Fault Classification and Fault Zone Identification in a Thyristor Controlled Series Compensator Based Transmission Line by using Decision Tree

Prasad Ranjan Ghosh, Srikant Mohapatra, Arjyadhara Pradhan, Soubhagya Prusty

Abstract: A new method has been introduced for classification of fault and to identify zone of fault in Thyristor Controlled Series Capacitor based line by utilizing Decision Tree method. PSACD/EMTDC software is used in this paper for the simulation of TCSC. Voltage and current samples after fault are used in this method as input against predicted output vectors for zone identification of fault. Decision Tree based classification algorithm also used to classify all ten types of faults in the TCSC based line. This method is being tested on simulated data and the results indicate that this method can classify different types of faults and also identify zone of fault more accurately than any neural network systems in a TCSC based line.

Keywords: TCSC, PSCAD/EMTDC, Fault Classification, Fault Zone Identification

I. INTRODUCTION

The increase in the demand of electricity supply has limited the construction of new transmission systems and lines due to the effect of right-of-way restriction and the recent development in the regulatory scheme which optimizes the use of existing transmission lines [1]. To satisfy these requirements addition of FSC (Fixed Series Capacitor) more precisely Thyristor Controlled Series Capacitor (TCSC) have been increased in the transmission network now a days.TCSC is one of the most important FACT device. It is used to enhance controllability, increase stability of the line, control power flow dynamically, and reduce system losses [2]. The addition of TCSC in a transmission line directly affects the performance of the distance based relay line protection process due to the rapid changes of the impedance of line. TCSC based compensation system have a thyristor controlled variable capacitor which is protected by Metal Oxide Varistor and an air gap [3]. Metal Oxide Varistor (MOV) protects the series capacitor of the TCSC at the time of fault.

To classify the fault and to identify the zone of fault in a transmission line with TCSC is very difficult one. If there is no FACTs device in the transmission line, during fault the calculation of impedance is like a normal transmission line [4]. If the transmission line includes FACTs device, during fault the calculation of impedance is accounted with the impedance produced by FACTs device.

II. TCSC BASED LINE

Thyristor Controlled Series Capacitor is a series compensating capacitor which is shunted by Thyristor Controlled Reactor (TCR).To obtain the desired voltage rating, several such basic compensators are connected in series.

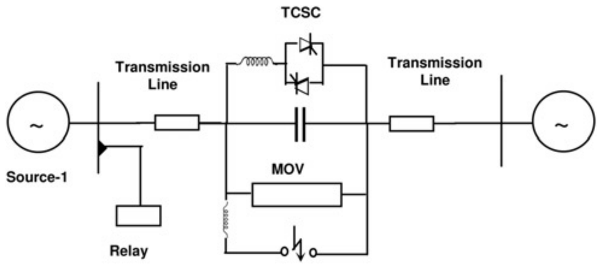

Fig - I: Transmission network with TCSC

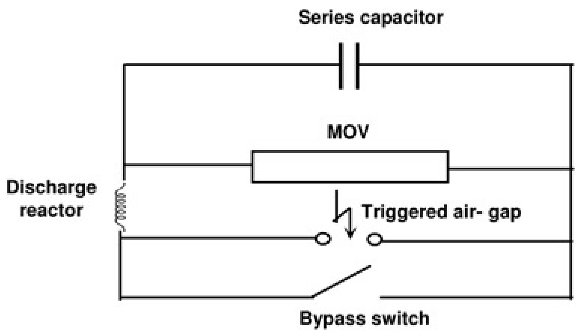

Fig -2: Design of a MOV

A 400 kV system which consists of 50 Hz frequency is shown at the above figure 1 and in the above figure 2, design of Metal Oxide Varistor is showed. The system consists of two equivalent sources where Thyristor Controlled Series Capacitor is situated at the middle of total 300 km transmission line [5]. This system also consists of some associate components like relay, MOV (Metal Oxide Varistor).

Zero sequence impedance of the transmission line Z_0 =37.95+j13.27Ω and positive sequence impedance of the transmission line Z_1 = 36.29 +j5.031 Ω.

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The value of E_s is 400 kV. This system is simulated in PSCAD/EMTDC and the design of TCSC provided minimum to maximum compensation of the line.

Sampling frequency has been considered as 1.0 kHz.

TCSC consists of Metal Oxide Varistor which is a non-linear resistor. Metal Oxide Varistor consists of zinc oxide discs which are linked electrically in series and parallel [6]. The function of this MOV is to prevent the voltage which is encountered by the capacitor when there is an overvoltage in the system [7]. This condition is mostly happen when fault occurs on a line which is compensated.

