Soft Computing Methods for Fault Detection in Power Transmission Lines

Farhan Rahman, Masooma Aliraza Suleman

Abstract*: Communication is a major aspect of our day to day life and for maintaining the transmission of the data; electric power transmission lines play a major role in acting as the medium for this transmission. The transmission lines can further be differentiated as an overhead transmission line and underground transmission line. But the transmission is often hindered by the physical factors or generally known as faults. In the past few years, the implementation of the underground cable has seen an upsurge as these cables are not easily affected by the physical factors as the overhead cables are, as a result, there have been various methods adopted by the engineers for the analysis, detection and control of these faulty lines. Depending on the supply range of a particular nation different materials are used for the transmission lines. Different fault detection methods are used for the exact location of the fault and implementing that in a digitized way is the optimum solution. Whenever there is a fault the entire transmission line is affected, to ensure that the safety of the transmission line a governing system has been implied in our proposed work. Locating a fault requires various detection methods, one such method is the time domain reflectometry (TDR) which we have inculcated in our analysis of fault lines. This technique incorporates the transmission of a pulse down the cable, any change in the characteristics impedance will cause a part of the incident pulse to reflect back, this knowledge is helpful for locating discontinuities in a system.

Keywords: Fault detection, Short circuit fault, Time Domain Reflectometry, Cascaded System.

I. INTRODUCTION

As we all come across various appliances in our day to day lives from using devices to using the street lights, the power system is the reason behind this generation, transmission and distribution of the networks. The power system is embedded with substation which uses transformers to maintain a certain voltage level to either increase or decrease the voltage according to the need of the users. The electricity generated by the power plant is transmitted with the help of power transmission lines to the end-users. The transmission is possible using transmission cables which are of different types and characteristics. Two such examples are the coaxial cable and twisted ac cables. An ideal transmission cable has a unique characteristic impedance which is altered whenever there is an emergence of fault inside the cable. This transmission is at times hindered by the physical factors thereby causing faults. The faults are further divided into open circuit fault and short circuit fault, so the analysis of these faults is quite essential. As in technology, it is requisite to have a system with the optimal efficiency and for that, every transmission line should be faultless and should have a valid fault recovery mechanism. For this, the system proposed in the following paper helps a person to detect the fault and the location of the fault with the help of various fault detection techniques. One of the most used methods is the detection of fault with the help of Ohm's Law, but this is method is not automated and does not relate to real-time systems. Another method showing the best approximation of the location of the fault and detection is implemented in this paper using our prototype of a transmission line with fault. Having to deal with faults we also need to implement a method that does not render the functioning of the rest of the transmission system. For this to be effective, we need circuit breakers or miniature circuit breakers to be installed in various sites for the safety of the entire system. This type of prototyping will ensure the optimal processing of the power system from end to end-user.

Revised Manuscript Received on December 16, 2019.

***** Correspondence Author
Farhan Rahman*, Electronics and Communication Engineering, Vellore Institute of Technology, Chennai, India . Email: farhanrahman02@gmail.com
Masooma Aliraza Suleman, Computer Science Engineering, Vellore Institute of Technology, Chennai, India. Email: masooma20suleman@gmail.com

II. LITERATURE REVIEW

The author of [1] has bestowed the studies of finding the failure location on a sample cable by exploitation the multiple pulse reflection technique and also the fault on the results of the measurement. A generator with an amplitude of 12 V and a pulse dimension from twenty ns to a pair of USA has been designed as a multiple pulse reflection meter. The speed of reflection pulse is marked in the embedded system. The SOPC system detects the reflection pulse and measures the time of N time's reflection pulses, then decides the fault kind and reckons the fault distance with the corrected speed of pulse developed for the measurement of pulse reflection by suggests that of pulse speed correction and is examined here. In [4], the author at each the ends of the line, current differential relays are thought of so as to search out a more refined answer for fault location. The projected fault location technique may be achieved by incorporating differential protecting relays with the fault locators. In this manner, differential relays communication infrastructure is used. So, extra communication links don't seem to be needed. What is more, differential relay utility is increased to an excellent extent. In order to detach the solely faulted line, it's crucial to differentiate the faults zone precisely and indicate actual fault kind with the help of 1 finish information solely.

