Outage Management System with Fault Passage Indicator

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A Thesis Submitted to

Indian Institute of Technology Hyderabad

In Partial Fulfillment of the Requirements for

The Degree of Master of Technology

भारतीय प्रौद्योगिकी संस्थान हैदराबाद

Indian Institute of Technology Hyderabad

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June 2015

Declaration

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Acknowledgements

First of all, I would like to thank my guide **Dr. Pradeep Kumar Yemula** for his invaluable guidance and encouragement.

I would like to take this opportunity to express my gratitude to all the members of faculty of Power Electronics and Power Systems group

I express my deep thanks to all my friends, seniors, especially **Naga Yatendra**, **Charan Teja** and **Y V Pavan Kumar** and all the members of my family for their incredible support, motivation and inspiration.

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Abstract

As the size and complexity of distribution networks is increasing, remote operated switches are being used to make the grid smarter. The distribution network is being continuously reconfigured to improve the voltage profile, reduce losses and to supply to a large number of customers. Consequently, when an outage occurs on this dynamically changing grid, it is difficult and time consuming to pin-point the location of the outage. In order to overcome this problem, fault passage indicators (FPIs) are installed at strategic locations on feeders at the branching points. FPI is a device which provides a remote and local visual indication of the occurrence of fault even after the isolation of line. While the technology of FPI is established, in this thesis, algorithms which are not sensitive to network reconfigurations, are presented for fast identification of fault location, based on the statuses of multiple FPIs received at the utility control center. Also a load flow simulation platform with fault passage indicators is presented, which suggests the state of the network and overall set of operations to be carried out by the outage management system, for a given network topology and data of the network provided by real time monitoring systems.

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Chapter 1

Introduction

Power companies are in immense pressure to reduce outage time for customers. Electricity customers are increasing day-by-day forcing the power companies to provide reliable power supply with less outages. Overhead lines are vulnerable to faults, because of the system equipment exposed to extreme weather conditions. Identification of fault on medium voltage distribution network is tedious and time consuming, because of the complexity of network, relatively less advanced infrastructure and access to locations.

Under these circumstances, fast location of fault plays a major role. Fault passage indicator (FPI) helps in identification and location of fault. A fault passage indicator is a device which provides visual and remote indication of a fault on the electric power system. FPI, also called as, faulted circuit indicator (FCI), is a device used in electric power distribution networks for automatic detection and identification of fault location in order to reduce the outage time [1, 2]. FPI operates in such a way to detect the change in magnetic field radiating from the overhead line conductors caused by a fault [3]. This change in status creates an alarm by communicating through remote terminal unit (RTU) to the distribution system operator. FPI is able to distinguish between fault current from load current associated with the healthy feeder [4].

1.1 Scope of Work

Scope of this thesis involves:

1. Study of Outage management system
2. Study the current practices of identification of fault location
3. Study the Concept of FLISR (Fault Location Isolation and Service Restoration)
4. To suggest an algorithm for fast identification of fault location for radial distribution networks
5. Study of Architecture of Outage Management System with fault passage indicator

1.2 Key Contributions

1. Survey on Distribution Automation System and Self Healing.

2. Development of Algorithms for identification of faults based on the signals of FPI in radial networks.

3. Development of Load flow simulation platform and integration with fault location algorithm

4. A paper [5] is published in *Indian Smart Grid Week, 2015* from the work of this thesis

1.3 Organization of Thesis

This report presents an algorithm for fast identification of fault location. Overview and operations of outage management system, concept of FLISR are discussed in chapter 2. Chapter 3 discusses the Architecture of OMS with fault passage indicator. Load flow analysis platform designed to represent OMS is presented in chapter 4, while chapter 5 presents the algorithms for identifying location of fault in radial distribution networks. Finally, Conclusion and further scope of work are discussed in chapter 6

Chapter 2

Outage Management System

Electrical distribution systems plays major role in electrical power systems in delivering power to customers. Distribution automation allows the utilities to enhance reliability, efficiency and quality of power to the customers. Distribution automation is broadly classified as substation automation, consumer premises automation and network automation [6]. Outage management and distribution management comes under network automation. In this chapter OMS is introduced, highlighting it's various functions operations and challenges.

2.1 Outage Management System

In modern day power systems, in order to restore the network from emergency state to normalcy, outage management plays a major role. This process involves identifying fault location, fault isolation and service restoration, sending outage alerts etc [7, 8]. Outage Management Systems collects information from different sources as trouble calls, Advanced Metering Infrastructures(AMI), estimation and prediction data etc. to perform the necessary operations on the modules mentioned in the OMS. These operations are again sent to the output modules like, Isolation and reconfiguration modules or to inform the customer by social networking or through personal information.

2.2 Functions of Outage Management System

1. Fault location.
2. Fault isolation and restoration.
3. Outage metrics calculation.
4. Network Reconfiguration.

2.2.1 Fault Location

Fault location is very important task in outage management in order to restore the power as early as possible during outage. Previously, when SCADA is also not available, the location of fault is based on customer complaints. Based on the calls,if more calls came from a particular location then that area is considered as outage and the crew will go that location for identifying and isolating the fault. Later the advent of software and communication technologies led to the development of SCADA, wherein the circuit breaker status or relay status is observed and based on the statuses and location of the tripped breakers, the crew used to isolate the fault [9]. But even with the SCADA exact location of fault in radial distribution network is a tedious process as it is found to be uneconomical to install these system on these feeders. In order to pinpoint the location of fault, fault passage indicators are used. Fault passage indicators indicate fault, when high current (higher than the preset reference values) is passed through it. Detailed description of fault passage indicator is explained in section 3.2.

2.2.2 Fault Isolation and Restoration

The main aim of the OMS system is to restore the power to maximum number of customers in very less time. Whenever a fault is initiated it should be isolated. This function has mainly two steps one is fault isolation, which will check which feeders need to be tripped, so that maximum number of customers are not affected. The other function is restoration, which includes re-closing of circuit breakers after the fault is isolated. In this step supply is restored. Utilities normally have the fault isolation and restoration algorithms which reconfigures feeders during planned outages or scheduled maintenance. These algorithms check for the state of the feeders whether they are operating in normal operation or emergency operation or faulty operation. Base on the situation if the feeder is not in normal operation the oms system will automatically reconfigures the distribution feeder. This function also includes the switching management. Utility will issue a switching sequence based on the condition the regional level substations must follow the switching sequence and reconfigure the network accordingly. In some cases switching management is a predefined look up table and the network is reconfigured based on that table. This results in coordinated, central-decentralized operation with intelligence.

2.2.3 Outage Metrics Calculation

This function aims at calculation of outage times, number of customers affected during outage and estimated restoration time. Suppose a fault is initiated, the customers need to know which part of the network is isolated and when it will be restored, ie, estimated restoration time.

