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# Multi Agent System Based Fault Restoration in Power Distribution Network with Distributed Generations

**O.U. Aliyu[1], G.A. Bakare[2], Y.S. Haruna[3] and Kalli, B. Mai[4]**
[1,2,3]Department of Electrical and Electronic Engineering Technology, Abubakar Tafawa Balewa University Bauchi
[4]Department of Electrical and Electronic Engineering, Ramat Polytechnic Maiduguri

***Abstract***: *This Paper aim to introduce a distributed protection methodology for fault isolation and restoration, with the view to enhance reliability of the network. Faults are identified based on current and voltage measurements and by comparing these values with preset values. The method based on multi-agent concept can be used to isolate the faulty section of a distribution network and restore the healthy section with the distributed generators (DGs) and feeder reconfiguration. In this work four different agents were considered; control agent, feeder agent bus agent and DG/switch agent. Three scenarios were considered in this paper, fault was introduced at Bus 1, Bus 12 and Bus 17. Fault set to cleared in few seconds to restore to normal state. Based on indication of fault, adjacent bus Agents communicate with each other to identify location of fault. A trip signal is then issued to corresponding Breakers in adjacent Bus Agents, isolating the faulty section of line. A case study was carried out to verify suitability of the proposed method. Considering nature of Distribution Network, separate breakers for each Bus considered. The proposed method has been tested on a 34 bus Bulumkutu feeder distribution network in Maiduguri. The simulation results indicate that the distribution network was restored within 0.225 sec after the fault. This indicates that the proposed MAS can provide the post-fault network restoration service with a suitable switching operation in a timely manner, hence increasing the reliability of electrical distribution network.*

***Keywords***: *Feeder, Distribution, Generation, Restoration, Power*

## 1.0 Introduction

Faults and outages are unavoidable in distribution networks. Thus, both the faulted area and some unfaulted areas may lose power supply. The system reconfigurations are meant to restore as many loads as possible by transferring de-energized loads in the out-of-service areas to other backup supporting feeders/laterals. Power system distribution automation (MAS) results in a fast response to operation problems, reduces operator intervention and human error, and decreases the duration of outages. The reliability of energy supplies is one of the major goals of the power industry. Eliminating power disruptions allows network operators to reduce economic losses and improve customer satisfaction. The intensive development of smart grids is characterized by a high level of comprehensive automation and monitoring of the distribution grid. It can result in fewer and shorter outages and an increase in grid efficiency, reliability, and security. one of the possibilities arising from these conditions is FLISR technologies and systems (Pawel *et al.*,2022).

The general understanding is that the MAS is the concept of modernizing the electric grid. Through the addition of advanced technologies, the MAS becomes more flexible, interactive, and has a self-healing capability. So, smart grid can intelligently integrate the actions of all connected participants to deliver sustainable, economic, and secure electricity supply. A multiagent system greatly reduces the need for human intervention as it can make autonomous and intelligent decisions based on the system variables and the agents can act to implement the decision at the physical layer level through intelligent electronic devices (IEDs) in the distribution system (Indhumathi and Joy Vasantha,2019).In recent years Power quality has, become more and more of a serious concern for utility customers. Power companies have to improve service in order to retain customers in the deregulated market. The purpose of the MAS system is to develop a service restoration plan for faults to assist distribution system dispatchers with restoring power service of outaged customers. Automation of the distribution system can enable much faster restoration of supply to downstream healthy zones by opening sectionalizes of the faulty sections and closing the tie switches from appropriate restorative backup feeders (Kazemi, *et al.*, 2009).

Therefore, distribution automation systems in (MAS) have been implemented at Yola Electricity Distribution Company (YEDC) distribution network as an intelligent way to enhance the reliability and operation efficiency of distribution systems. Fault Detection, Isolation and Restoration (FDIR) is considered to be most important aspect of multiagent systems. The aim is to apply multi agent system to recognize faults, isolate the faulty section and restore power to the healthy section with available back up. The work is limited to 11kV, 34 buses Bulumkutu feeder in Maiduguri.When fault occurs in a distribution network, it takes time to detect the location of the Fault and this delay may lead to major faults. When the location is finally known, isolating the fault is another challenge. However usually the entire network is shut down in order to isolate a minor fault. This influences negatively on the provider as well as the consumers. When a fault occurs in the Distribution network, corresponding reclosers will lock out and the fault-free zones will be out of service also. It is important for the electric utility companies to restore loads in the out-of-service areas as soon as possible. When conventional operation is used, there is need to investigate the fault Location by conducting manual switching approach to isolate the faulted area and restore service to customers located on healthy feeder portion. In such a situation customer will call to inform the problem and the maintenance crew will swing into action for fault location or switching operations to restore service. When FLISR is used, power is rapidly restored to customers located on healthy zone of a feeder. The time required for fault location and isolation will be reduced FLISR systems. Furthermore, if FLIR switching and protective devices are monitored in real-time then there is no need to wait for customer calls to dispatch crews. Thus, in addition to its reliability benefits FLISR also has a direct impact on reducing operators and crews' assignment.