The author of [5], Koley et al. (2011), has incontestable a technique for fault analysis in the six-phase transmission system with the help of artificial neural networks. a completely unique approach for the double line to ground faults in teed transmission lines exploitation neural networks was bestowed by Warlyani et al. (2011). During this methodology, a double line to ground faults was known with the assistance of the voltage and current signals at one finish of the teed circuit. In this paper, a technique for identifying the location with fault appearance in the underground cable is presented.

This paper of [11] deals with fault detection for underground cable victimization microcontroller. The aim of this project is to work out the space of underground cable fault from the base station in kilometers. This project uses the easy idea of ohm's law. Once any fault like contact happens, free-fall can vary reckoning on the length of fault in cable, since the present varies a group of resistors are so accustomed represent the cable and a dc voltage is fed at one finish and also the fault is detected by police work the amendment in voltage employing an analog to voltage converter and a microcontroller is employed to create the required calculations in order that the fault distance is displayed on the digital display.

III. PROPOSED FRAMEWORK OF FAULT DETECTION

In proposed we have used the TDR technique and the ohms law detection method of fault detection over various types of fault starting from open circuit fault to short circuit fault which can further be classified as line-line, line-ground, and line-line-ground. The analysis and detection of fault are very essential for maintaining the efficiency of the power system. Carrying out our detection technique will provide us with methods to analyze the efficiency of various types of transmission cables used in electrical transmission starting from coaxial cables to twisted cables or cross-linked ac cables. The comparisons are made keeping in mind the characteristics impedance values and the change in the impedance value whenever there is a change in the cable due to a fault. To create a fault we have implemented a **π-network** of lumped elements at the joints and ensured that the frequency of the system, $f = \omega/2\pi \leq 1$ **kHz,** thereby following the general standards of the power systems**.** The capacitance, resistance, impedance and characteristics impedance value can be referred from Table 1, depending on the available characteristics values fault analysis is carried out by the TDR method and the efficiency of each cable is tabulated. Further, a study between faultless lines is carried out for a better understanding of the anomalies caused by the degradation of the transmission lines. To prevent even worse damage to the power system connected to the faulty line a monitoring system is implemented using an MCB.

IV. IMPLEMENTATION OF FAULT-DETECTION FRAMEWORK

In our proposed framework we implemented the TDR technique over a modified fault circuit prototype. Using a cascaded system of different dimensions of ac cable so as to create a joint fault other than the use of lumped elements makes the system or the transmission line prototype redundant with faults at the joints. According to real-time simulations, there should be a fault or a ripple at the joint consisting of a fault. The use of three cables with different dimensions creates a joint with a fault between two non-degraded cables.

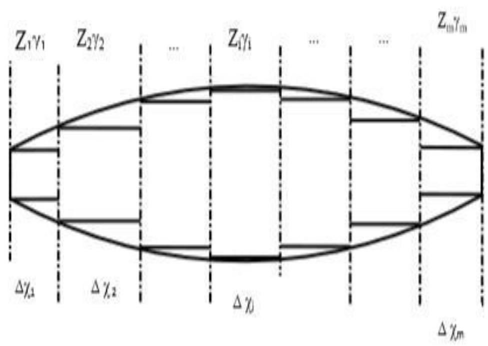

Fig. 1. Non - uniform AC cable for joint creation

The figure [1] shows a model of non-uniform joint created with the help of different sections. In our model, we used three different sections of ac cables for the purpose of the joint generation. The introduction of a joint creates a fault in the transmission cable system. The implementation of the above-proposed work is carried out in Simulink, with the help of various appropriate parameter selection for the ac cable, which is shown in figure [2].