2.2.4 Network Reconfiguration

In distribution system, network reconfiguration algorithm, changes the status of sectionalizing switches. The algorithm is combination of optimization algorithm and reconfiguration process. Whenever a fault is initiated, first the circuit breaker will trip, then this algorithm checks for the case where maximum number of customers could be supplied, power from the other sources, line loadability and according the switching sequence is updated and the switches are operated in such a way to reconfigure the network satisfying the afore mentioned criteria.

2.3 Operation of Outage Management System

Fig. 2.1 shows the operation of outage management system. An outage management system consists on network model facilitating the electrical features [10]. Generally the network model is obtained from a Geo-spatial information system (GIS) with link to customer information systems (CIS). The notifications obtained are analyzed by interfacing the information with CIS, integrated voice response (IVR), and an automated metering infrastructure (AMI) [11, 12]. Later the obtained calls are grouped in order to predict the exact protection device. OMS takes input from the supervisory control and data acquisition (SCADA) systems and manual inputs from an operator or service provider. Based on the inputs obtained predictions using the prediction algorithms. Considering the advantage of intelligent land and road network information, it is easy to locate the closest location to the qualified crews.

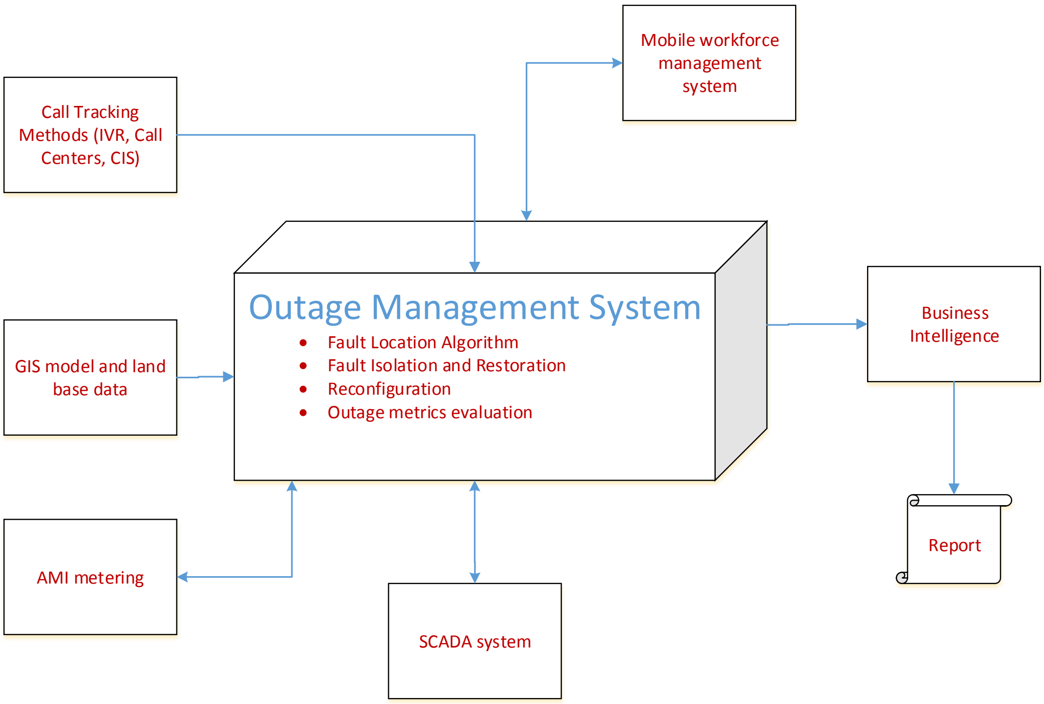

Figure 2.1: OMS Operations

Mobile workforce management helps in supporting the mobile computing solutions to all types of network. This includes dispatch, scheduling etc. This also allows the field crews and service providers to view unique network mapping and work details. The following are the advantages of mobile workforce management

1. Data entry errors are reduced.

2. Reduction in paper usage.

3. Timely communication to customers.

4. Productivity is improved by providing the crew with appropriate tools and resources for completion of job.

5. Monitoring of crew can be done wireless.

The above section mentioned the major functions of outage management system whereas in addition to that trouble analysis is done which has the following features which are part of the major functionalities of OMS.

1. Safety and operational tagging placement

2. Modifications to the connectivity model by changing device status and adding temporary network devices, such as cuts or jumpers

3. Completion of outages and capture of closing information

4. Partial restorations, including automatic calculation of customers restored by each step

5. Ability to change the predicted outage location to the next logical upstream or downstream device

6. Network tracing

7. Transfer of incorrectly mapped customers to correct device

8. Dynamic colorization of the network based on real-time status

9. Automatic generation of customer callback lists to verify restoration

10. Generation of customer lists downstream from network devices and outage locations

11. Automatic calculation of estimated restoration times for all outages based on outage type, device type, time of day, day of week, and weather condition.

OMS provides business intelligence and reports to utilities and customers about the outage. Business intelligence includes the metrics calculations with pricing details like from the point of view of utility, business intelligence report includes the lloss that he need to bear hen the outage is occurred. From the customer view point it consists of how much time and reasons for the outage are mentioned. Thus based on the reports obtained from the oms business models are modified accordingly. Finally summarizing the operation of OMS, it takes the input from the SCADA system, taking the help of GIS, CIS, AMI and mobile workforce management modules, provides output commands like switching sequences back to SCADA system and issues a report of outage to the utilities and customers.

In this chapter, OMS is introduced and it's various functions and operations are discussed. In Chapter 3, FPI and it's working is discussed and the architecture for OMS with FPI is introduced.

Chapter 3

Architecture of Outage Management System with Fault Passage Indicator

3.1 Architecture Overview

The architecture of the OMS is presented in Fig. 3.1. Block 1 in the figure represents static data, which consists of Network model in the form of bus-branch data, data regarding the locations of Fault Passage Indicators, Circuit Breakers, Sectionalizer switches. This data would remain same unless the actual distribution network undergo any physical changes like operation of any switch, erection of any new line or reconfiguring the network. Load flow program is continuously run on this static data and the branch currents from this analysis is used to update the reference values of fault passage indicators as mentioned in block 6. The significance of updating the reference values is discussed in section 4.2. Block 2 indicates dynamically changing data, which contains, actual distribution system data such as Loads and Generation profiles, line currents, Bus voltages. From this layer, the actual status of fault passage indicators is known

Block 3 represents load flow simulation platform which is implemented using *pypower* module [13] in python. This platform continuously runs load flow on the static data and provides voltages at each bus and currents in each branch. Network state Identification algorithm runs continuously on dynamic data to identify the state regarding abnormality of the network. Block 5 represents the possible states of the network. Normal working state of a network is represented in *Normal* state. Since, In radial networks, the currents in the branches away from the generator bus are less compared to that of the branches near to it. This demands the setting of different reference values for each FPI on the network. So, during this state, the reference values of fault passage indicators are updated based on the base case network data. When the system indicates faulty state, statuses of FPIs from the dynamic data is considered and it is given as input to Fault location algorithm mentioned in block 9 and discussed in section 5 to find the location of fault. After identifying the fault location, the commands for isolating the fault are executed which is to isolate the faulty part, during which the system will be in isolated state.After isolating rest of the network form the faulty