## 2.0 Literature Review

In an electrical power system made of generation, transmission and distribution, there is a larger possibility that faults will occur on power lines. This is true because power lines are widely spread, have great lengths and pass through various types of terrains and environment with different characteristics. Other condition such as high wind, rainfall, landslides, erosion and animals, falling trees and vandalism by humans lead to greater occurrence of fault on power lines. Faults that occur on power line ranges from short circuit faults and open circuit fault or loss of phase fault. Open circuit fault occurs when a power line is ruptured and it can no longer deliver power to a load. Apart from ruptured lines, open circuit faults can still occur due to lose connections on terminals and contacts of circuit breakers or isolator that fail to close or make proper connection (Siu and Kwong, 2017). This action of not giving much consideration to open circuit faults in a distribution network has made final users of electricity to be serviced with power that is below regulated specifications over a long period of time (Chrysogonus, *et al.*, 2020).

In Tebekaemi and Wijesekera (2019), a communication model for autonomous and decentralized control of an intelligent network. It is expected that this network will be able to protect itself and recover from the faulty condition. The proposed decentralized Multi Agent System allows the intelligent reconfiguration of the distribution network in an autonomous way. The work did not explore the use of distributed generators as alternative source when the grid fails. In Naik and Yadav (2018), a fuzzy inference system has been used to develop the fault detector and classifier of high impedance faults on the radial distribution system. They did not take into account the problem of network restoration and minimizing the switching time. Data-driven strategy has been proposed to detect faults and identify their locations. The study was conducted on the distribution systems with distributed energy resource. However, the faulty buses were not identified and the number of switching operation was not considered in the research. Peter et al, (2022) presents smart fault monitoring technologies in distribution systems by using Internet of Things (IoT). With IoT integration effectively reduces the power outage experienced by customers in the healthy section of the faulted feeder from approximately 1 h to less than 5 min which is too large, but with MAS arrangement the time will be reduce to less one minute.A new protection scheme using agents has been proposed for distribution systems in (Rahman et al, 2019), in which the agents interact with each other by exchanging their local information. Distributed generators were not used as backup in case of total feeder failure, in which case it can be used to restore power to the healthy section.

In Shirazi, *et al.,* (2019) smart grid solutions can be used to remotely monitor power equipment to total system failure.Various studies have been carried out to solve the service restoration problem through centralized o schemes which read the whole system data and process. The implementation of centralized control in large size systems is quite challenging, owing to the large amount of data to be processed and the huge number of control and decision variables determined by the central controller. In such systems, the centralized approaches are subject to whole system collapses (Asadi, *et al.*,2020). Decentralized approaches are introduced to solve the centralized scheme limitations and to focus mostly on parallelizing the solution of the self-healing problem. In other words, in the decentralized restoration approach, the control and protection actions are taken within each distribution system or primary substation individually; then, the entire system performance results from the combination of these individual behaviors (Zidan, *et al.*,2017). Multi agent systems (MAS)-based control schemes have emerged as a liable and robust technology for achieving decentralized, distributed control in different applications, ranging from small systems to large ones (Hafez. *et al.*,2018). MAS has been studied to fulfill distribution systems needs for fault diagnosis and service restoration and monitoring as introduced (Al-hinai, *et al.*,2021). however, the researcher used feeder configuration for restoration.

