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A novel distance estimation technique for single line to ground fault in electric distribution network using smart meter

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Smart grid concept promises a reliable and efficient supply of electricity. It recognizes the growing importance of Information and Communication Technologies (ICTs). Monitoring, communication and controlling are the main systems which can transform the conventional grid into the Smart Grid. A vivid study of components of the smart grid i.e. smart meter, ICT, Internet Protocol (IP) based hierarchies, Advanced Metering Infrastructure (AMI) is completed. Smart phone based communication is drawing attention now days in Smart Grid environment because of the use of Global System for Mobile Communication (GSM) technology and its real time interactivity. It is based on Client–Server communication. To initiate a point to point Client Server connection, the transmission control protocol (TCP) would be used. This paper includes a novice technique for locating single line to ground fault, and methodology to be applied for it. Fault location is calculated using the real time data obtained from 400 kV Jejuri substation. The length of the Bhigwan – Bilt Graphics line has been measured using Tauraus kit, and inferences are drawn.

Keywords: *Single line to ground fault; smart meter; Client Server communication; fault location, TCP.*

1.0 INTRODUCTION

Electrical transmission and distribution network is susceptible to various types of faults such as Single Line to Ground, Double Line to Ground, Line to Line and three phase fault. These faults are caused due to the different reasons like bridging by birds, falling of tree on the transmission line, mechanical damage to insulators, lightning, etc. To ensure uninterrupted, reliable, and quality power supply, it is necessary for the transmission utility to locate the point on the transmission line at which the fault has occurred and attend the same quickly. The traditional method of fault location in the transmission system is based on manual outage mapping using consumer's calls and customer's outage reports. This procedure is time consuming.

Now-a-days, number of new techniques for fault location have been proposed, which are applicable to transmission network. These developments include, bidirectional communication between utility and consumer, access to real time data corresponding to the fault event. First generations of relays are electromechanical relays. Static relays are the second generation relays. Now the third generation of relays has emerged which are the numeric relays. The numeric relays are microprocessor based relays whose operation is based on the principal of sampling. The numeric relays are sensitive, fast andaccurate as compared to first and second generation relays. The efforts would be taken to minimize the deviation between actual fault location displayed on the numeric relay, and the calculated value of the distance at which fault has occurred from the bus using a

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new technique; and to implement the proposed technique for fault location in ring main distribution or transmission system.

2.0 COMMUNICATION TECHNOLOGY IN SMART GRID

Today's grid is lack of communication capabilities. Comparison of smart grid and conventional grid, communication networks in smart transmission and distribution grid, communication security and challenges and opportunities in communication are explained in [1]. Ruofei Ma, Hsiao-Hwa Chen, Yu-Ren Huang, and WeixiaoMeng, has elaborated Smart Grid communication infrastructure and technologies, technical challenges in communication and security [2]. Client–server communication in Android Based Platform, basic service layers of architecture and Polling and Pushing techniques are figured out by taking an example of CNC machine considering TCP /IP protocols in [11]. New features of AMI, relationship of power supply and applications of AMI in Smart Grid, AMI overall design is focused in [12].

2.1 Client Server Communication And TCP/ IP [14]

The connection between Client and Server can be established in two ways; polling and Persistent Socket Connection. Persistent Socket Connection is advantageous because, it offers power saving, less network data consumption. The connection diagram between Client and Server is shown in Figure 1.

For initiating point to point client server connection, the transmission controlprotocol would be used. TCP is a reliable protocol.

