1
	BFg	74	50	40	3	3	0	1	0	0	0	1	1
	BFg	74	120	40	3	3	0	1	0	0	0	1	1
	BFg	74	160	40	3	3	0	1	0	0	0	1	1
	BFg	74	200	40	3	3	0	1	0	0	0	1	1
	BFg	74	240	40	3	3	0	1	0	0	0	1	1
	BFg	74	290	40	3	3	0	1	0	0	0	1	1
	BFg	74	330	40	3	3	0	1	0	0	0	1	1
R is changing and L, Fault type, FIA and Section are fixed	DEF	92	135	15	1	1	0	0	0	1	1	1	0
	DEF	92	135	30	1	1	0	0	0	1	1	1	0
	DEF	92	135	45	1	1	0	0	0	1	1	1	0
	DEF	92	135	60	1	1	0	0	0	1	1	1	0
	DEF	92	135	80	1	1	0	0	0	1	1	1	0
	DEF	92	135	100	1	1	0	0	0	1	1	1	0
	DEF	92	135	120	1	1	0	0	0	1	1	1	0
	DEF	92	135	140	1	1	0	0	0	1	1	1	0
Section is changing and L, Fault type, FIA, R are fixed	ABDEFg	68	315	50	1	1	1	1	0	1	1	1	0
	ABDEFg	68	315	50	2	2	1	1	0	1	1	1	0
	ABDEFg	68	315	50	3	3	1	1	0	1	1	1	0
	ABDEFg	68	315	50	1	1	1	1	0	1	1	1	0
	ABDEFg	68	315	50	2	2	1	1	0	1	1	1	0
	ABDEFg	68	315	50	3	3	1	1	0	1	1	1	0
	ABDEFg	68	315	50	2	2	1	1	0	1	1	1	0
	ABDEFg	68	315	50	3	3	1	1	0	1	1	1	0

5. CONCLUSION

Fault protection in SPTS is a very important issue in nowadays. A protective relaying technique based on SVM is proposed in this paper with reach setting up to 99.986% in both reverse & forward paths of SPTS. Two different SVM have been developed faulted line discrimination and faulty phase identification in time domain. The positive-sequence component phase angle and Haar wavelet currents are prerequisite for SVM. It is worthy to mention here that the suggested SVM offers excellent accuracy for both reverse & forward paths also using only middle two buses data. Furthermore, its robustness against numerous fault locations, numerous fault resistances and numerous fault types is also studied. It was confirmed that for all cases, the reach setting of fault relaying is much superior to other methods.

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