High Impedance Fault Analysis in Distribution System Using ANN And RVM With Wavelet Transform as Feature Extraction Technique

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Abstract- *Transient faults that are not been sensed by most of switchgear devices like the distance relays and the over current relays are being taken in to consideration in this project. The transient fault because of the high impedance is not sensed by the relays. Wavelet transform that has been considered to be the feature extracting parameter for the signals would provide the frequency and the time data, which gives the idea about the fault occurrence. The decision-making algorithms like the ANN and the RVM are considered in this project in order to detect the high impedance fault. The input parameters that are given for the decision-making algorithms are sum of energy, standard deviation and entropy of coefficients based on the wavelet transform. The performance of these decision-making algorithms like the ANN and the RVM for prediction accuracy and the MSE reduction are taken in to consideration. MATLAB based implementation is carried out and the results are tabulated.*

Keywords- High impedance fault, Artificial Neural Network, Relevance Vector Machine, MATLAB

I. INTRODUCTION

Everybody in the world require quality power that motivates improvements in locating the fault of a distribution system to speed up the restoration. Faults and outages cause power quality problems in terms of continuity. In distribution system fault causes Power outages, information and economic loss and sometimes damages to the appliances. Utilities are forced to use efficient appliances which in turn reduce power demand. Location of fault is nothing but determining where fault has occurred. Almost 80% of power interruptions occur due to faults in distribution lines and developing the algorithm for location of fault is not so easy because of complex network and operating rules such as type of fault, load taps, the available measuring instruments, radial operation and type of network configuration.

Reliable power along with good maintenance is very important in power systems. Supplying large generated power from generating station to the utility point is the major factor in reliability. In actual means there are many problems in locating the fault. In the past, many algorithms are developed using intelligent programming techniques for location of fault. In general a distribution system includes all parts of utility system, bulk power supply sources and small consumer power equipments along with large number of nodes, to serve vast geographical area to ensure safe operation in several special conditions.

It is very challenging to detect high impedance fault (HIF) in electrical distribution system. High impedance fault causes large impedance which reduces fault current to a very low level such that fault is not detected by conventional over current relays. The main goal of this thesis is to detect HIF using a new algorithm in distribution system.

II. HIGH IMPEDANCE FAULT (HIF)

Since from 1970's nature of high impedance fault and its detection techniques is been the interesting topic. When an energized conductor makes an electrical contact with insulating materials like tree, equipment or falls on the ground or on a surface with high resistance then there occurs high impedance fault (HIF). This fault results in very low value of current of range 10-100A depending on the type of surface which cannot be detected by over current relays. If this fault is not cleared then there will be the risk of fire hazard that is arcing. Normally HIF occur at 15kV and below 15kV of distribution voltages. The problem is not so serious at voltages of 25kV and above. Usually based on consumer complaints distribution utilities will detect and locate the fault which are then cleared by passing information from call center to operation center and then to maintenance people.
Accordingly HIFs cause electric arcs and they have characteristics such as asymmetry, nonlinearity, buildup, shoulder, intermittence.

- Asymmetry: The peak fault current is different in +ve and –ve half cycles.

- Nonlinearity: Current and voltage curve is nonlinear.
- Buildup: there is a gradual increase in the current value to its maximum.
- Shoulder: gradual increase in current value stops after some cycles.
- Intermittence: after Some cycles the energized conductor interrupts the contact with the ground or soil.

There are two steps to identify HIF:

1. Feature extraction.
2. Classification.

From many years researchers and engineers have found various feature extraction and classification methods such as wavelet transform (WT), Kalaman filtering, digital signal processing etc, and classifiers such as Artificial Neural Network (ANN), ANFIS (Adaptive Neuro-fuzzy inference system)etc. Here we are using digital signal processing by applying Wavelet transform for extraction. For classification Neural Network (NN) and relevance vector machine are used. Comparison between these two is done depending on their accuracy.

III. DISCRETE WAVELET TRANSFORM

Discrete wavelet transform is a wavelet transform in which the signals are discretely sampled. It is more advance compared to Fourier transform that it captures both location and frequency. Discrete wavelet transform is a time-frequency signal-processing technique which is used for the analysis of signals with localized transients. Form past ten years discrete wavelet transform is widely used for power system problems that too for transient analysis. It divides frequency of the input signal as low and high frequency bands called approximation(c) and detail coefficients(d). to extract the high impedance fault frequency components is by applying wavelet transform. The continues signals are analyzed based on their frequency and translating as single function called mother wavelet.