An automatic fault isolation and restoration solution for distribution systems using JADE-based multi-agents is introduced (Chellaswamy and Rani, 2019). According to Martins and Batista (2020) a strategic plan for energy restoration is proposed aiming at maximizing the number of loads restored through switching. Given priority to loads will only restore few customers, therefore in this work priority was given to restore large number of Buses so that more customers will be restored.The study carried out by El-Sharafy and Farag (2017) suggests for an environment comprising multiples agents, a process for distributed restoration in the network, considering a solution based on intelligent distribution on networks. However, the researcher did not examine the actions of circuit breakers during and after the fault. According to Jain et al. (2018) developed an algorithm to automatically perform the restoration of distribution system services, which have distributed energy resources, but the researcher did not include fault location, which is also another advantages of this work. Sekhavatmanesh, *et* *al*., (2018) implements a multi-agent concept in the smart grid and applies it to create a structure capable of recovering itself. According to tests carried out on distribution network, with 70 buses, modeled in the MATLAB the result shows that there is proper restoration of the network. However, the number switching and the faulted buses were not discussed. Meskina, *et al.,* (2018) presented research which is capable of detecting failures, carryout isolation and restore the systems which contained multiples agents. Locating the fault position is the limitation of the research. The work in Shirazi and Jadid (2018) proposes a method build on agent perspective to provide restoration in intelligent distribution systems to the services involved in it. It was suggested the use of three agent types as the feeders, zone, and switching, which can provide both communication and cooperating, employing services provided to the customers for which the services are not working properly. The researcher did not used Buses as agent, because using bus agent will give efficient system performance. Similarly. The work of Shirazi and Jadid (2019) purposes the method, build on agent perspective, including the distributed generation (DG) agent in the architecture comprised by the feeder, zone, and switching agents. Agents can provide communication and cooperate through services provided to the customers. The researcher did not consider feeder reconfiguration for restoration and this another achievement of this work.

### 2.1 Agent System

An agent is a special software component that has autonomy, provides an interoperable interface to an arbitrary system and behaves like a human agent working for some clients in pursuit of its own agenda. The notion of an agent is meant to be a tool for analyzing systems, not an absolute characterization that divides the world into agents and non-agents', being able to distinguish agent systems from existing systems is important. Again, agent is simply a software entity that is present in an environment and is able to autonomously react to changes in that environment, which must be observable by each intelligent agent. The environment may be a physical system, for example a power system, observable through electronic sensors. Agents may alter their environment by taking control actions through either physical actuators or by storing diagnostic information in a database for others to access. The word agent can be taken as a group of autonomous computer programs that has the ability to cooperate with other agents over network communications. Intelligent autonomous agents have two basic criteria: a knowledge base and message functionality, that is each uses its communication capability to exchange a message or information with the others to achieve their common goal (Shihanur, 2014).

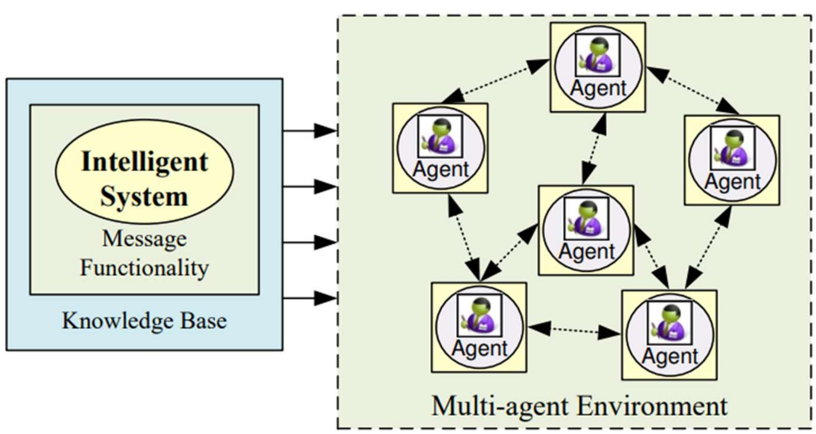


Figure 1: *Intelligent System Wrapped as Multi Agent Framework (Shihanur, 2014)*

**3.0 Material and Method**

The purpose of the Multi Agent system in this work is to develop a fault location, fault isolation and service restoration plan for fault contingencies to assist distribution system dispatchers in restoring power to out of service customers. The service restoration problem in the power distribution system is a multi-objective problem. Service reliability is a key objective that can be achieved by maximizing the number of restored customers. Materials used in this work includes one line diagram of Bulumkutu distribution network,Basic for java tool and Microsoft Visio.