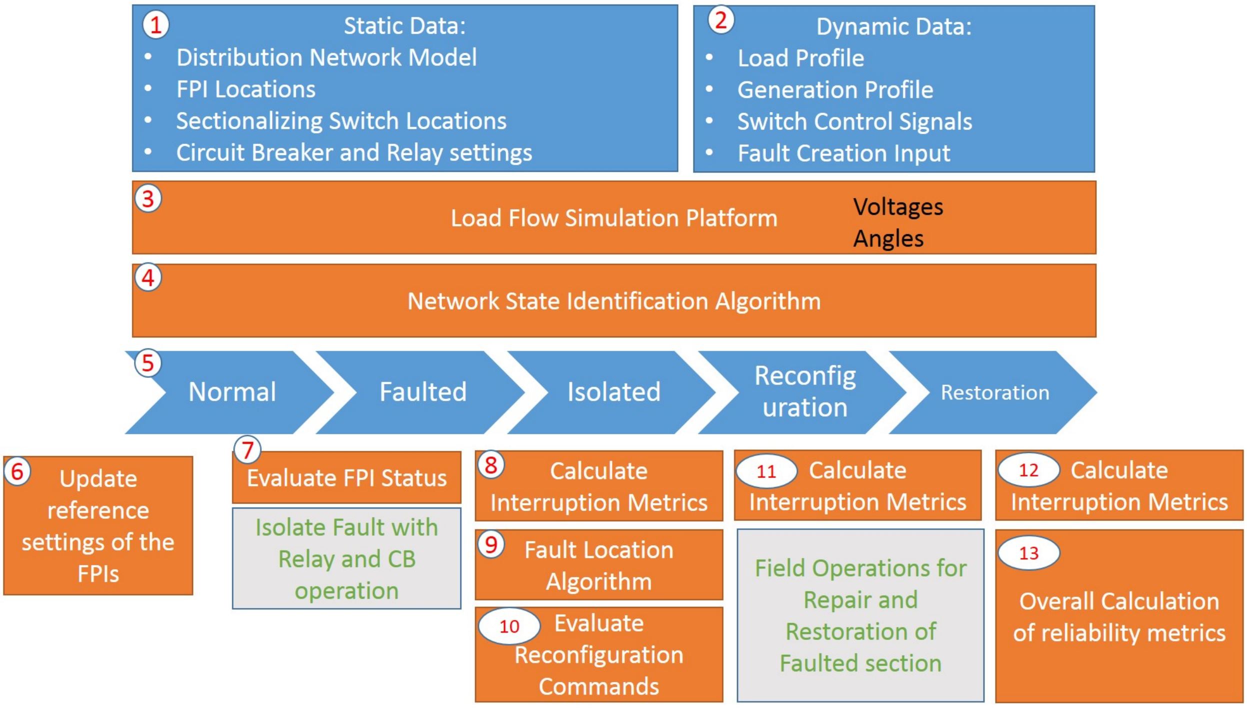

Figure 3.1: Architecture of OMS with Fault Passage Indicator.

part, works are carried out to restore the network to it's normal state. Meanwhile, based on the location of fault, identified by the fault location algorithm, the network will be reconfigured so as to supply maximum number of customers through an alternate path until the original network is restored to normalcy

3.2 Fault Passage Indication

Even though electrical distribution network design, construction and operation is robust, occurrence of fault is inevitable at some point of time. The fault occurs because of many reasons like weather conditions, aging effects etc [14]. In most of the networks, fault means that either customer supply is lost or state of network is disturbed. This section explains how the faulty section can be identified remotely in a radial distribution system.

3.2.1 What is Fault Passage Indicator (FPI)

"The fault passage indicator (shown in Fig 3.2 [15]) is a device that can be located on the over head lines at some strategic locations on the distribution system that will give an indication if it senses any fault current passing in the line on which it is located" FPI has the capability of differentiating the fault current from load current flowing through the feeder. FPI is generally associated with a light, which lights up when a fault current is passed through it. The simplest and most common fault passage indicator is the earth fault passage indicator which looks for a zero sequence (earth fault) current exceeding the predefined reference value. For example, if 50 amps current flows for 50 milliseconds through fpi, fpi lights up the local indication light to indicate that the fault current

Figure 3.2: Fault Passage Indicator.

is flowing through that particular location. FPI is capable of detecting the all types of faults like phase-to-phase faults etc as it is located on each phase of the network.

The earliest types of fault circuit indicators (FCI) used to be simple over current devices that employs the magnetic flux field of a high magnitude to mechanically move or rotate a flag to indicate the passage of the fault current. These devices required resetting manually after every operation, and if reset properly after every incident, did reduce troubleshooting time significantly [16]. Fault indicators continued to grow at a faster rate as the importance of reliability of the power supplied increased. Public Utility Commissions and customers began pressurizing the power companies to provide power with better quality. Indices such as "System Average Interruption Duration Index (SAIDI)," "Customer Average Interruption Index (CAIDI)," and other indices are mandate measures for power companies [11]. Reducing outage times by faster identification of trouble location was one method to achieve a reduction in overall outage duration. Fault indicator application on a widespread basis was recognized as the most economical and expedient means to reduce outage times. This solution provided a proactive method to address the concerns of Regulating commissions. Estimates of outage reduction capability of fault indicators ranged from 25 % to 50%. Empirical public data is scarce, but a review of one utilities success is available as published in T&D magazine in August 1995. With the advent of microprocessor and communication technologies, FCIs are added with storage feature. The addition of this feature to standard FCI products further enhances the ability of fault indicators to adapt to circuit load parameters wherever they are to be installed. Further developments for the integration of fault indicators into smart automated distribution systems is progressing at a number of companies on a trial basis but is difficult to justify economically on a stand alone basis. The fact remains that troubleshooting personnel must still patrol the faulty circuits during outages. The instantaneous notification via communication systems of the fault progression on a circuit can be beneficial if remote reconfiguration is available. [3]

FPI helps in improving the reliability of the system as it will improve the system average interruption duration index (SAIDI) and customer average interruption duration index (CAIDI), also helps in reduction of the energy not supplied (ENS). [17]. Fault Indicators can be used as a preventive tool in order to reduce costs to utilities and their customers, also it had an advantage of using with and without distribution automation [18, 19].

3.3 Working of Fault Passage Indicator

Given a situation without FPI, location of fault is a tedious process, as the repair crew might travel the whole area where the power is lost, as a result more time is spent on restoring the network. FPI will indicate the location of fault, so the operating crew can avoid traveling and reach to the location directly, so that power is restored comparatively earlier [20]. Thus providing the time and economic benefits to the utility.