IV. ARTIFICIAL NEURAL NETWORK

Artificial neural network is same as that of human brain. It contains neuron which is of multilayered. Each and every neuron is interlinked that is each neuron is connected to its neighboring neurons which are called as strength of neuron. This connection is because of its coefficient of connectivity. To obtain specific result some adjustments has to be done for the strengths. Artificial neural network has various applications in the field of medicine like Bio-chemical analysis, image processing, and drug development etc. An artificial neural network is used to detect cancer cells and heart problems in diagnostic systems, to analyze urine and blood samples, to find glucose level for diabetic patients, to find iron contents in the body and to know tuberculosis conditions in bio-chemical systems. ANN has applications in MRI scanning, to detect tumor, to determine skeletal age and in some cases brain maturation is detected by applying artificial neural network. It also has application in developing the drug for AIDS and cancer.

V. RELEVANCE VECTOR MACHINES:

Relevance vector machine is a growing technology in the research field since there are many advantages present in it. The base of Relevance vector machine is Bayesian computation of a linear system which results in a sparse representation. Support vector machine is a technique for classification, regression with a sparse kernel function. Since it has many disadvantages such as failed to give probable outputs and need for Kernel functions. So Relevance vector machine is used which is a Bayesian function with a linear model form to SVM.

Training a model with some data and predicting particular output for a given input is how a machine learning techniques work. For supervised learning SVM is used widely and it is been represented in the following form:

$$y(\mathbf{x}) = \sum_{n=1}^{N} w_n K(\mathbf{x}, \mathbf{x}_n) + w_0,$$

Where, *{wn}* : model 'weights'
K(- ,-) : Kernal function.

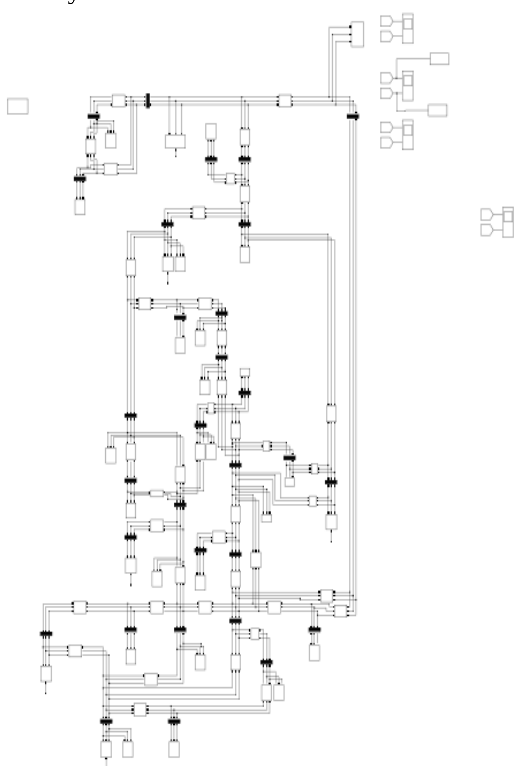
Some of the disadvantages of SVM are:

- There are no probabilistic predictions.
- SVM use Kernel functions liberally.
- Kernel functions must satisfy Mercer’s condition. So we making use of Relevance vector machine which is identical in functions as that of SVM. RVM uses Bayesian approach for learning.
- RVM is found to be more advantageous compared to SVM by following aspets:
  - The numbers of decision making relevance vectors are fewer than SVM.
  - During the training phase RVM doesn’t need regularization parameter as that of SVM. But training of RVM involves non linear optimization.

Like ANN RVM also has training and testing phase. In the training phase RVM has to be trained with particular input and output. So in the testing phase we obtain predicted output for the given input.

