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Intelligent Control System to Identify Fault in Distribution Network of Smart Grid through Neural Network

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Abstract: In distribution network of smart grid there are various type of fault occur in the network, which are challenge for the control system to identify its type of fault, location and restore the network automatically.
In this paper we applied neural network to determine type of fault in order to do predictive maintenance and recover the network as early as possible depending on the fault type. The paper also presents the accuracy level of neural network model to determine the type of fault accurately at any mentioned condition and environment.

Keywords: Smart Grid, Electrical Fault, Neural Network, PMU

I. INTRODUCTION

Conventional relay [1, 2] installed at distribution network buses do not have communication medium to send or receive the current data in terms of voltage and current phasors installed at different locations of buses in order to trip the network by providing the primary and secondary protection of the network and only depends on local measurement [3] resulting the cascading fault which reaches to completely black out the network [4].
In order to overcome this limitation, modern sensor Phasor Measurement Unit (PMU) [5] are deployed in distribution network buses which work on the principle of measuring the current and voltage phasors and connecting with global positioning system (GPS) in order to find the exact location of fault in the distribution network. PMU also has an ability to communicate with the other PMU sensor through communication medium by sharing the current status of current and voltage sensor. In this regard, researchers in [6] collects the line parameters of network by showing the current and voltage phasors through PMU sensor of medium voltage steady state distribution network of smart grid. Similarly, researchers in [7] estimates the probability of failure of transmission network by utilizing PMU as a secondary protection system to the network of smart grid. In addition researchers also briefly describe that the PMU sensor plays an critical role in determining the location of fault appropriately in smart grid and can provide the back-up protection to the distribution network by measuring the voltage and current phasors by entering the sum of positive or zero sequence entering in the phasor measurement unit and comparing this data after communicate with other PMU of the network. Similarly, researchers in [8, 9. 10] determines the line parameters i.e. resistance, reactance, conductance and susceptance of transmission line through PMU sensor.

To analyze the types of fault detection of distribution network we have lookup table to predict the accurate fault detection in a live mode. But due to limitation in lookup table that it can grow as the network can become large, we have experimented a simple neural network (NN) with only 97 parameters which generalizes the whole lookup table to single model which predicts the fault with optimality. Thus, we can integrate the NN with PMU output to get the prediction.

The rest of the paper is organized as follows: Section II presents a summary on Electrical fault types with its equation. Section III discusses the proposed methodology to identify each type of faults. Section IV explains the neural network modeling and section V represents the result along with discussion. Section VI concludes the paper.

II. ELECTRIC FAULT TYPES

Phasor measurement unit which is equipped with GPS mainly used to determine the exact location of fault. In electrical distribution / transmission network, there are mainly six types of fault occurred in the network i.e. Single-phase fault, phase to phase fault, phase to phase to earth fault, three phase faults (with or without ground), single phase open circuit fault and cross-country fault which are discussed below.

A. Single Line to Ground Fault (SLG Fault)

The most common types of fault occurred in medium voltage of distribution network is single phase to ground fault. The phase voltage of ground fault will reaches to 0 volts while current on other phases reaches to 0 A. The following equations can be written in order to represent the single phase fault in which the fault current due to short circuit is two to three times more than the normal line current and trip the circuit breaker through over current or differential protection relay.
We have assumed that the phase ‘a’ has SLG fault.

$V_a = 0$ (1)
$I_b = I_c = 0$ (2)
$V_b = V_0 + a^2V_1 + aV_2$ (3)
$V_c = V_0 + aV_1 + a^2V_2$ (4)
$I_a = 3I_O = 3E_a / Z_o + Z_1 + Z_2$ (5)
Where:
V_a & I_a = Voltage & Current at phase A.
V_b & I_b = Voltage & Current at phase B.
V_c & I_c = Voltage & Current at phase C.
V_1 & Z_1 = Positive sequence voltage & Impedance
V_2 & Z_2 = Negative sequence voltage & Impedance
V_0 & Z_0 = Zero sequence voltage & Impedance
I_o = Zero sequence voltage
$A = 1 \llcorner 120$ & $a^2 = 1 \llcorner -120$

B. Line to line Fault (LL Fault)

During steady state condition of network, PMU sensor calculates the reactive, conductive and susceptance parameters of line along with voltage and current phasors while the real power, reactive power and apparent power varies according to inductive or capacitive loads.
During phase to phase short circuit, the fault current varies tremendously i.e. five to six times of full load current and need a relay which sense this abnormal condition with in 100 to 200ms in order to trip the circuit breaker. Following equation represents the phase to phase fault during unsteady state condition of network.
We have assumed that phase ‘a’ and ‘b’ have LL fault.

$V_b = V_c$ (6)
$I_a = 0$ (7)
$I_b + I_c = 0$ or $I_b = -I_c$ (8)

C. Double line to Ground fault (DLG Fault)

Phase to phase to ground fault is very common fault in medium voltage of distribution network where short circuit occurs between two phases equal to 5-6 times of the full load current and then this fault is grounded in order to save the electrical asset from deterioration by tripping the coil of circuit breaker. The fault equations are represented below.
We have assumed that phase ‘a’ and ‘b’ have LL fault.