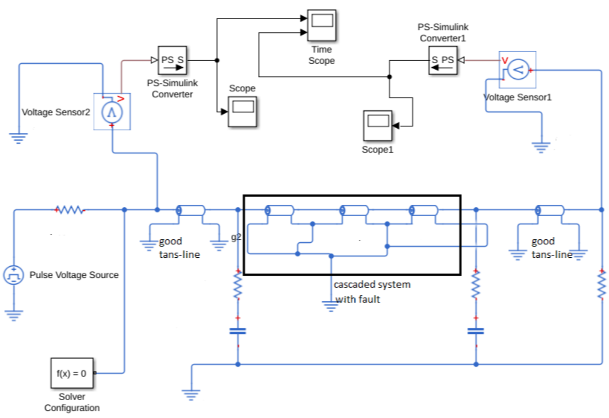

Fig. 2. Simulation of MATLAB/Simulink of a degraded line

Retrieval Number: A10471291S319/2019@BEIESP
DOI:10.35940/ijeat.A1047.1291S319

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

Another method implemented in this proposed work is the analysis of various types of faults, mainly short circuit which involves line-line to a fault, line-line-ground fault and line-ground fault using Simulink. The analysis for this method is carried out in LT Spice using appropriate circuits shown in figures [3, 4 &5] below. The circuits are modeled after standard equivalent faults and for fault detection, we have used ohm's law. The results are then compared to the theoretical calculations in the conclusion section. The simulated circuits are the equivalent interconnected circuits for the figures shown below. The interconnected circuits are a result of various faults been integrated into a normal prototype and applying the necessary conditions.

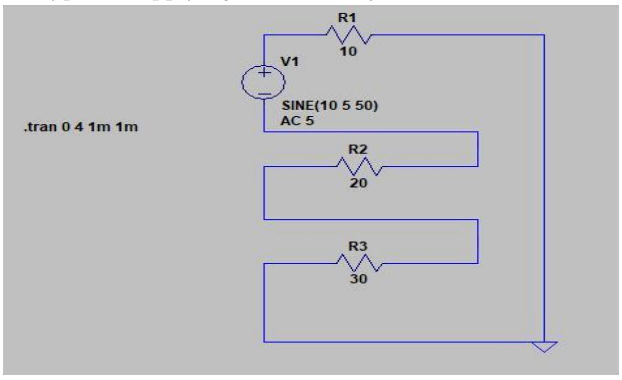

Fig. 3. The interconnected equivalent circuit for Single Line-to-Ground Fault

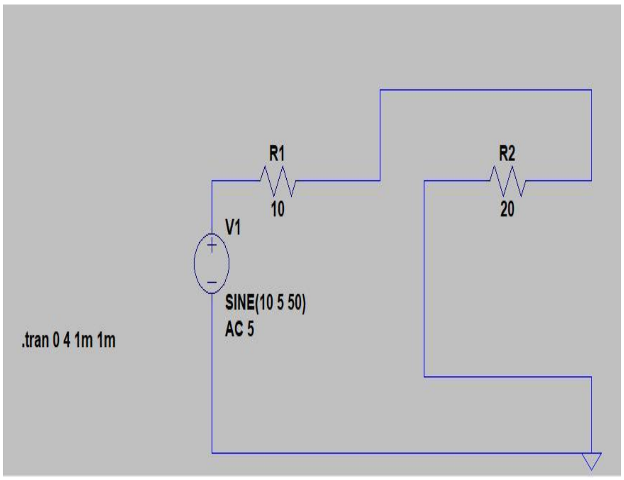

Fig. 4. Interconnection of sequence networks for L-L fault

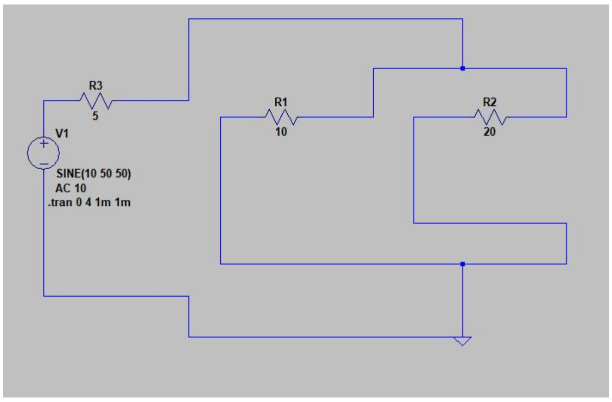

Fig. 5. Interconnection of sequence networks for L-L-G fault

The simulated circuits are the equivalent interconnected circuits for the figures shown below. The interconnected circuits are a result of various faults been integrated into a normal prototype and applying the necessary conditions.