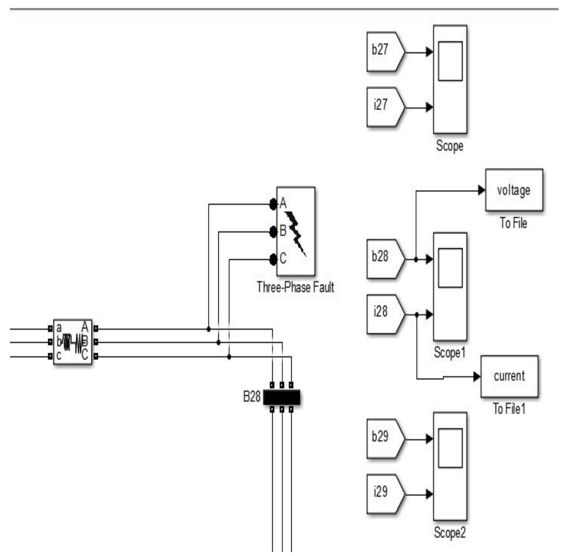
VI. PROPOSED TECHNIQUE

IEEE 30 bus system

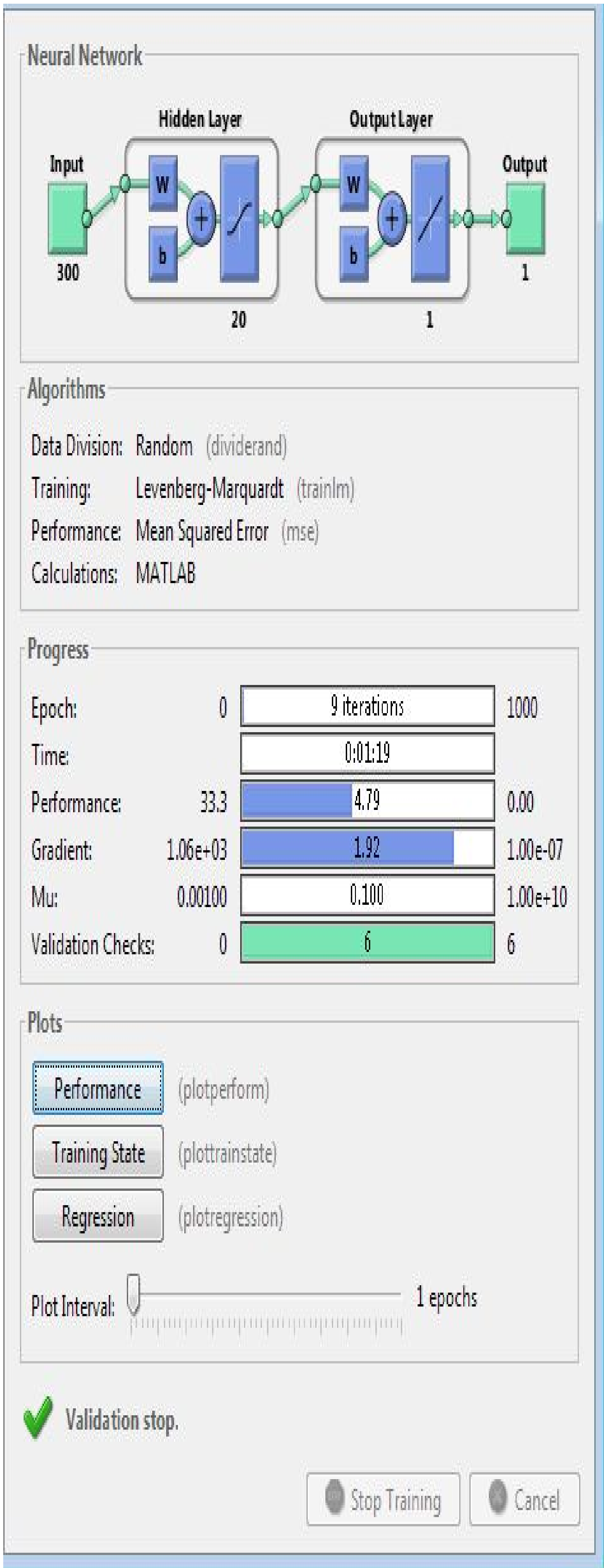


As the name says High impedance fault will make very low fault current because of large impedance value. Fault gets unnoticed by conventional relays as it fails to detect such low value of current. Since relays does not detect it has become an important topic to discuss with. Many inventions are going on for the detection of HIF. High impedance fault is nothing but all single line to ground fault, double line to ground fault and three phases to ground fault with some special cases such as capacitor switching and load switching conditions. For the analysis we are using standard IEEE 30 bus system with fault at the 28th bus. The system is run with all different fault condition. For analysis MATLAB simulink software is been used. Every method will have its own technique and complexity present in it, but all methods will have some improvement compared to previous one and there will be some advantage and disadvantage. Here we are also taken up a topic of detecting High impedance fault, and discrete wavelet transform is used for feature extraction and for classification artificial neural network and Relevance vector machine is used. Comparison of results obtained from both artificial neural network and relevance vector machine are used, by this comparison which is more effective in detecting fault has been found. DWT is used for converting analog signals into digital signals. Both ANN and RVM technique has training and testing phase and need to be trained for some specific inputs and outputs. Then when the same situation occurs fault will be detected by artificial neural network and relevance vector machine. Fault is created and it is run for several numbers of times with noise and without noise and which will detect the fault more accurately will be tabulated.