$V_b = V_c = 0$ (9)
$I_a = 0$ (10)
$IF = I_b + I_c = 3I_o = 3(-Z_2E_a/Z_oZ_1+Z_oZ_2+Z_1Z_2)$ (11)

D. Three Phase Fault (3-phase Fault)

Three phase faults are called balanced electrical fault in which voltage at each phase is equal to the rated voltage while the sum of current is equal to zero as describe in below equations.

$V_a = V_b = V_c$ (12)
$I_a + I_b + I_c = 0$ (13)

E. Single Phase Open Circuit Fault (1POC Fault)

It is also important to analyze the open circuit fault i.e. single-phase fault along with short circuit fault in order to determine its behavior in the distribution network of smart grid. The following equation represents the single-phase open circuit equations of the distribution network of smart grid.

$I_a = 0$ (14)
$V_b = V_c = 0$ (15)
$V_1 = V_2 = V_o = 1/3\ V_a$ (16)
$I_a = I_1 + I_2 + I_o = 0$ (17)

From eq 16 and eq 17, it is concluded that the positive sequence, negative sequence and zero sequence current are connected in parallel in distribution network.

F. Cross Country Fault (CC Fault)

Cross country faults are those faults in which two faults occur in the same distribution network at the same time but in different location and possibly in two different phases. The following equation represents the cross-country fault in distribution network of smart grid.

$V_a = 0$ (18)
$I_b + I_c = 0$ (19)
Therefore
$I_{a1} = I_{a2} = I_{a0}$ (20)
$V_{a1} = V_{a2} = V_{a0}$ (21)

III. PROPOSED METHODOLOGY

Neural network is a collection of artificial neurons which is modeled against human brain’s neurons. The neurons are basically weights which combine to learn complex problem and optimization algorithm with activation function tries to find pattern which then as result provide a high order mathematical equation which maps the problem/dataset.

In our analysis, the data set of voltage and current phasors are obtained from [6]. Using that fault conditions were applied to steady state to generate possible states of four different faults i.e. Line to line, Line to Ground, Three Phase Fault and Line to Line to Ground to generate the dataset. For each fault 17 parameters were considered; $V_{a,b,c}$ (voltage), $I_{a,b,c}$ (current), $Var_{a,b,c}$ (reactive power), $Watt_{a,b,c}$ (power), $Ap_{a,b,c}$ (apparent power), Frequency and Power Factor.

Neural Network are poor when data are sparse; spread in different units. Similarly, each parameter has their own unit which has different range respective to it genre. Passing this sparse data can affect the overall accuracy of the neural model. These values were scaled to 0-1 using values from table [Table 1] and dividing them with respective parameters value.

Table 1 Scaling value to bring input value to 0-1 range.

Type	**Scale**
Voltage (V)	10k
Current (I)	200
Reactive Power (Var)	100k
Watt (Var)	100k
Apparent Power	100k
Frequency	100
Power Factor	1

After applying the scaling, value was scaled using standard scaler so that mean and standard deviation of dataset become 0 and 1 respectively.
Target class (fault) were converted to integer and then binary class [Table 2] to make it compatible for Neural Network.

Table 2 Target class values in number and binary class.

Fault	**Number**	**Binary Class**
Steady	0	[1 0 0 0 0]
Line to Ground	1	[0 1 0 0 0]
Line to Line	2	[0 0 1 0 0]
Three Phase	3	[0 0 0 1 0]
Line to Line to Ground	4	[0 0 0 0 1]

IV. NEURAL NETWORK MODEL

Research in [6] measured the voltage and current phasors through phasor measurement unit sensor along with reactive, conductive and susceptance line parameters. We calculate the real power of network by applying; VI cos ϴ, reactive power through; VI sine ϴ and apparent power through; VI, of the medium voltage distribution networks of smart grid at steady state condition and train our neural network by applying these conditions in order to predict the normal state of the distribution network.
Moreover, we have trained the neural network through supervised learning and applying the different fault condition data set in order to determine the exact fault condition i.e. single-phase fault, phase to phase fault, phase to phase ground fault, three phase fault, single phase open circuit fault and cross-country fault. Once the supervised learning of neural network have been done, we have a given an anonymous data set in order to predict the condition and behavior of distribution network whether the network is in steady state or in fault state in order to do preventive maintenance in order to rectify the fault as early as possible by given the location of fault along with its types.

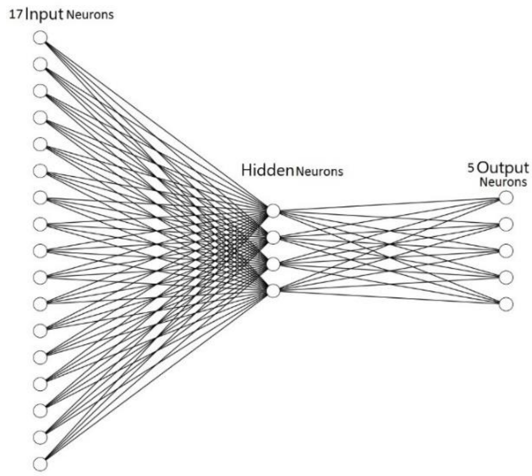

Fig. 1: Neural Network with input, hidden & output, layers.