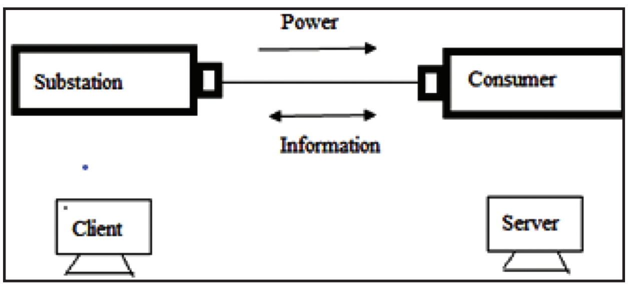

FIG. 1 CLIENT-SERVER COMMUNICATION

3.0 FAULT LOCATION TECHNIQUE FOR TRANSMISSION AND DISTRIBUTION LINES

To prevent cascade tripping due to different faults, various techniques like artificial neural network, fuzzy logic, fuzzy - neuro, fuzzy logic wavelet based and phasor measurement unit-based concepts are being used [3]. A prototype fault locator which estimates the location of shunt faults on radial sub transmission and distribution lines explained in [13]. A fault location method for new protection scheme of distribution grid is suggested in paper [14]. New single phase-to-ground short-circuit fault location algorithm for overhead three phase radial distribution lines with single-ended measurements using the sinusoidal steady-state analysis method is proposed in [4]. Paper [5] explains an algorithm which is based on steady state analysis of faulted distribution network. Paper [6] describes a new approach to fault location for double-circuit transmission lines based on only the voltage data of both ends of the faulted circuit. Some unconventional approaches have been introduced to detect and locate short duration faults in [7]. The proposed method in paper [8] uses synchronized voltage and current measurements at the interconnection of Distributed Generation units. A new fault location method which is impedance based is detailed in paper [9]. The smart meter not only used for billing purpose or meter reading but also used to facilitate two –way-communication, data management system,and real time access to information. After the fault is detected, the proposed method in [10] is used to locate the fault in distribution system using measurements from the smart meter. In this paper bus impedance matrix is used to develop a new fault location method. The future scope for this work is, finding out the optimal placement of the smart meters, and implementing the proposed fault location technique considering distributed generation, i.e. considering different topology which is ring main.

Above papers are based on the different fault location techniques, but lot of work has to be done for accurate fault location. Also these papers propose techniques for fault location in radial transmission or distribution system, but fault location in ring main transmission or distribution system need to be addressed.

After paying visits to 220 kV Bhigwan substation, 400 kV Jejuri substation, and undergoing the literature survey, it is observed that, by implementing the existing fault location techniques, there is a considerable error in the measured distance from the bus and the point at which the fault has occurred. Some techniques identify only the zone in which the fault has taken place. It is time consuming to find out the accurate fault location in that case. The Taurus Kit is currently used for measuring the line length can be used for fault location, but the measured length will not be accurate. Taurus measurement gives direct digital display of distance to fault with the accuracy of ±100 m [19]. It is necessary to find out the novice technique, which locates the fault more accurately to reduce the error and which is also fast.

4.0 NUMERIC METER [16]

Numeric meter is a key component of AMI. Input signals from CT and PT are sampled in Sample and Hold circuit. These analogue signals are converted in digital signals using ADC. The output of ADC is fed to the CPU. CPU performs the calculations of V_{rms} , I_{rms} and power factor.

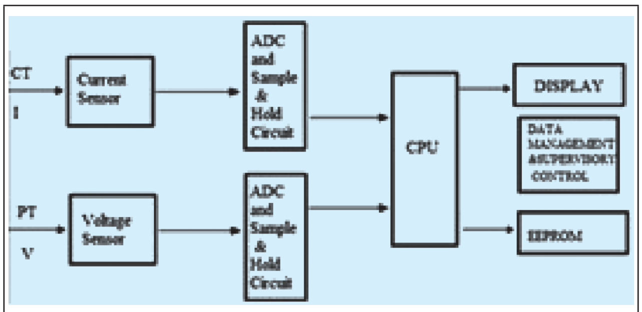

FIG. 2 BLOCK DIAGRAM OF NUMERIC METER

5.0 PROPOSED TECHNIQUE FOR FAULT LOCATION

The proposed work is focused on Single Line to Ground fault location, using smart meter .The circuit of the proposed method for finding out the fault location is given as shown in the Figures 3 and 4.