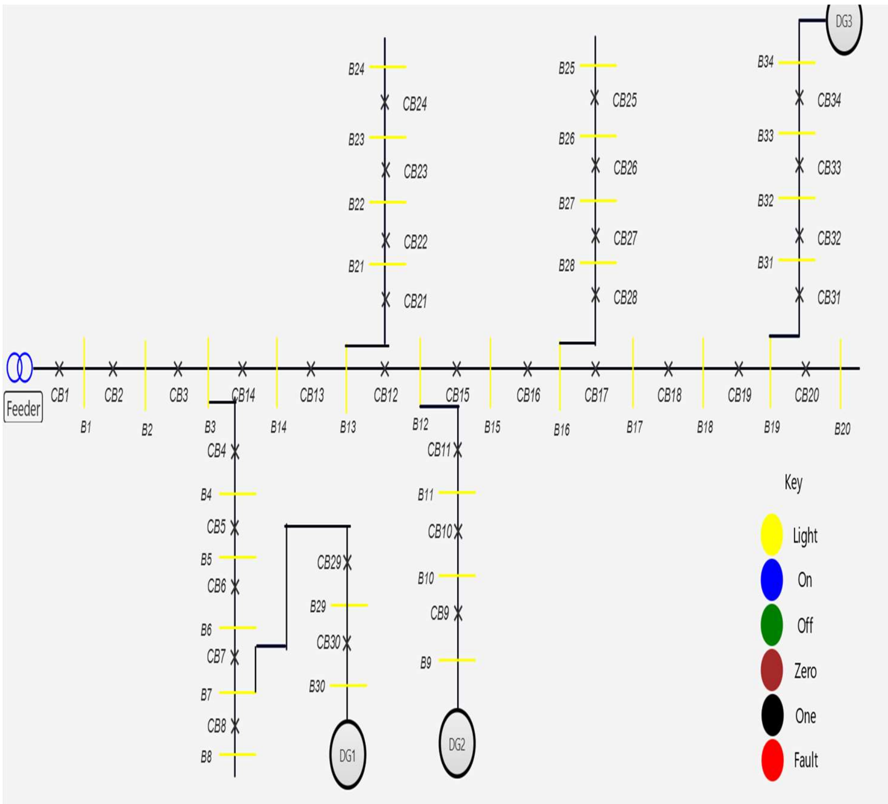


*Figure 2: Bulumkutu 34 Bus Distribution Network*

**3.1 Fault Analysis using Distributed Agent-based**

The most common technologies of fault location, particularly with improvements in smart grid technology, will be the decentralized techniques. The decentralized fault location process is become easy. With increasing intelligent electronic device (IED) as well as other installations in distribution systems and communications developments, which are capable of identifying electric fault and sent the signal to the control room, indicating the fault state. The distributed IEDs can determine the fault location on a local level, alternatively, upper-level systems can use measurements from sensors along the feeder to deduce the damaged line section.

A single fault in power systems can lead to multiple faults and collapse the whole network. Fault analysis comprises detecting faults along with their location and isolating the faulted section from the rest of the network. In the process of isolating a fault, areas that are not faulty may be cut up from the supply, consequently, it is necessary to restore power to them as quickly as possible which needs a system with fast and efficient operation of circuit breakers. An electrical power network should withstand constant increases in demand, while when there is a fault in a power system the performance of the system changes and the autonomous agents in the distributed framework communicate and negotiate with each other to rapidly disconnect the faulted section from the rest of the system, reconnect it when the fault is cleared and provide faster restoration of the network.

That means the agents coordinate the operation of protection equipment by detecting and isolating the fault when its current flow violates the threshold value. Given this knowledge, the agents use their distributed characteristics to simultaneously and efficiently control CB operations to restore service in the power systems. In this work the agents also identify the location of the fault using smart measuring Device (SMD). The types of faults to be analyzed in this work are;

i. Single line to ground fault
ii. Line to line fault
iii. Balanced three phase fault

**3.2 MAS Agents for the work**
Distributed control algorithms for FLSR were developed using MAS having five agents for FLSR process; the Control Agent (CA),feeder Agent (FA), Bus Agent (BA) and Distributed Generation Agent (DGA). A Control Agent is the controller for decision-making based on agent's negotiation and fault localization. The feeder agent is responsible for providing available capacity for the estimated fault duration. DGA support the service restoration after the occurrence of a fault.

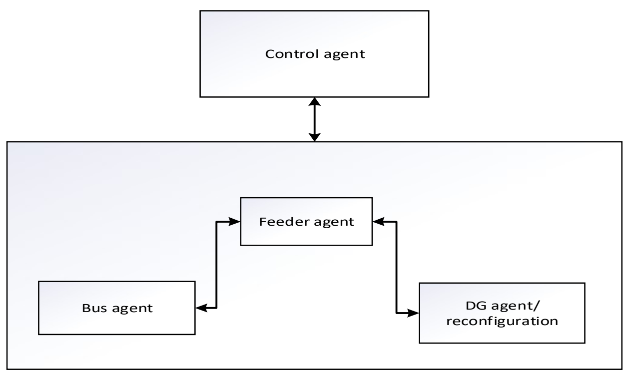


*Figure 3*: *Proposed Multi Agent System*

**i. Fault localisation**
In this study, fault localization was accomplished by finding the fault section. The fault localization uses sensors with circuit breakers installed in the distribution network to determine where the fault has occurred using the distributed method in which different agents collaborate. Sensors with fault detection capability distributed within the network can detect and locate the faults.