A. Layers

Neural Network (NN) have three layer which are Input Layer from where NN take the datapoint, Input layer which is then connected with Hidden layer, learns the problem and find the pattern and then forward result to output later after applying activation function.
When there is multiple hidden layer then whole network is referred as Deep Neural Network.

B. Activation Functions

It returns activating value in a specific range depending on function used sigmoid, softmax (max value) or tanh which activates next neuron as each neuron is responsible for learning and triggering connecting neurons to pass learned information to next neurons.

C. Gradient Descent

Adding up all the data points makes an n-dimensional complex function, on which solution near to optimal has

to be figured out.
To find global minima, optimization algorithm like Gradient Descent takes iterative steps to find the solution and similar stochastic gradient descent find solution by taking random steps in the complex function to find the approximate solution quicker.

V. RESULTS & DISCUSSION

A Neural Network with 17 input neurons, 4 hidden neurons and 5 output neurons was compiled [Fig. 1] with Sigmoid and SoftMax activation for hidden and output layers respectively and using Stochastic Gradient Descent (SGD) model was trained.
Our neural network was evaluated and achieved 100% efficient and accurate [Fig. 2] in determining the fault types which can be very useful for line men and crew in finding the fault location and type of fault to rectify the fault as early as possible and restore the network by improving the SAIDI and SAIFI [11] of the distribution network of Smart Grid.

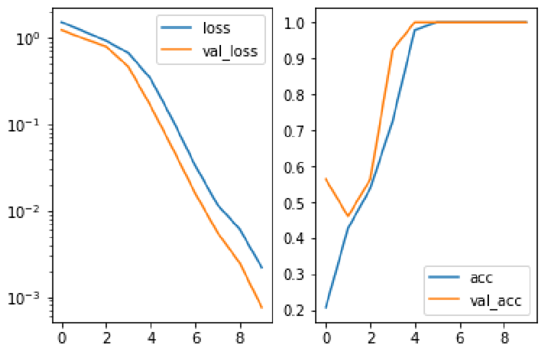

Fig. 2: Accuracy of Neural network model (acc: Accuracy, val_acc: Validation accuracy)

VI. CONCLUSION

Phasor measurement unit of medium voltage distribution network plays an important role in measuring the voltage and current phasors by determining its steady state condition and fault condition in real time domain which is helpful for line technician in finding the exact location of fault as well as fault type in order to restore the network as early as possible to improve the SAIFI and SAIDI of the network. In our research, the neural network model gives 100% accurate result in determining the fault type and can be implemented with real time domain and integrated with PMU sensor in order to predict the type of fault in advance by looking at the distribution parameters of the network of smart grid and give alarm by identifying the fault types in advance.

REFERENCES

[1] S. Savulescu, Real-time stability in power systems: techniques for early detection of the risk of blackout: Springer, 2014
[2] A. G. Phadke and J. S. Thorp, Computer relaying for power systems: John Wiley & Sons, 2009
[3] M. Zima, T. Krause, and G. Andersson, "Evaluation of system protection schemes, wide area monitoring and control systems," 2003.
[4] S. Horowitz and A. Phadke, "Third zone revisited," IEEE Transactions on power delivery, vol. 21, pp. 23-29, 2006.
[5] M. Adamiak, A. Apostolov, M. Begovic, C. Henville, K. Martin, G. Michel, et al., "Wide area protection—Technology and infrastructures," IEEE Transactions on Power Delivery, vol. 21, pp. 601-609, 2006
[6] Vicol, Bogdan, et al. "Synchrophasor measurement method for overhead line parameters estimation in MV distribution networks." Proc. 16th Int. Conf. on Harmonics and Quality of Power (ICHQP). 2014
[7] Naseem, Syed Atif, Raheleh Eslampanah, and Riaz Uddin. "Probability estimation for the fault detection and isolation of PMU-based transmission line system of smart grid." 2018 5th International Conference on Electrical and Electronic Engineering (ICEEE). IEEE, 2018
[8] Tianshu Bi, Jinmeng Chen, Jingtao Wu, Qixun Yang, "Synchronized phasor based on-line parameter identification of overhead transmission line," Electric Utility Deregulation and Restructuring and Power Technologies, 2008. DRPT 2008. Third International Conference on, pp. 1657 - 1662, April 2008
[9] E. Janecek, P. Hering, P. Janecek, A. Popelka, "Transmission line identification using PMUs," Environment and Electrical Engineering (EEEIC), 2011 10th International Conference on, pp. 1 - 4, May 2011
[10] Marija Bockarjova, Goran Andersson, "Transmission line conductor temperature impact on state estimation accuracy", IEEE Power Tech, Lausanne, Switzerland, July 1-5, 2007
[11] J. Chen and S. Chang, "A neural network approach to evaluate distribution system reliability," IEEE International Conference on Systems Engineering, Kobe, Japan, 1992, pp. 487-490.