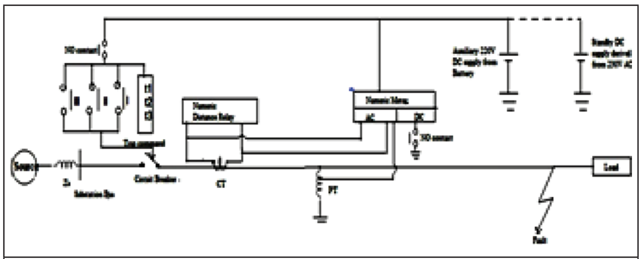

FIG. 3 PROPOSED TECHNIQUE FOR FAULT LOCATION

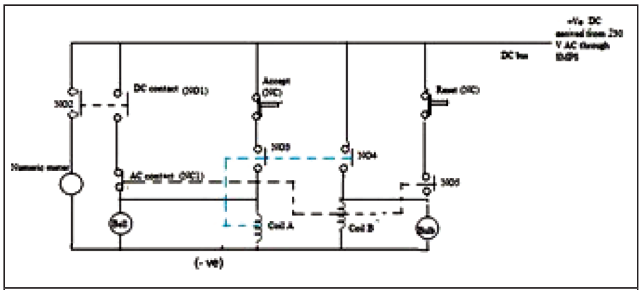

FIG. 4 CIRCUIT ON THE CONTROL PANEL

A transmission circuit is mainly divided into two parts, i.e. Power Circuit and Control Circuit. Power circuit consists of Current Transformer (CT), Potential Transformer (PT), circuit breaker, transmission lines, bus, sensors etc. Figure 5 describes the Control circuit. In the above Figure 3, Z_s is the source impedance. During normal operating condition, CT carries normal rated current which flows through the relay circuit. This relay provides 3 stepped distance protection. Step I: It is an instantaneous protection, which is provided at 80 – 90 % distance of the line. Step II: In second step, the remaining 20 – 10 % line length, remaining out of first step, and in addition to it, 50 % of the adjoining line section is covered. Step III: It is provided for giving full backup to the next line section. It covers the 100 % of the next line section and reaches further into the system. t_1, t_2, t_3 are the time settings of the relay.[17]

After the occurrence of fault, the relay in corresponding zone will give the trip command to the circuit breaker. When there is single line to ground fault, CT carries very high current for momentary time period. As a result, the relay coil gets energized and creates magnetic field. Because of magnetic field generated by relay coil, circuit of trip coil is closed, i.e. Normally Open (NO) contact of trip circuit is closed. Thus, D.C. circuit is completed and trip coil gets D.C. supply from 220V D.C. source. As a result, the trip coil is magnetized. The trip coil gives trip command to circuit breaker and circuit breaker trips and isolates the fault. In suggested method for measurement of fault distance of the line, let the time required for tripping of the Circuit Breaker is equal to t second. It is proposed to connect 220 V D.C. supply through Normally Open (N.O) contact connecting the transmission line. During normal operating condition, (N.O) contact is open and D.C. source is isolated from power circuit. When there is fault on transmission line, relay gives trip command to open the Circuit Breaker contacts. After contacts are open, the trip coil will close N.O contact of D.C. source in + Δt second. Since, the type of fault is single line to ground fault, D.C. circuit across transmission line is completed. (Since, line is tripped, A.C. is already cut off).

When there is occurance of fault, Normally Open contact (NO1) closes because of the magnetic effect of the relay coil.Therefore NO2 gets closed, and indication is received by numeric meter that fault has occurred. Such indication is appeared on numeric meter display. D.C current flows through NO1 and NC1. As a result following two actions take place:

1. Bell starts ringing
2. Coil A gets energized.

Due to magnetization of coil A, following actions will take place:1. NO3 closes2. NO4 closes.