Faults in 3Ø Circuits:

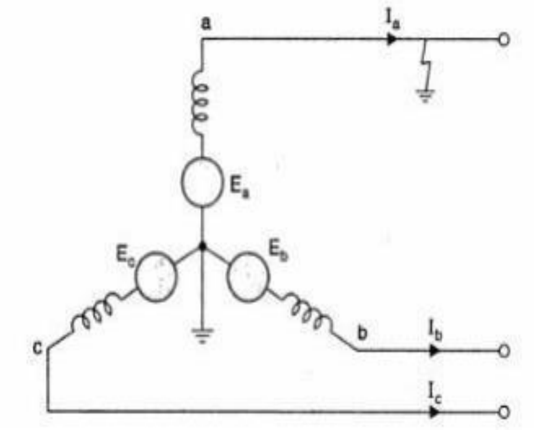

Fig. 6. Single line to ground fault

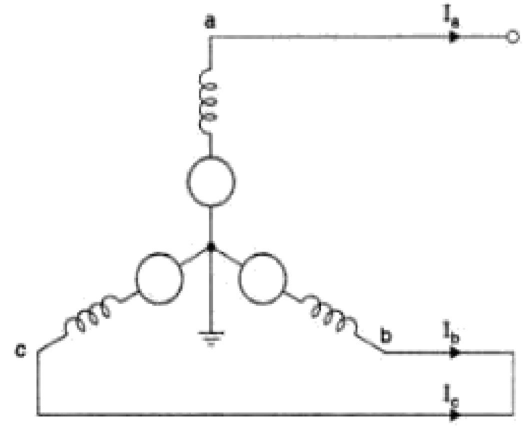

Fig. 7. The line to line fault

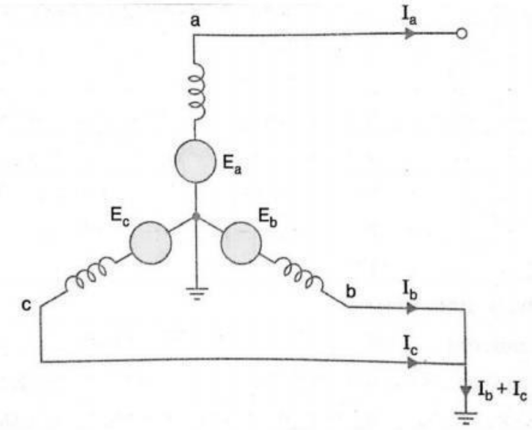

Fig. 8. Line –line-ground fault

V. CONDITIONS APPLIED AND FORMULAS USED:

Single Line-to-Ground Fault:

For this fault, we have used the standard formulas present in the work by the author of [11], which provides us with the theoretical calculation of a line to ground fault which is further matched with the simulated results. For this calculation, we have used the formulas for current and voltage across different terminals.

$$I_{a_1} = \frac{E_a}{Z_1 + Z_2 + Z_0}, \quad V_a = 0 = V_{a_1} + V_{a_2} + V_{a_0}, \quad I_{a_1} = I_{a_2} = I_{a_0}$$

Line-to-Line Fault:

The conditions and formulas implemented for this fault is as follows

$$I_{a_1} = \frac{E_a}{Z_1 + Z_2}, \quad I_{a_1} = -I_{a_2}, \quad V_{a_1} = V_{a_2}, \quad I_a = 0, \; I_b + I_c = 0, \; V_b = V_c$$

Line-line-ground fault:

$$I_a = 0, \; V_b = 0, \; V_c = 0, \quad V_{a_0} = V_{a_1} = V_{a_2}, \quad I_{a_2} = -\frac{E_a - I_{a_1}Z_1}{Z_2}, \quad I_{a_1} = \frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_0 + Z_2}}$$

VI. RESULTS AND DISCUSSION

The Simulink implementation of the proposed work of the faulty transmission cable of figure [2] is shown by the figure [9], with the slight ripple showing a discontinuity in the cable wherever the fault is created. This type of fault is generated by placing a cascaded system of non-uniform cables at the joint between two non degraded cables of 200m in length. The result is consistent as it is expected to show a certain delay whenever the cable is degraded by a certain kind of fault. The non-uniform joint in figure [2] is created by using three cables of a different dimension of length measuring 50 m, 70m and 80 m respectively. As it is known from prevailing studies that a degraded cable tends to have a certain time delay the below result in figure [9] is supportive of the claim.