**ii. Fault Isolation and Restoration**

In this step, the FISR application issues control commands to open the nearby CB; required to totally isolate the faulted segment of the feeder based upon the fault location examination. The MAS application breaks all control actions until the routine reclosing sequence is accomplished. When these conditions are met, the FLISR application follows the permanent fault to operate.

This is the last step performed by the MAS application after isolation of the faulty segment of the feeder, is to restore the service to the healthy segments of the feeder by employing the normal source of supply to the feeder. After the tripping of a CB interrupts the large short circuit fault current, the boundary line CB of the faulted zone are opened to isolate the faulted section. The CB is then closed to restore the customer power service of the downstream sections. Restoration of Service will be carried out based on load transfer to the DG which can serve the load under fault. The proposed MAS operates the CBs to isolate the fault zones. Then, service restoration mechanism is applied. DG participate in service restoration in that is, if the DG is within the out of service zone, DG could supply the out of service zoon and operate in islanded mode,

**iii. Fault detection**

In a power systems, faults and outages are probable to occur, an effective fault detection and isolation is necessary for proper fault diagnosis. In the proposed distributed agent-based framework, the smart measuring device (SMD) will be used to detect the fault and its location.

The fault is detected from the following relationship among fault current, relay current, and threshold value of relay current. The fault current is given by;

$$I_F = \begin{cases} I_L > I_{TH}; \text{ fault detected} \\ I_L < I_{TH}; \text{ no fault} \end{cases} \quad (1)$$

where $I_f$ is the fault current, $I_L$ is the current flowing through the line and $I_{TH}$ is the threshold value of the line current which is set for each smart measuring device to precisely detect the fault. When there is a possible fault in power systems, the control agent measures its current and compares it with the threshold value of the line current and if it exceeds this threshold value, the control agent confirms the occurrence of a fault and send this information to the neighboring agents which take the necessary steps to send trip signals to the CBs for opening their contacts.

If there are no faults in the system, i.e., the current across the relay is less than the threshold value, normal operation is ensured.

**3.3 Proposed Fault Isolation and Restoration Process**

Figure 5 shows the flow diagram of the proposed FLIR with MAS. As soon as a permanent fault occurs on the electric distribution system the system will fall into the fault state, and circuit breakers will operates to clear the fault. The permanent lock-out of the feeder CB initiates the MAS to change into the Fault Location and Isolation state where all the zones on the faulty feeder would isolate in preparation for service restoration. The control agent will detect the fault and with the help of coordinated agent communications the faulted zone is identified and isolated. Hence the service restoration will be activated, where the fault-free zones that have no power are restored from a DG or with feeder reconfigurations.

For fault isolation the control agents use simple control logic to provide CB status signals, and the tripping logic for opening and closing of CBs can be written as;

$$CB_i = \begin{cases} 0, \text{ for opening} \\ 1, \text{ for closing} \end{cases} \quad (2)$$

Under normal operating conditions, when there are no disturbances in the system, the breaker status signal is set to 1 and 0 for open state. Where CBi is the breaker status signal for the ith breaker and i = 1, 2, ……… n.

During the entire process, the agents perform the following steps to communicate with each other for the proper coordination of protection devices.

i. Inform other agents about the faults.
ii. Confirm the occurrence of the fault with other agents.
iii. Request other agents to trip the breakers.
iv. Accept a proposal for tripping the breakers.
v. Demand other agents to reclose the breakers after clearing the fault.
vi. Accept an offer for reclosing the breakers.