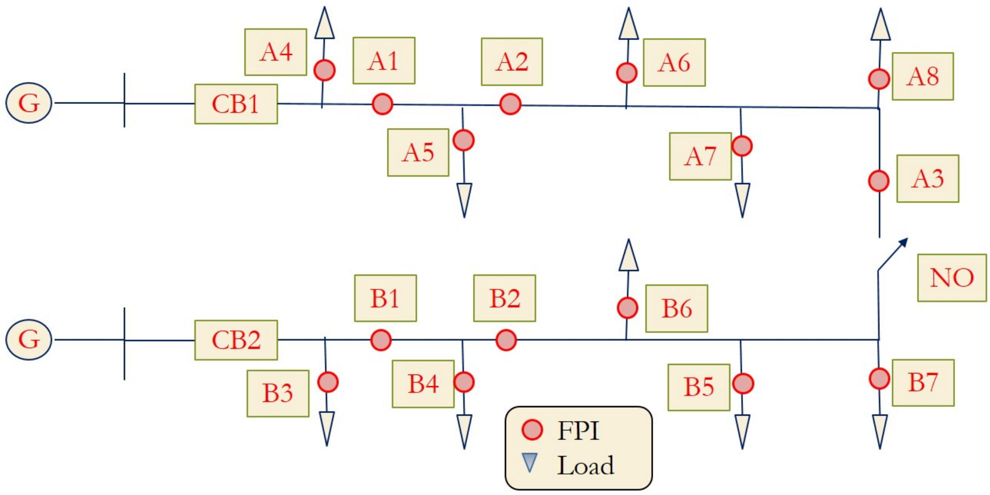

Figure 3.3: Sample Radial Distribution network.

Most of the distribution networks are radial with one source of supply or multiple sources of supply. Fig. 5.3 shows two radial networks connected at ends with a normally open tie line switch. Supposing a fault occurs at B3, circuit breaker CB2 would trip, as a result supply is lost to B4, B5, B6, B1, B2 and B7. Generally, FPIs are not directional, they will indicate only whether the fault current is passed through it or not. When the fault is initiated, the operator should check for the circuit breakers tripped and fault indicators at every level. Here in this case CB2 will trip and FPI at B3 will indicate the fault. The operator will now know the exact fault location. However consider a case where in normally open (NO) switch is in closed condition and both the sources are supplying the power to the loads. In this case, if a fault is occurred and FPI is indicating the fault. Here in this case the operator doesn't know which source is the reason for the fault current because of non directional indication of the fault. This type of scenario occurs when there is a fault between two substations. Therefore directional FPIs might be required for closed loop/meshed networks. By which they can indicate whether the fault is upstream or downstream when viewed from the location of the FPI.

3.4 Necessity of FLISR

Say the fault is created at t = 0 instant as seen in Fig. 3.4 [21]. The time taken to generate report, traveling time and repair time could be same with or without automated fault location identification. But, the patrol time will reduce by considerable extent. Thereby almost immediately after identification of fault location, the algorithms for network reconfiguration will generate switch operations for restoring supply to maximum possible customers. Hence reducing both patrolling time and time required to execute and validate switching commands manually.

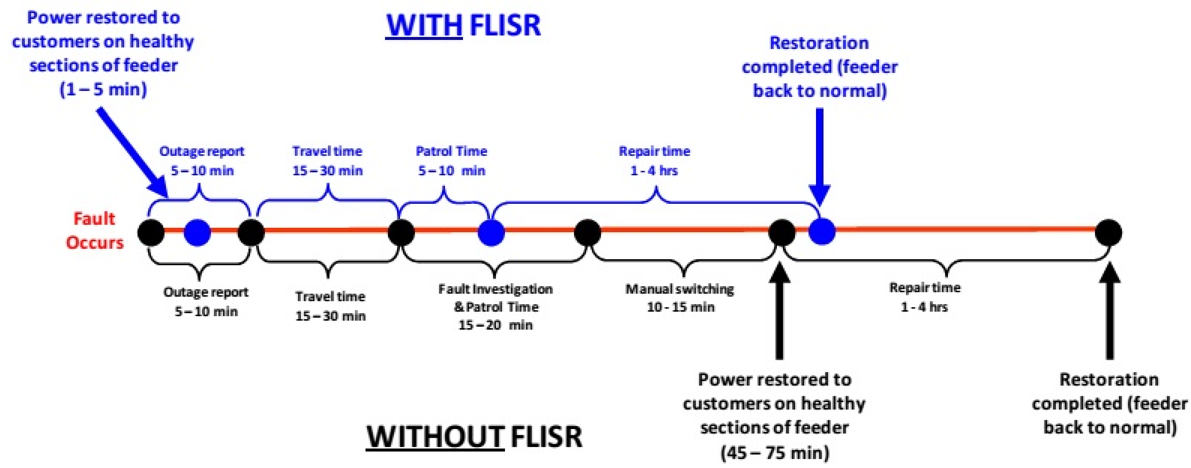

Figure 3.4: Time Line Diagram Explaining Importance Fault Location Algorithm.

Current use of fault passage indicators is, either the control center is aware of the distribution of the network and location of fault passage indicators and personnel in the control center observe the status of FPIs and point out the location or a replica of the original network is created in control centers with led lights as fault passage indicators to observe the fault location. In either of these methods, to reconfigure the network, the personnel has to check for the location of fault and then should run reconfiguration and/or restoration. Using the fast fault location algorithm, will overcome the afore mentioned problems and this *fault location* given by the Fault Location algorithm is then given as input to the program in block 10 of 3.1 which evaluates and set the reconfiguration commands.

In this chapter, the architecture of OMS with FPI is presented explaining the principle and working of Fault Passage Indicator and also the importance of FPI is discussed. The above mentioned architecture implementation on an IEEE 69 bus radial network is presented in chapter 4, working of OMS with fault passage indicators is demonstrated and the necessity of setting reference values for FPIs are also discussed.

Chapter 4

Load Flow Simulation Platform

4.1 Case Study: IEEE 69 bus system

The algorithm presented in section 3.1 is implemented on IEEE 69 bus radial system [22] shown in Fig. 4.1. It consists of 69 buses and 73 branches, of which, branches 69 to 73 are normally open tie line connectors, network data is added in appendix **??**. Under any fault or other intended operation conditions, so as to reconfigure the network, these normally open switches are operated. Operation of these normally open switches should also consider that the network should remain radial network. Fault Passage Indicators are placed on the over head lines at each junction of the radial network as shown in the Fig. 4.1.

4.2 Base Case Study

The block 1 which consists of the static data is loaded with IEEE 69 bus network model. Load flow algorithm is then run on the static network model and this calculates the line currents as shown in the Fig. 4.2 . As seen in the figure, the currents in each branch is different, this makes the setting the reference values for fault passage indicators different for different locations. For example, if a reference value of 20 amps is chosen, currents in branches 3-4, 4-5 and 8-51 will be higher than the reference value. This will trigger the fault passage indicator to indicate fault even if there is no fault. So in order to avoid this problem, the line currents obtained from the load flow analysis is multiplied by a factor and is updated as the reference values of the FPIs. Here, the reference value of each FPI is different from others and it depends on load.