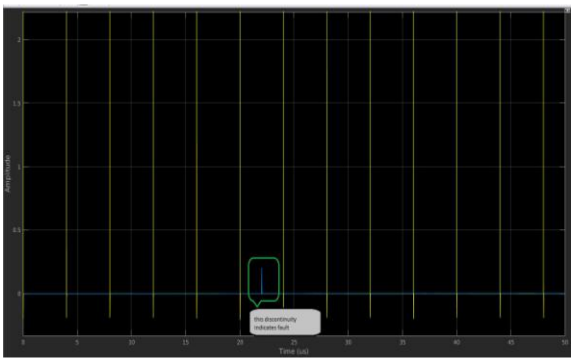

Fig. 9. Simulink display for a transmission line with the fault

The figures below are the results from the simulation carried in LT Spice of different faults detected by the Ohm's law method. The tabulated form of the same is shown in the table [2] with both the theoretical and simulated values of current obtained by the equations and conditions mentioned above. The results are consistent with the practical values as well. These types of fault are standard in-home appliance applications and can be measured using the ohm's law and by comparing the obtained results with the prevailing one, this is supported by the table [2].

Table 1: Theoretical and Simulated values of Fault currents

Type of fault	Theoretical value of current(mA)	Simulated value of current(mA)
Line-line fault	333	330.4
Line –ground fault	166.6	165.5
Line-line-ground	454.5	451.5