The size of the capacitor in TCSC controlled the degree of compensation in the system [8]. In normal condition Thyristor Controlled Series Capacitor operates in capacitive mode but when the fault occurs it operates in inductive mode and the fault current is bypassed through inductor in this situation.

III. DECISION TREE

For classification and prediction of high dimension pattern, Decision Tree is one of the most useful technique.Decision Tree refers a structure which looks like a flowchart and helps user in decision making [6]. Mainly 3 types of nodes are present in DT. Those nodes are root node, leaf nodes and internal nodes. In case of classification, the process of decision making starts from the root node and the class lebel is denoted by each leaf node. The process of testing are made on root node [9]. The visualization of a Decision Tree is like a flowchart that is why it is easily understand and interpret by human being.

The training time of Decision Tree is faster in comparison with any other neural network algorithm [10]. A large dimensional data can handled by Decision Tree with better accuracy than any other existing technique.

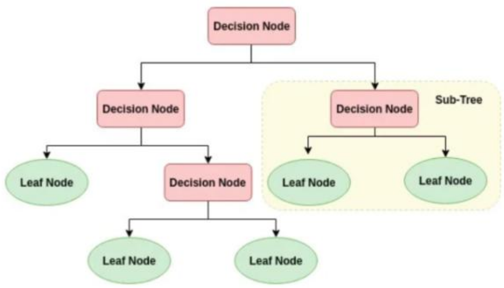

Fig 3: Flow –chart diagram of DT.

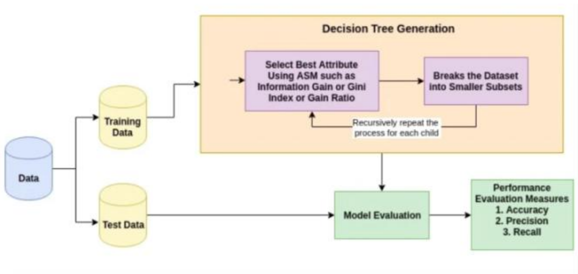

Fig 4: Data Flow diagram of Decision Tree

In the above figure 3, flow chart diagram of Decision Tree is showned and the diagram of flow of data is shown in above figure 4.

The proposed Decision Tree method is able to classify large amount of data without requiring more computational burden [11]. This method provides a clear signal that which section is more important for classification and prediction.

IV. EMTDC/PSCAD SIMULATION

The simulation of the entire work is carried in PSCAD/EMTDC platform using the components of power systems.

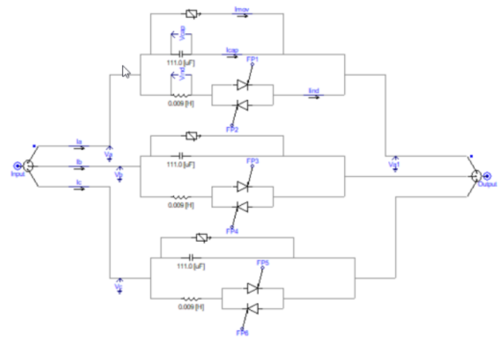

Fig 5: Shows the layout of two source power system and the Thyristor Controlled Series Capacitor is in the mid point of transmission line.

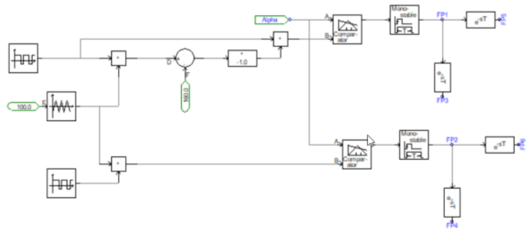

Fig 6: Control logic circuit of TCSC.

In the above figure 5, two souce power system is shown where TCSC is placed in the middle point and corresponding control logic circuit is shown in the above figure 6.

In this PSCAD/EMTDC simulation, we get large number of data sets by varying the firing angle(α), different fault locations, different fault inception angle and also by varying fault resistance.

TCSC operates normally in capacitive mode when α lies between 124.8 to 180° and at that time any fault which is outside of the of protection is able to detect by the distance relay.

V. FAULT CLASSIFICATION

To classify the types of fault in this TCSC based transmission line current and voltage samples after fault are decided for using as the input for this DT algorithm [12].