4.3 Case Study after Creating Fault

Dynamic data from block 2 mentioned in architecture of OMS, which resembles the real time distribution network is loaded and run continuously. This block outputs the line currents of each branches, statuses of each fault passage indicators and statuses of all switches. Based on the status of FPIs, the state of the system can be differentiated from Normal state and Fault state. The system is said to be in fault state, if any of the FPIs indicate fault. During which, the *fault location algorithm* mentioned in the section 5 and represented in block 9 of architecture is executed on the statuses

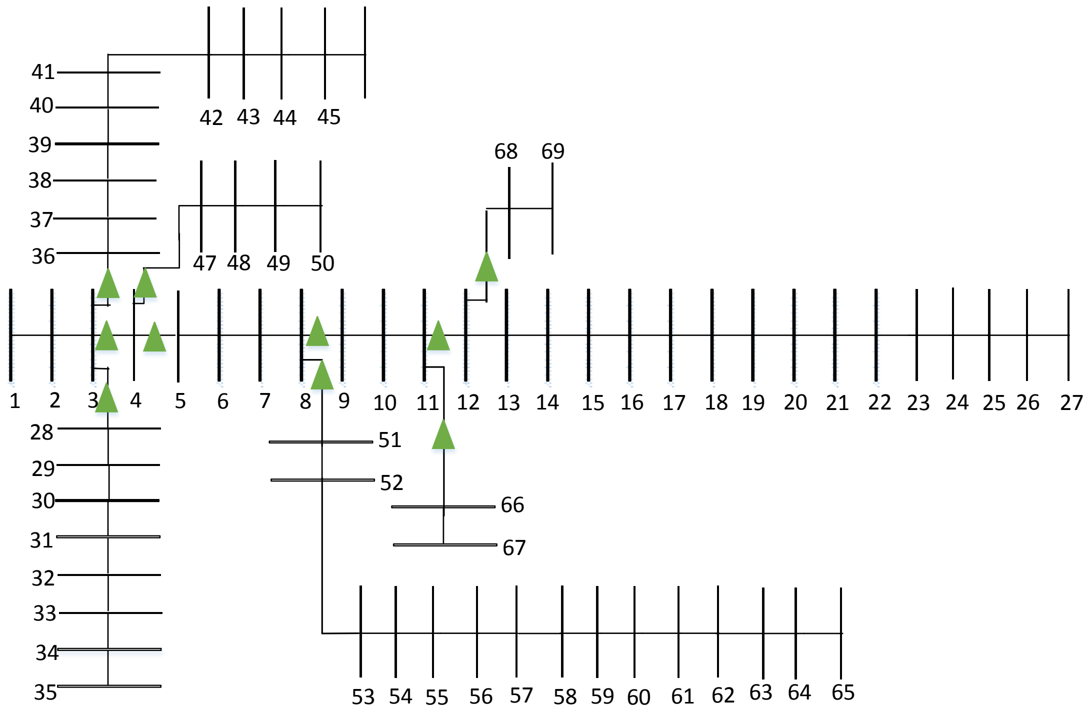

Figure 4.1: IEEE 69 Bus Radial Network.

of FPIs present in the network, given by the dynamic model, this algorithm will output the *Fault Location*.

For the purpose of illustration, a fault is created at bus number 19 in the system by changing the dynamic data of the network at time instant 5 and is cleared at 7. Line currents of the network on which FPIs are installed are shown in the Fig. 4.4 and the bus voltage during fault is shown in Fig. 4.5. From this figure, it can be noticed that the branches between nodes 3-4, 4-5, 8-9, 11-12, 12-13 observe high currents in this duration. In this state, the FPIs located on the respective branches change it's status to 1 (indicating fault) and this change in the status of fault passage indicators indicate the system is in *Fault* state.

After the creation of fault at bus number 19, the network looks like as in Fig. 4.3, this indicates that the fault should be downstream to the last fault indicating fault passage indicator. For the completeness of algorithm, the fault isolation and reconfiguration algorithm could isolate branches between nodes 18-19 and 19-20 and tie line switch number 70 between nodes 13 and 21 can be closed. In this set of operations, only loads at bus 19 are affected. However, these set of operations are not unique. For example the branches 71 and 73 can be closed, between nodes 46-15 and 65-27 respectively and opening the branches between 11-12 and 19-20. From these sets of various

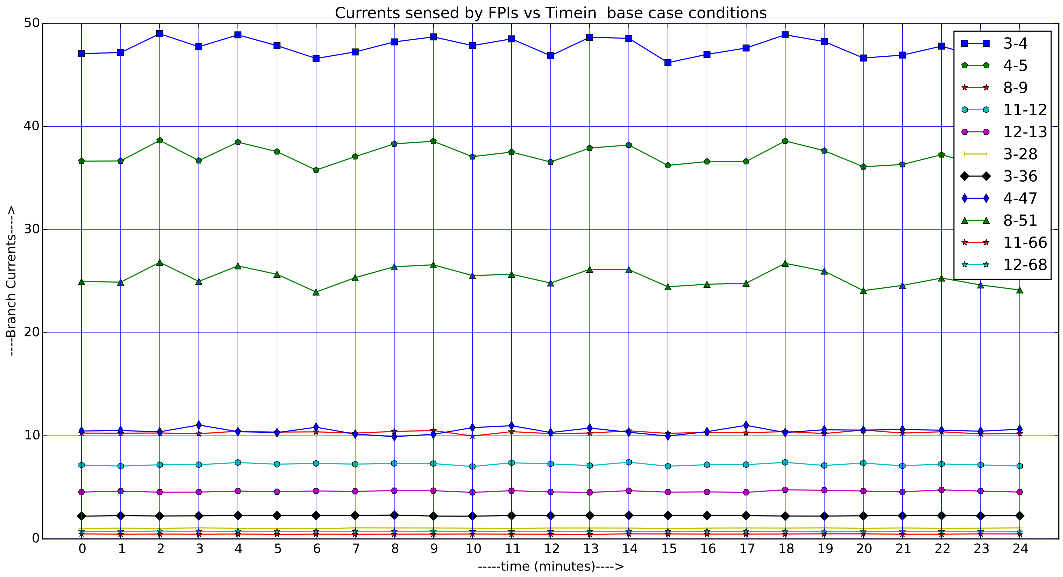

Figure 4.2: Base Case Currents

possibilities, the set which is best suited under the constraints of, the system is to be radial, maximum possible number of customers are to be restored, power flow losses should be minimum, number of switching operations to reconfigure the network is to minimum, is selected and that set of operations is implemented to reconfigure the network [23, 24, 25]. During this entire state of operations, the system is said to be in *Reconfiguration* state. During this process, workforce management module in OMS dispatches the crew to restore normalcy by repairing the faulty section.