Fault at 28th bus



Training of ANN



FAULTY PHASE DETECTION OF HIF FAULT WITH 50dB NOISE USING ANN

OVERALL PERFORMANCE OF ANN

Signal		No noise	Noisy condition	
	Total cases		50dB	40dB
HIF	350	334 (95.42%)	323 (92.28%)	320 (91.4%)
No fault condition	50	50 (100%)	50 (100%)	46 (92%)
Average accuracy	400	384 (96%)	373 (93.3%)	366 (91.5%)

FAULTY PHASE DETECTION OF HIF USING ANN

Class of HIF	Normal condition	Noisy condition	
		50 dB	40dB
A-G	100%	88%	82%
B-G	100%	94%	89%
C-G	100%	96%	94%
AB-G	96%	82%	93%
BC-G	80%	75%	68%
AC-G	76%	68%	64%
ABC-G	100%	94%	97%
ACCURACY	93.14%	85.28%	83.85%

OVERALL PERFORMANCE OF RVM

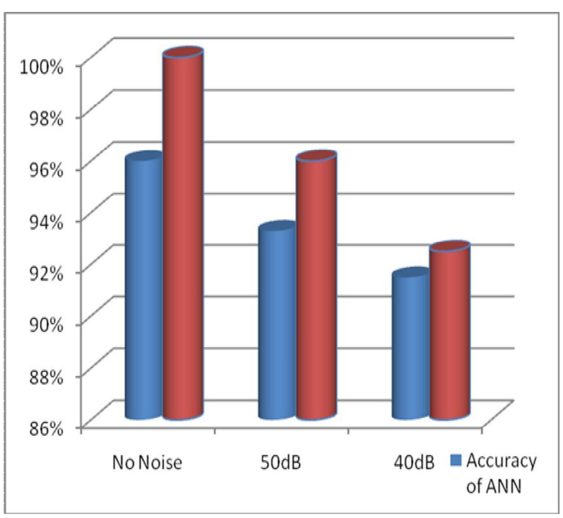
Signal		Normal condition	Noisy condition	
	Total cases		50dB	40dB
HIF	350	350 (100%)	338 (96.5%)	324 (92.5%)
No fault condition	50	50 (100%)	46 (92%)	46 (92%)
Average accuracy	400	400 (100%)	384 (96%)	370 (92.5%)

OVERALL PERFORMANCE OF FAULTY PHASE DETECTION OF HIF USING RVM

Class of HIF	A-G	B-G	C-G	AB-G	BC-G	AC-G	ABC-G
A-G	50	0	0	0	0	0	0
B-G	0	50	0	0	0	0	0
C-G	0	0	50	0	0	0	0
AB-G	0	0	0	48	01	0	01
BC-G	0	0	0	0	40	0	10
AC-G	0	0	0	0	0	38	12
ABC-G	0	1	0	2	0	0	47
accuracy	100 %	10 0%	100 %	96%	80%	76%	94%
Over all accuracy	92.2857%						

Class of HIF	Normal condition	Noisy condition	
		50dB	40dB
A-G	100%	94%	88%
B-G	100%	95%	81%
C-G	100%	89%	78%
AB-G	100%	80%	72%
BC-G	100%	87%	81%
AC-G	100%	91%	88%
ABC-G	100%	96%	90%
ACCURACY	100%	90.28%	82%

COMPARISION OF ANN AND RVM FOR HIFs CLASSIFICATION BASED ON ACCURACY



VII. CONCLUSION

In this work performance of ANN and RVM in the detection of HIF using wavelet transform as feature extraction process has been used in an IEEE 30 bus system. The comparison is done between these machine learning techniques in determining and classifying the fault. Based on the results obtained and graph shown in figure 5.15 RVM is the better machine learning technique as compared to the ANN in determining and classifying the HIF.

VIII .FUTURE SCOPE

This paper gives accurate results under fault conditions. Further work can be carried out in detecting special cases like capacitor switching and load switching conditions. It can also be implemented on real time system which experience more frequent High Impedance Faults.

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