The input vectors are taken as I_1, I_2, I_3, V_1, V_2, V_3, IF_1, IF_2, IF_3 against target output fault cases which is denoted as all ten types of different fault classes [13]. Those fault classes are categorized as (a-g), (b-g), (c-g), (a-b), (b-c), (c-a), (ab-g), (bc-g), (ca-g), (a-b-c).

There are different numbers of fault situations which are simulated and used for training and testing for the DT algorithm. Huge data sets are generated under different operational conditions when this model is simulated is PSCAD/EMTDC.

Large data sets are used to train and test for the DT algorithm by various % such as 60-40%, 70-30%, 80-20%, and 50-50% [14]. Better classification accuracy is found in 70-30% training testing dataset and it is also found to identify fault zone. To classify the type of fault this training testing ratio is considered.

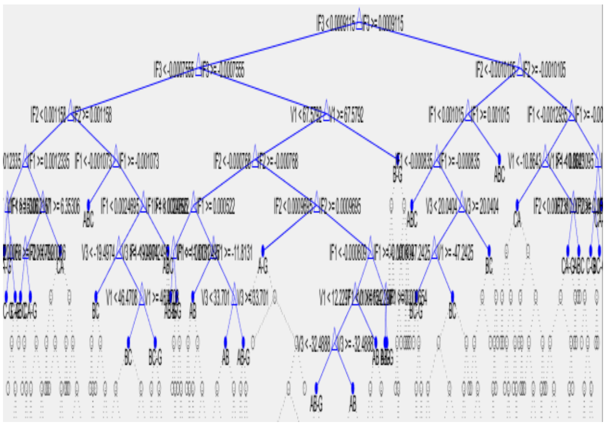

Fig 7: Decision Tree based fault classification for all ten types of fault in a TCSC based line.

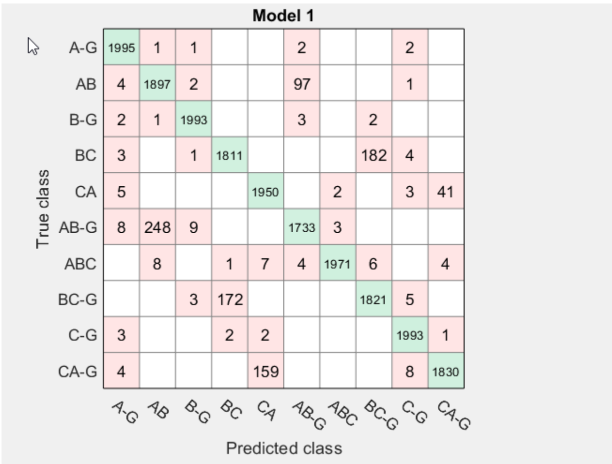

Fig 8: Confusion matrix to classify faults using Decision Tree algorithm for 70% training 30% testing case.

Figure 7, shows that Decision Tree based fault classification for all types of fault and in the above figure 8, confusion matrix after classification of faults is shown using Decision Tree. Confusion matrix that is obtained to classify fault is shown in the above table for TCSC based transmission line with the ratio of 70-30% training testing dataset. In the above confusion matrix the predicted class with respect to original class is given for 10 types of shunt faults. In the a-g fault, 1995 cases are classified but 6 cases are found as misclassified with other classes where as in case of b-g fault, 1993 cases are classified but 8 cases are misclassified. Similar results are happened in other types shunt fault.

For all ten types of fault, classification accuracy is 94.9% for the proposed Decision Tree algorithm which is much higher than existing technique Support Vector Machine. The processing time and the computational burden are also less in case of proposed Decision Tree algorithm with respect to other techniques.

VI. FAULT ZONE IDENTIFICATION

Basically for fault zone detection, current and voltage samples after fault are used as input data which are fed to the Decision Tree against target vector 'pre' for the fault which is occurred before Thyristor Controlled Series Capacitor and 'post' for the fault which is occurred after TCSC [15][16]. Sampling frequency for the simulation is 1.0 kHz. A large amount of cases of 'fault' and 'no fault' are simulated. This simulated data are used for training and testing in Decision Tree algorithm with different % like 70-30%, 60-40%, 50-50%.

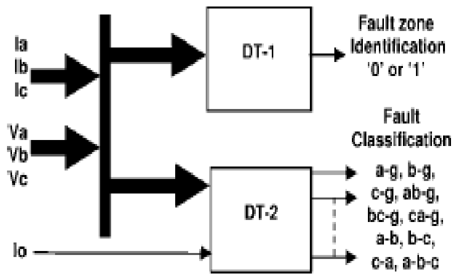

Fig 9: Figure shows the proposed Decision Tree based protection scheme.