In this chapter, load flow simulation platform implementation on IEEE 69 bus radial network is presented and the importance of setting different references for each FPI is explained. The fault location algorithm mentioned in the above architecture is explained in Chapter 5. Two algorithms with it's implementation on a simple radial network is discussed.

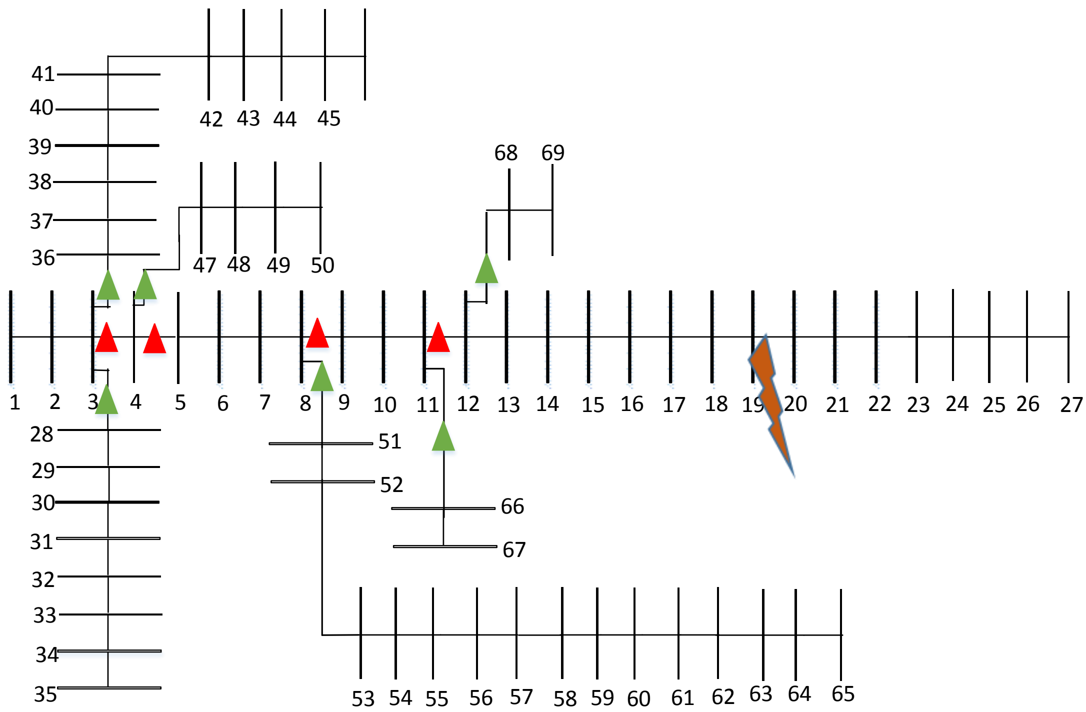

Figure 4.3: Fault at Bus 19 on IEEE 69 Bus Radial Network.

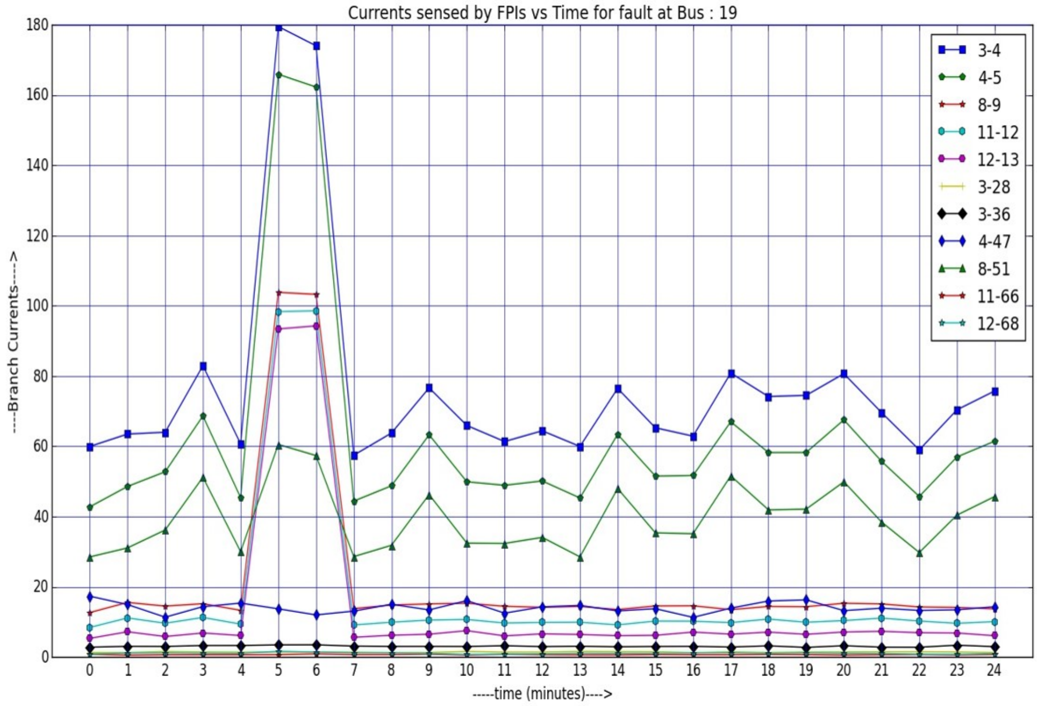

Figure 4.4: Currents sensed by FPIs.

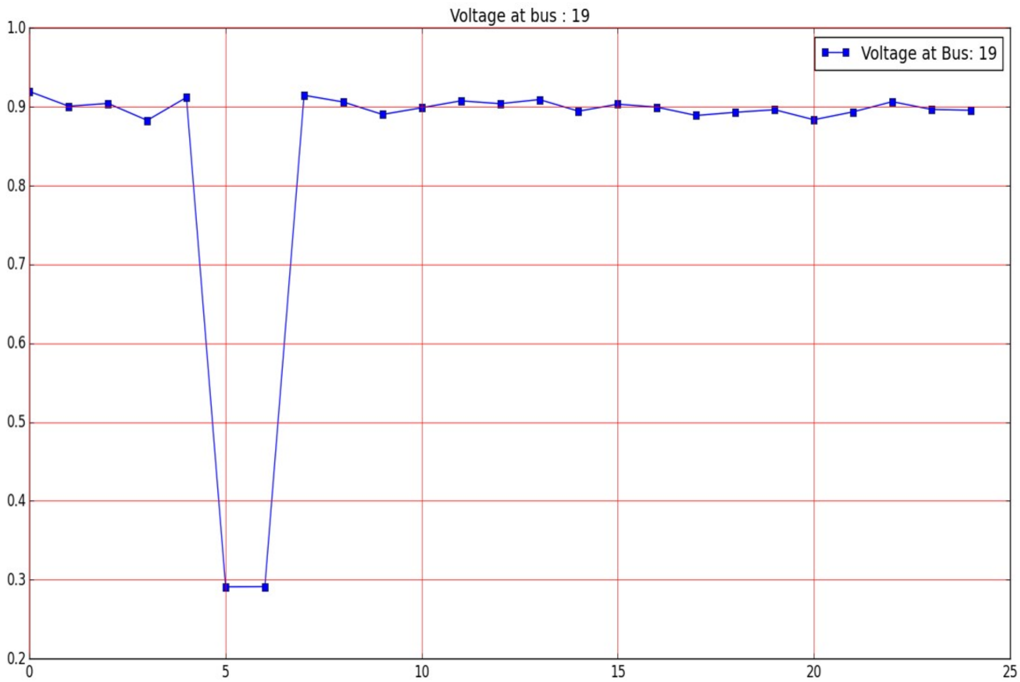

Figure 4.5: Voltage at Bus 19 under Fault.