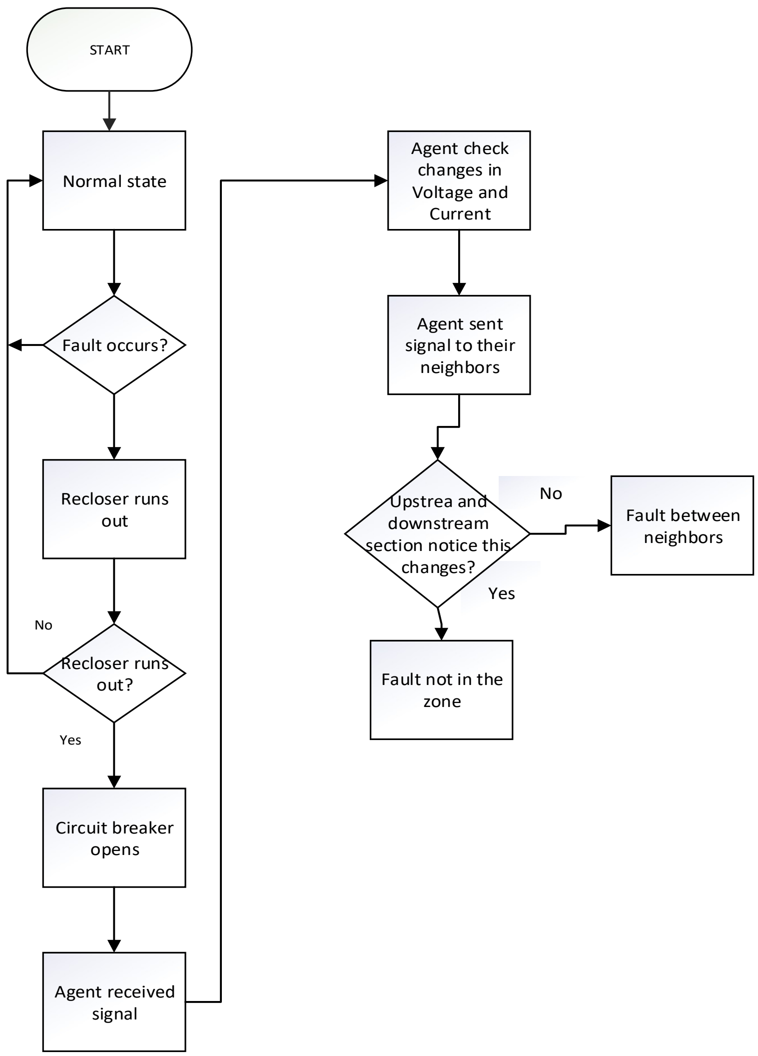


*Figure 4: Flow Chart for Fault Location and Isolation*

### 3.4 MAS Service Restoration

The proposed MAS uses the decentralized concepts to restore power to the healthy sections of the network. Feeder Agent waits until the CB is completely locked-out on a permanent fault and it receives fault isolation confirmation from a down-stream to start the restoration process. And the fault isolation is achieved by coordinated communications among agents. The first step in the restoration process is that the control Agent will sends out command signals to all agents with the exception of faulted section to open their respective CBs. All CBs are opened to isolate the faulted section for Fault occurrence on the feeder. And then closed to restore service to customers that are on the healthy section. The operation rules to perform switching operation for service restoration with feeder reconfiguration is that, the out-of-service area can only be restored by another supporting feeder by closing the normally open tie switch between the two feeders. The supporting feeder and main transformer assumed to be capable of withstanding the load.

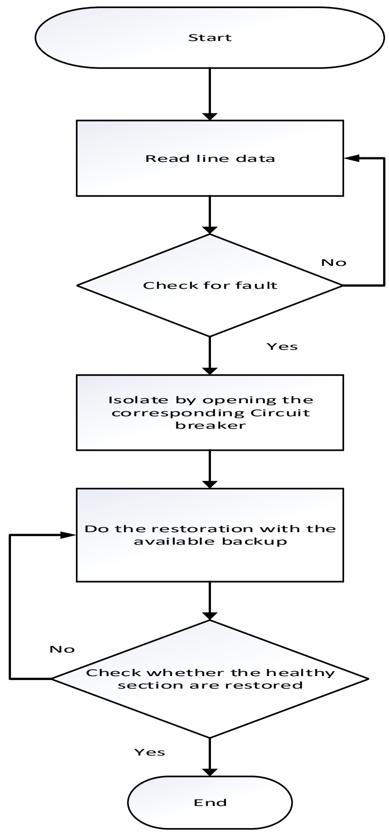


*Figure 5: Flow chart for restoration process*

The steps of this process are listed as follows;

Step 1. Each BA computes its current and voltage continuously and updates it using the information from measuring devices;

Step 2. When there is a fault in the feeder, the feeder circuit breaker (FCB) goes for its three trials and the FA informs its neighboring agent;

Step 3. After CB tripped, the FA notifies its BAs about the trip;

Step 4. The BAs exchange the changes in their drawn current with their FA. This current change is continuously calculated by the BAs before and during the CB trials;

Step 5. The FA studies current for each bus and communicates with CA. If difference between the current of a certain bus and that of the neighboring bus exists, then the fault location is detected within this buses;

Step 6. CA starts communicating the downstream BA of the zone in which the fault is diagnosed to confirm fault isolation by asking the switching devices to open and separate the faulted downstream buses;

Step 7. Then, the upstream service buses are restored by the closure of the CB;

Step 8. Finally, a service restoration algorithm is applied to restore the service of healthy section.

Step 9. The CA will now communicate with DGA/SWA for restoration.