Bell gets D.C voltage from two sources: 1.Through NO and Accept NC.Coil B gets D.C. supply and gets magnetized , therefore following actions take place:NC1 opens and NC5 closes. NC1 is now open. When the operator presses accept button(Normally NC), D.C. voltage applied to the bell will get cut off. Therefor, NO3 and NO4 are nowopen. Asa result, coil B gets de energized and opens contact NO5 .When operator presses reset NC, D.C voltage to bulb is cut off, and bulb stops glowing.

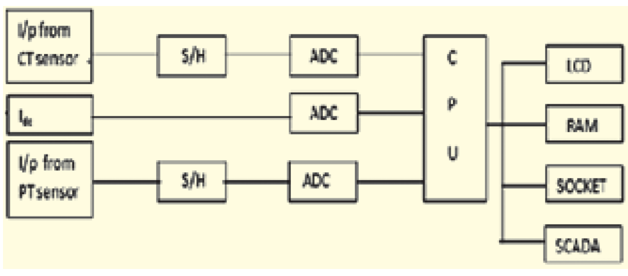

FIG. 5 THE CONTROL CIRCUIT

5.1 Fault Location Calculations

CPU provided inside the numeric meter will perform the following steps:

1. Input of transmission line details: 400 kV, 0.4 ACSR Moose, 2000 A, with rated fault current of the system 40 kA.
2. Therefore, from reference charts, resistance of 0.4 ACSR Moose conductor is 0.0439 Ω/km. [18]

Let, $I_{dc}$is current, flowing through D.C circuit. Assumed that, I_{dc}= 140 A

R= V_{dc}/I_{dc} = 220 V/140 A = 1.571 Ω

If resistance of line having length 1 km is 0.0439 Ω;

Then let,L_f be the length at which the fault has occurred, having resistance of 1.571 Ω .

Thus, L_f = 1.571 Ω /0.0439 Ω = 35.78 km.

That means, the fault has occurred at the distance of 35.78 km from the bus at Jejuri end.

TABLE 1

DETAILS OF FAULT EVENT ON 400 KV JEJURI - KOYANA TRANSMISSION LINE

Type of Fault	Currents (A)			Fault location from Jejuri End
	I_R	I_Y	I_B	
Single Line To Ground	1250	33	40	35

5.2 Methodology Formulation

- Data would be collected for the transmission lines mentioned in Figure 6.
- New smart meter algorithm would
- be developed for Single line to
- ground fault.
- Calculation for the distance estimation would be done according to the new technique.
- The results and the actual readings would be verified; and the results would be displayed on the numeric meter.
- Comparison of the results obtained using Taurus kit, numeric meter and by using the proposed method would be done.

The results obtained by using proposed method would be communicated to customer as well as to the utility engineers by using Client–Server communication and socket programming.

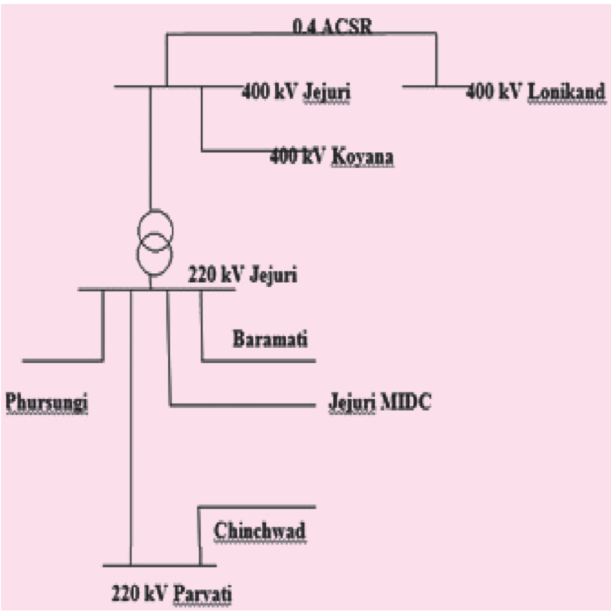

FIG. 6 TRANSMISSION LINES UNDER STUDY OF SINGLE LINE TO GROUND FAULT.