Chapter 5

Algorithm for Identification of Fault Location

In this chapter, two algorithms, one (*Upstream Algorithm*) which considers only it's upstream devices for identification of fault and the other(*Upstream and Downstream*) which considers all the devices neighboring the device are presented. Implementation, advantages and disadvantages of each method is also discussed.

5.1 Upstream Algorithm.

The algorithm starts with radial network data which contains the status of circuit breakers and fault passage indicators. The algorithm takes the input as pairs of devices like (FPI, Upstream FPI) and when the fault is initiated the algorithm processes the status of FPI by following the steps as shown in Fig. 5.1. After all steps in the flow chart are executed, output of the algorithm is fault location in terms of the index of FPI. This algorithm is relatively fast, as the algorithm does not proceed sequentially in identifying the fault location. But, as the network configuration changes, the algorithm needs to be updated. To address this issue another algorithm is presented in the following section.

5.2 Upstream and Downstream Algorithm.

The algorithm takes the input as sets of devices like (FPI, Upstream FPIs, Downstream FPIs) and when the fault is initiated, the algorithm processes the status of FPI by following the steps shown in Fig. 5.2. This algorithm initially checks for the circuit breaker status after the fault is initiated. Depending on the circuit breaker status it checks for the corresponding neighboring FPI status and processes according to flow chart. As this algorithm takes all neighboring FPIs into consideration, this algorithm not sensitive to network reconfigurations. However, as the program progresses sequentially it may relatively be slow in identifying faults far down stream.

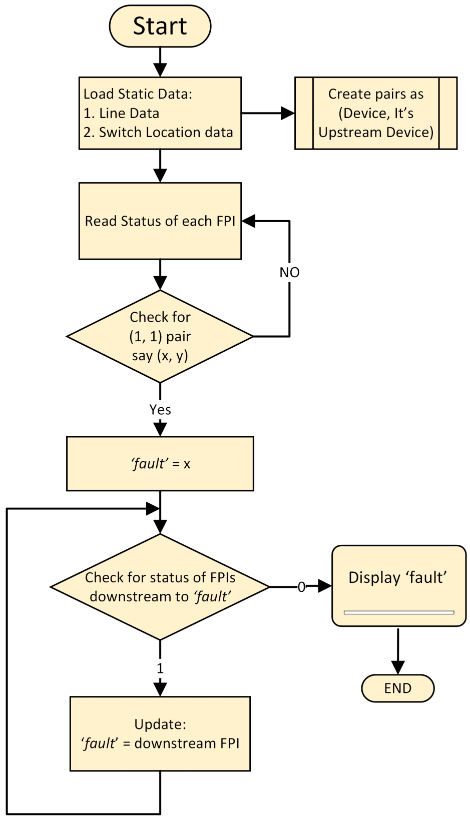

Figure 5.1: Flowchart for fault location using upstream FPIs

5.3 Illustrative Example

Consider a radial network shown in Fig. 5.3, although the figure is presented in section 3.3, it is also presented for the sake of completeness. The feeder is connected through a circuit breaker and FPIs are connected at each branching point along the feeder. The example is used to explain the above mentioned algorithms.

5.3.1 Upstream Algorithm

Initially, a file is created with status of (Circuit Breaker, FPI) which is the input to the algorithm. A fault is created by connecting a fictitious ground between A7 and load point. Now, the algorithm check for all combinations of device pairs and if any device pair is (1,1) then fault = 'first part of the pair' like if we consider the pair as (x,y) then *fault* = 'x' and then it starts checking for the downstream FPIs. If any FPI status in the downstream is ON, then update the *fault* variable. This process repeats until all the downstream FPI's status are checked. After completion of this process the output is *fault*=A7.

5.3.2 Upstream and Downstream Algorithm

Like in the previous algorithm, In this algorithm also a file is created with sets of FPI with its upstream and downstream FPIs. For the considered example, one of the sets is (A1, CB1, A4, A5,

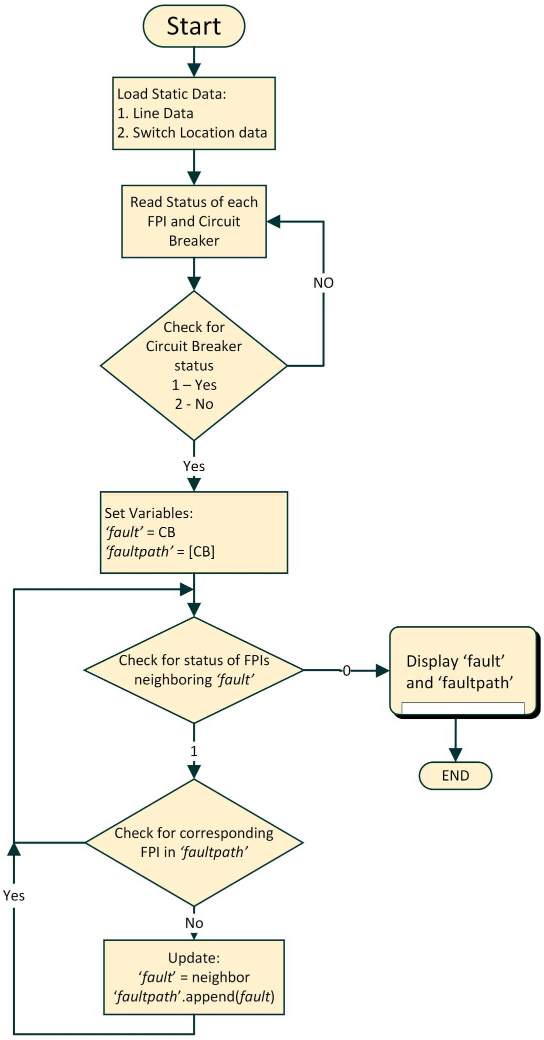

Figure 5.2: Flowchart for Upstream and Downstream fault location

A2). Here, in this pair, A1 is the device and CB1 is the Upstream device and the remaining are the downstream FPIs before reconfiguration. Consider a fault is created by connecting a fictitious ground between A7 and load point. In the next step, check for the circuit breaker status and if the circuit breaker status is '1' then the *fault* variable is equal to CB and the first element of the *faultpath* array is set to CB. For the considered example *fault* = CB1 and *faultpath* = (CB1, A1). A1 is appended to the *faultpath* since the status of A1 is ON and it is not present in the *faultpath* before this step. Now *fault* = A1 and check for the neighboring devices. Repeat the process until all the neighboring FPIs are verified. Finally, the output is *fault*=A7. and *faultpath*=(CB1, A1, A2, A7).