## 4.0 Results

In power distribution systems, faults can occur due to various reasons such as equipment failures, natural disasters, or human errors. Rapid identification, isolation, and restoration of faults are crucial for maintaining reliable and efficient power supply. Traditional fault management methods often rely on centralized control and communication systems, which can be limited in terms of scalability, robustness, and adaptability. To overcome these limitations, multi-agent systems (MAS) have emerged as a promising approach for fault management in distribution systems. This study presents the results and discussions of fault location, isolation, and restoration techniques using multi-agent systems with and without the integration of Distributed Generation (DG).

In this chapter the results of network restoration with DG are compiled. Three scenarios are considered for the case study. Three different scenarios were analyzed, the fault are simulated at Bus 1, 12 and finally at Bus 17. In both cases fault was introduced at 0.1 seconds and cleared at 0.325second to restore to normal state. When there is a fault in the system circuit breaker will trip, the system will start its fault isolation and restoration process following a signal sent to Multi Agent System. Once the fault is detected, MAS will locate isolate the faulted zone and restore power to the unaffected zones and was tested on 34 bus distribution network. The results are presented below.

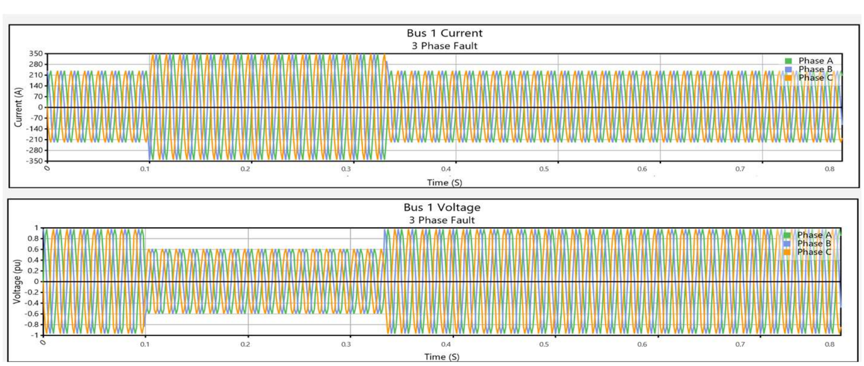


*Figure 6: Three Phase Fault Current and Voltage at Bus 1*

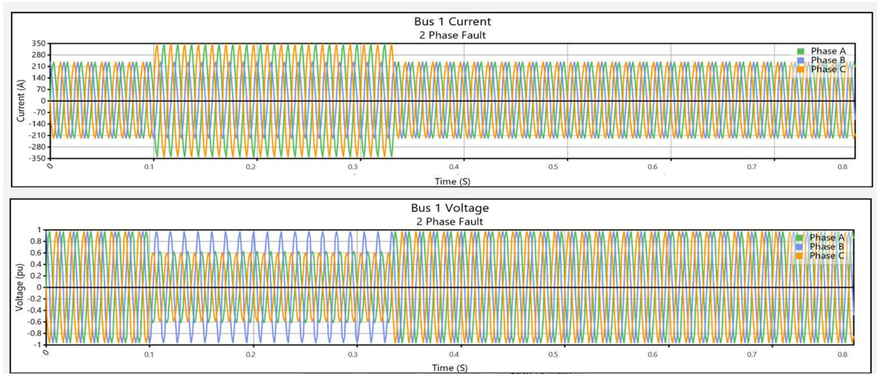


*Figure 7: Double Phase Fault Current and Voltage at Bus 1*

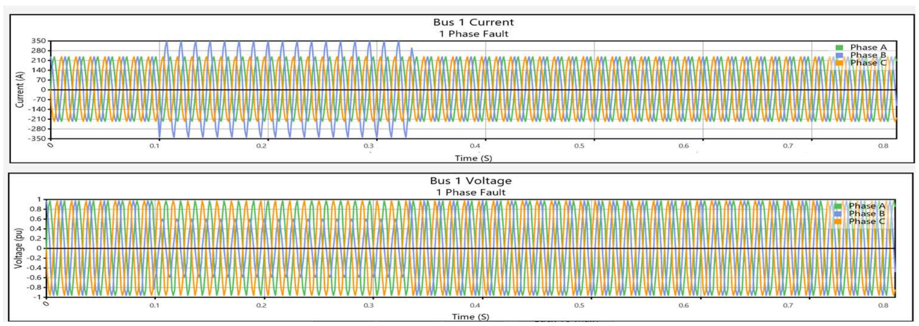


*Figure 8: Single Phase Fault Current and Voltage at Bus 1*

Fault occurred at B1, the circuit breaker CB1 was opened to isolate the fault from the main grid, and power is restored to the healthy section of the network by the DGs connected. In the figures above, the fault occurs near the main grid at Bus1, the grid is isolated by an immediate action of multi agent system and hence secured all loads. In the duration of 0.225 seconds control agents senses the changes and provide the information between the agents and immediately a main breaker is opened due to a control action. The fault occurs at 0.1 seconds and cleared of the fault is at 0.325 second to restore the fault healthy zone. The voltages are in per unit and the current in amperes. In figure 6, a three phase fault occurred, it can be seen that the voltage drops to almost 0.59pu while the current increases to 350A.also in figure 7, a double phase fault occurred on phase A and C. In figure 8, a single phase fault occurred showing all the one phase was faulty. in each case the system was restored by the DGs after the fault was cleared.