5.3 Measurement Of Length Of The Line Using Tauraus

The total length of each phase of 220 kV, 0.4 ACSR Zebra, and 575 A Bhigwan – Bilt Graphics line was measured, byconnecting Tauraus kit at Bhigwan Substation and the other end of the line at Bilt Graphics was grounded. The measured distance of R, Y, and B phase was 11.6 km, 11.7 km, 11.7 km respectively. It was observed that, the distance measured using Tauraus cannot be accurate. Because, the total length measured by Tauraus is L+L' where, L is the actual length of the line, and L' is thelength of the jumpers, connecting the wave trap. As shown in Figure 7.

5.4 Field Data For Single Line To Ground Fault

- Single Line to Ground fault on Jejuri – Jejuri II Link:
- R phase – N shorted.
- Zone 1 fault.
- Distance protection operated
- Earth wire was touched to 220 kV R phase of Jejuri – Jejuri II Link at MIDC Jejuri end.
- Length of the line : 6 km
- Fault location : 5.98 km from Jejuri end.

Table 2 shows the magnitude of phase currents at the time of this fault event.

TABLE 2

PHASE CURRENTS AT THE TIME OF FAULT EVENT

I_r	I_y	I_b
4.357 kA	431.07 A	120.09 A

- Single Line to Ground fault on 220 kV /132 kV Parvati- Rasta Peth line:
- Window Indication: Distance Protection operated.
- Relay Indication: Distance Trip
- Auto reclosure Lockout
- CB SF_6 lock.
- Total length of the line : 7km
- Fault Distance from Parvati end : 1.1 km

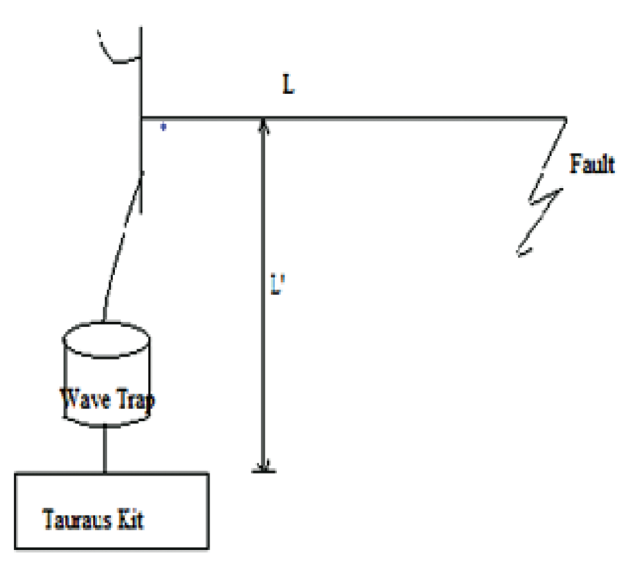

FIG. 7 FAULT LOCATION USING TAURUS KIT WHEN WAVE TRAP CONNECTED TO THE LINE

6.0 CONCLUSION

Fault location is the potential application of smart meter. The smart meter available in the market does not locate the fault.

It was observed that, the distance measured using Tauraus cannot be accurate. Because, the total length measured by Tauraus is an addition of the actual length of the line, and the length of the jumpers, connecting the wave trap. Proposed work will include an addition of display parameters of the smart meters e.g. distance at which fault has taken place, type of the fault, date and time. Intimation of these parameters would be onsmart phone, by establishing persistent socket three parameters i.e. distance obtained from real time data, distance obtained from Taurus kit, and distance displayed on the smart meter would be conducted. Proposed method is suitable only for single line to ground fault, creating the short circuit and it is not possible to locate the fault, if the line is open. Also, it is always required to inject 220 V DC input at sending end and to earth the other end of line at receiving end.

7.0 ACKNOWLEDGEMENT

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