5.4 Implementation of Fault Location Algorithm

The two algorithms are implemented for a radial network as shown in the Fig. 5.3 [26]. The implementation is carried in a three layer process as shown in the Fig. 5.4. The first layer is the

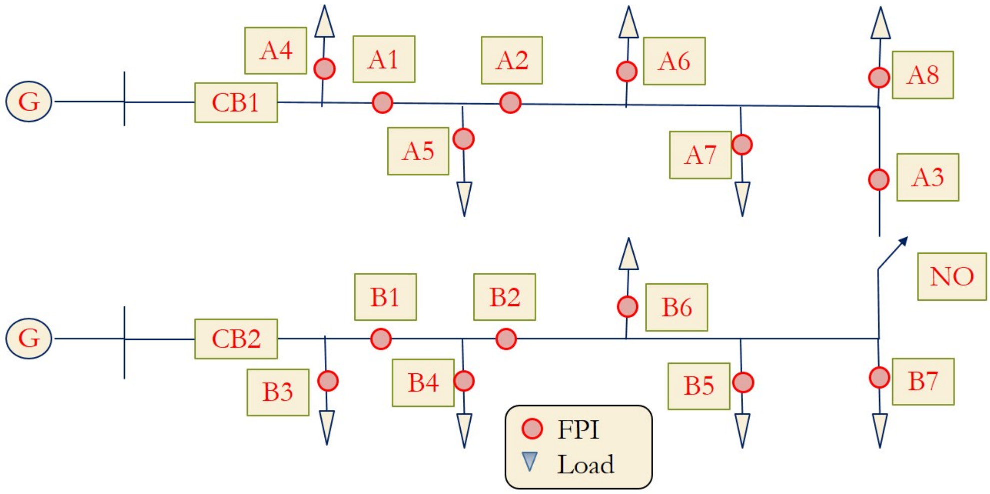

Figure 5.3: Radial Distribution network

input layer which contains the text files as switch data as the input to the second layer which is a processing layer. Switch data contains two columns, in which first column device id and the second column is the array of the neighboring devices corresponding to device id. The text file doesn't change till the network is reconfigured. The second layer consists of FPIDemo python program which implements the above mentioned algorithm. And finally in the third layer the output is displayed. The results obtained by considering different faults are tabulated below.

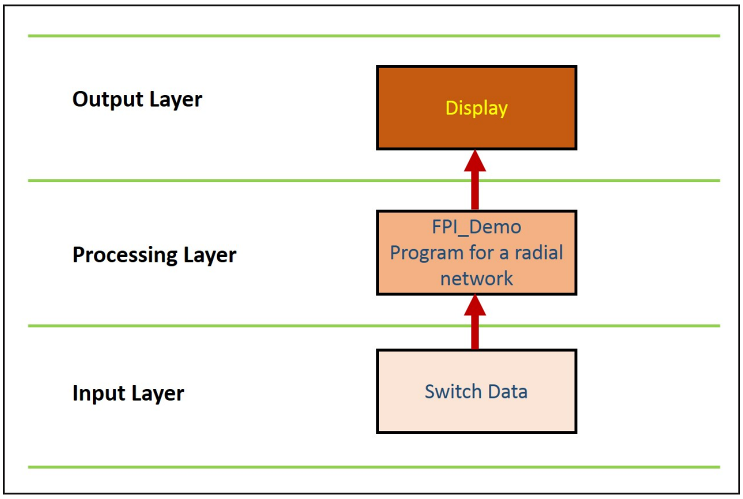

Figure 5.4: Implementation of Fault Location Algorithm.

The results obtained by implementation of the Upstream algorithm are shown in table. 5.1. The first column indicates the fault created at load point by connecting a fictitious ground and second column index or the FPI that is activated for the fault. Here a fault is created at a location near to A8 and A1 individually, and the program is executed for both the conditions and the result shows the index of the fault passage indicator (FPI). Similarly with the same fault location Upstream and Downstream algorithm is implemented then the result obtained is shown in the following table. 5.2. Here in the table first colum indicates the fault created at load point by connecting a fictious

Table 5.1: Radial Network Result (Upstream Algorithm)

Fault created at	FPI index
At load point after A8	A8
Between A1 and A2	A1

ground, second column indicates the indexing of the fault passage indicator. Third column in the table presents the fault path i.e., the fault current path. This indicates the path to the power companies crew to check for the fault and isolate. If the FPI id contains the geographic location then it would become more easy to isolate the fault. This clearly indicates the reduction in the outage time for the fault.

Table 5.2: Radial Network Result (Upstream and Downstream Algorithm)

Fault created at	FPI index	Fault path
At load point after A8	A8	CB1, A1, A2, A8
Between A1 and A2	A1	CB1, A1

Table 5.3: Re-configured Radial Network Result (Upstream and Downstream Algorithm)

Fault created at	FPI index	Fault path
At load point after A8	A8	CB2, B1, B2, A3, A8
Between A1 and A2	A2	CB2, B1, B2, A3, A2

The network is reconfigured by turning ON Normally Open (NO) switch in the Fig. 5.3 and CB1 is turned OFF. The Upstream and Downstream algorithm is implemented for the reconfigured algorithm and the results obtained, are shown in the table. 5.3. The columns in this table are same as previous table. It is observed from the second row of the table, same fault is created by between A1 and A2, but the fault and fault path are changed when the circuit is reconfigured. This algorithm provides the added advantage of reconfiguration. If the circuit is reconfigured remotely by a distribution company through distribution management system (DMS) then FPI indication will work with the presented algorithm. FPI will automatically resets if the fault is isolated remotely.

Chapter 6

Conclusion and Further Work

6.1 Conclusion

Even though the faults in a Power distribution networks are common, identifying the location of fault in such systems has either been time consuming or inaccurate with the conventional techniques. Two algorithms were presented in chapter 5, to identify the location of fault in radial distribution systems. While the upstream algorithm is sensitive to network to reconfigurations, the second algorithm considers the statuses of FPIs both upstream and downstream to it, which makes it non sensitive to network reconfigurations. Load flow simulation platform is presented in chapter 4 which demonstrates the working of Outage Management System. In this simulation platform, load flow is run on the radial network model and this works with the afore mentioned algorithms for identification of fault

6.2 Further Work

Fault location identification has only been introduced in this work, Isolation and network reconfiguration algorithms can be developed to work in-line with the fault location algorithm to develop a complete module in OMS application. Performance analysis of the overall system can be evaluated to measure the effectiveness of the whole algorithm.

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