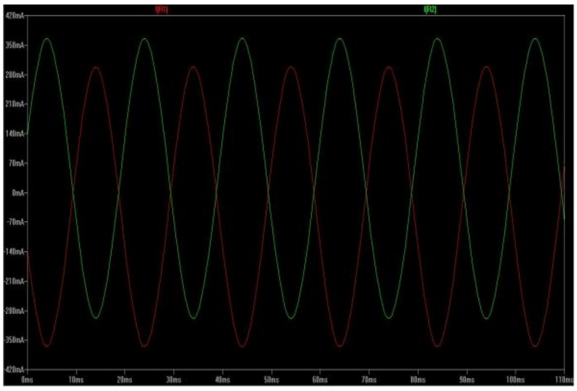

Fig. 10. Line-Line fault

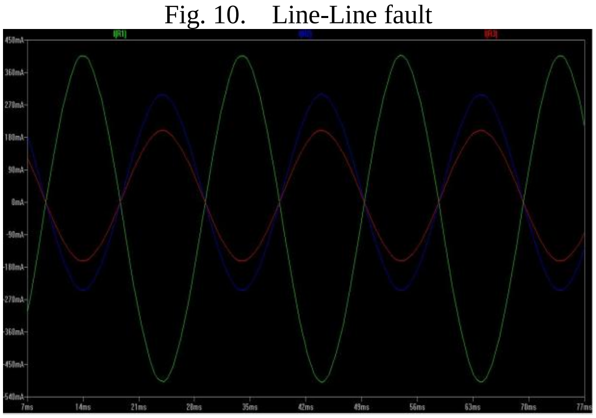

Fig. 11. Line-Line-Ground fault

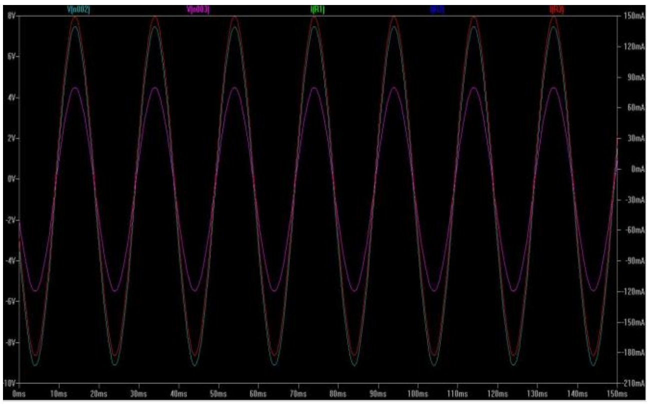

Fig. 12. The line to the Ground fault

Retrieval Number: A10471291S319/2019©BEIESP
DOI:10.35940/ijeat.A1047.1291S319

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

VII. CONCLUSION AND FUTURE WORK

As it is evident from the above table [2], Ohm's law technique is consistent and is helpful for the detection of fault and calculation. The results from figures [10, 11, and 12], show that fault calculations for standard circuits can be implemented easily but the types of fault have to generate and therefore it is just a theoretical method for detection of a fault. This (Ohm's law)method of fault calculation is not based on the practical or physical parameters of a transmission of a power system so it better to use TDR method for detection of fault, as the TDR method is more realistic as it is automated and predicts the location of the fault for the proposed prototype. In day to day life, the fault is created by bad weather conditions or physical factors, thereby fault detection is essential for this the method has to be efficient and a natural technology. The results from figure [9] verify the MATLAB/Simulink simulation of joint configured by the use of cascaded power cables. The two non-degraded cables are connected with the help of non-uniform cables of different dimensions. The faulty cabled is recognized with the help of the discontinuity in the reflection of the signal caused by the fault in the joint, this can be interpreted as a delay in the pulse signal. Therefore the proposed work can be implemented for further analysis of fault detection techniques. It can be finally inferred that for the natural implementation of fault detection TDR method is practically more accepted because of the inbuilt and automated detection of a fault. The method of using theoretical values is often flawed and non-dynamic.

REFERENCES

1. B. Clegg, Underground Cable Fault Location. New York: McGraw Hill, 1993.
2. Saha, M.M., Rosolowski, E. and Izykowski, J., "A fault location algorithm for series compensated transmission lines incorporated in current differential protective relays" The International Conference on Advanced Power System Automation and Protection, pp. 706-711, 2011.
3. Apostolov AP, George W. Protecting NYSEG's six-phase transmission line. IEEE Comput Appl Power.1992;5(4):33–36.doi:10.1109/67.160044.
4. Sharma, R., Ahmad, A. and Shailendra, K. S., "Protection of Transmission Lines using Discrete Wavelet Transform," International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 3, Issue-1, June, 2013.
5. Koley E, Yadav A, Thoke AS. A new single-ended artificial neural network-based protection scheme for shunt faults in six-phase transmission line. Int Trans Electr Energy Syst. 2014.
6. Tze Mei Kuan, Azrul Mohd. Ariffin, Maria Madelina Bemmynser Sedau. Advancement of TDR Technique for Locating Power Cable Insulation Degradation Vol.7 (2017) No. 6 ISSN: 2088-5334
7. Katsumi Uchida, Yoichi Kato, Masahiko Nakade, Daisuke Inoue, Hiroyuki Sakakibara, and Hideo Tanaka, "Estimating the Remaining Life of Water-Treed XLPE Cable by VLF Voltage Withstand Tests," Asia Pasific IEEE PES Transmission and Distribution Conference and Exhibition, Vol. 3, October 2002, pp. 1879-1884.
8. T. M. Kuan, S. Sulaiman, A. M. Ariffin and W. M. S. W. Shamsuddin, "MATLAB/Simulink Power Cable Modelling for Cable Defects Assessment," Journal of Fundamental and Applied Sciences, Vol. 10 (5S), 22 March 2018, pp. 571-588.
9. Moon Kang Jung, Yong June Shin and Jin Bae Park, "Application of Time-Frequency Domain Reflectometry based on Multi-band Signal for Detection and Localization of Fault.
10. Qinghai Shi, Uwe Troeltzsch and Olfa Kanoun, "Detection and Localization of Cable Faults by Time and Frequency Domain Measurements," 2010 7th International Multi-Conference on Systems, Signals and Devices, Amman, pp. 1-6, 27-30 June 2010.
11. Dr R.K.Jena , Power System Protection Lecture notes.
12. David L. McKinnon, "Insulation Resistance Profile (IRP) and Its Use for Assessing Insulation Systems," IEEE International Symposium on Electrical Insulation (ISEI), San Diego, June 2010, pp. 1-4.
13. Yan Li, Paul Wagenaars, Peter A.A.F. Wouters, Peter C.J.M. van der Wielen and E. Fred Steennis. Power Cable Joint Model: Based on Lumped Components and Cascaded Transmission line approach International Journal on Electrical Engineering and Informatics – Volume 4, Number 4, December 2012
14. Y. Tian, P. Lewin, and A. Davies, "Comparison of on-line partial discharge detection methods for hv cable joints," IEEE Transactions on Dielectrics and Electrical Insulation, vol. 9, no. 4, pp. 604–615, Aug 2002

AUTHORS PROFILE

Farhan Rahman, currently pursuing Electronics and Communication Engineering from VIT Chennai. Research interest field consists of Internet of things, Digital Signal Processing .

Masooma Aliraza Suleman, currently pursuing Computer Science Engineering from VIT Chennai. Research interest filed consists of Internet of Things, Networking .