In the above figure 9, the proposed Decision Tree based protection scheme is shown.

Those large numbers of data sets are simulated under different operating conditions.

Variations in R_f are taken from 0Ω to 200Ω.

Variations in locations of the fault are taken as 10%, 30%, 40%, 48%, 52%, 60%, 70%, 80% and 85%.

Variations in fault inception angle are 30°, 45°, 60°, 75°, 90°.

Variations in firing angle taken for the simulation are from 150° – 180°.

Total 9 types of fault (a-g), (b-g), (c-g), (a-b), (b-c), (c-a), (ab-g), (bc-g), (ca-g) are taken as input at the time of simulations.

Total simulations done for the TCSC based transmission line are 7(R_f)*5(FIA)*7(Firing Angle)*9(Types of fault)*9(Different fault positions) = 19845.

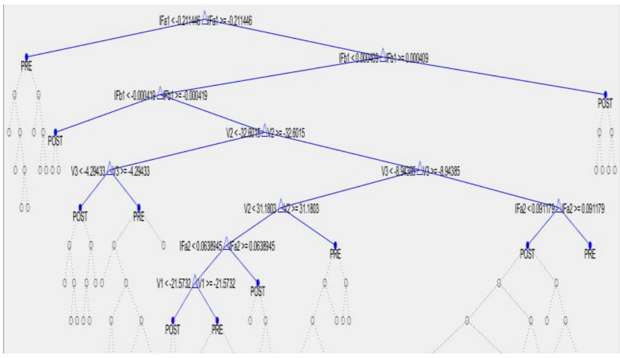

Fig 10: Figure of Decision Tree for fault zone identificatrion.

The Decision Tree is used for training and testing for large numbes of different data sets such as 70-30%, 60-40%, 50-50% respectively. This above technique is done to collect information of the training pattern from the testing data.

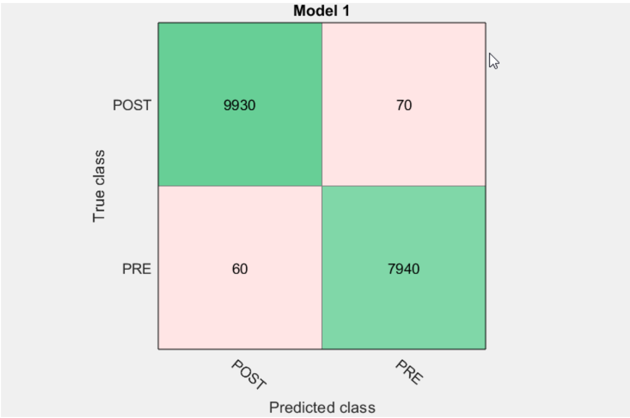

Fig 11: Confusion matrix for fault zone identification using DT for 70% training 30% testing case.

In figure 10, DT to identify the fault zone is shown and in figure 11, confusion matrix for fault zone identification using DT is shown. The confusion matrix in the above table shows the predicted class with respect to original class during the time of testing to identify fault zone in the Thyristor Controlled Series Capacitor based transmission line. In this method the Decision Tree creates the confusion matrix based on testing data that means in case of 70-30% data , confusion matrix creates results only on 30% of total data. It is found that in case of total training- testing data sets, 17870(9930+7940)

Cases are found as classified data and 130 (70+60) cases are found as misclassified. Classification accuracy for this simulation is 99.3%. Decision Tree provides maximum classification accuracy in the TCSC based line with respect to other existing technique. From the training-testing data sets it is also observed that accuracy of this classification is decreasing in 80-20% and 90-10% data sets. This phenomena occurs because of over fitting of data.

VII. DISCUSSION

In the above section, a new method has been implemented to identify the zone of fault and to classify fault for the TCSC based line. After simulation, post fault current and voltage samples are used for making Decision Tree. The above Decision Tree method is compared with existing Support Vector Machine and it is found that computational burden is less in Decision Tree. It is also found that the processing time is less in the proposed Decision Tree method than any other existing method.

VIII. CONCLUSIONS

This proposed method provides a modern approach for fault classification and to detect the fault zone in a TCSC based transmission system with better accuracy. This proposed Decision Tree method is more reliable in comparison with existing machine learning approach like Support Vector Machine. This Decision Tree method is executed with huge data sets including large number of operating conditions. This proposed method is strong enough to show its potential for the protection of TCSC based large transmission network.

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