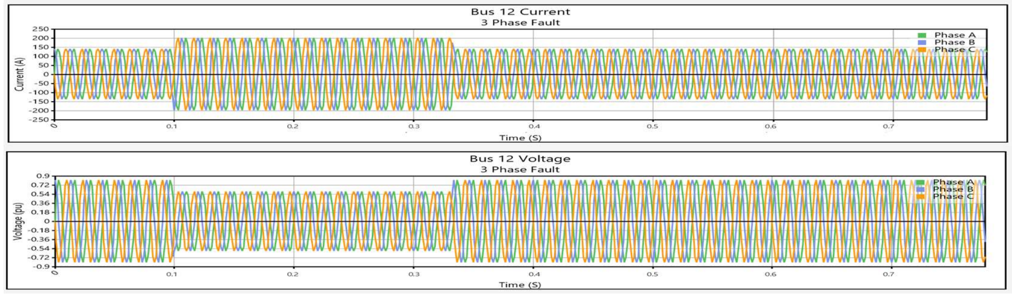


*Figure 9: Three Phase Fault Current and Voltage at Bus 12*

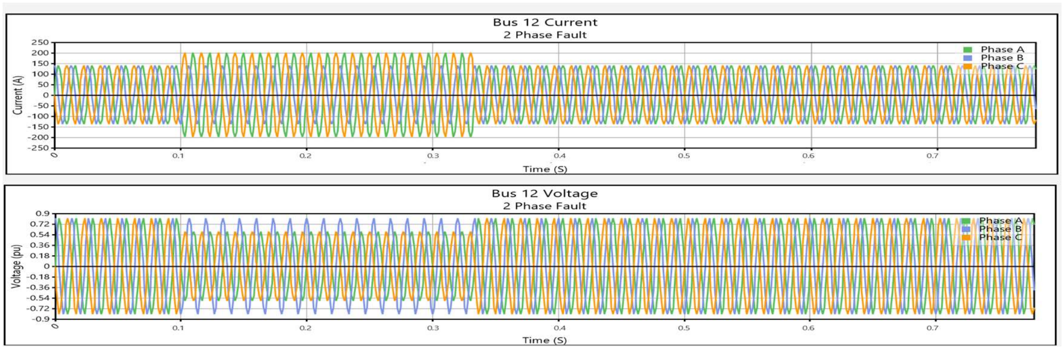


*Figure 10: Double Phase Fault Current and Voltage at Bus 12*

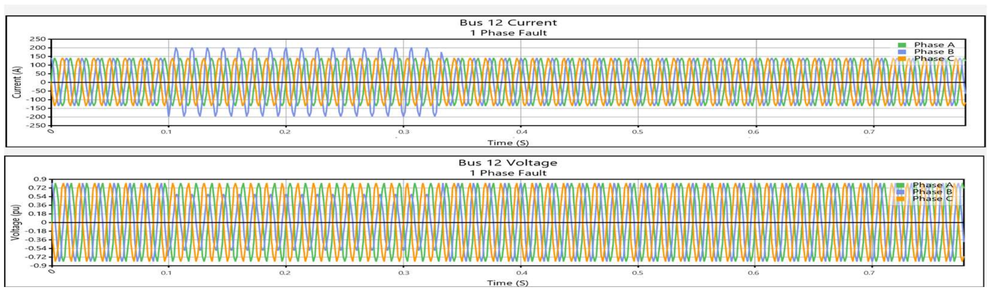


*Figure 11: Single Phase Fault Current and Voltage at Bus 12*

Fault occurred at B12, CB11,CB14,CB13,CB15 and CB16 was opened to isolate the fault and then CB16,CB11 and CB13 was reclosed so that the three distributed generators will restore power to the entire healthy sections separately. From the above figures, the fault occurred at Bus12, the grid is isolated by an immediate action of multi agent system and hence secured all loads. In the duration of 0.225 seconds control agents senses the changes and provide the information between the agents and immediately a main breaker is opened due to a control action. In figure 9, a three-phase fault occurred, also in figure 10, a double phase fault occurred. In figure 11, a Single-phase fault occurred showing only one phase was faulty.

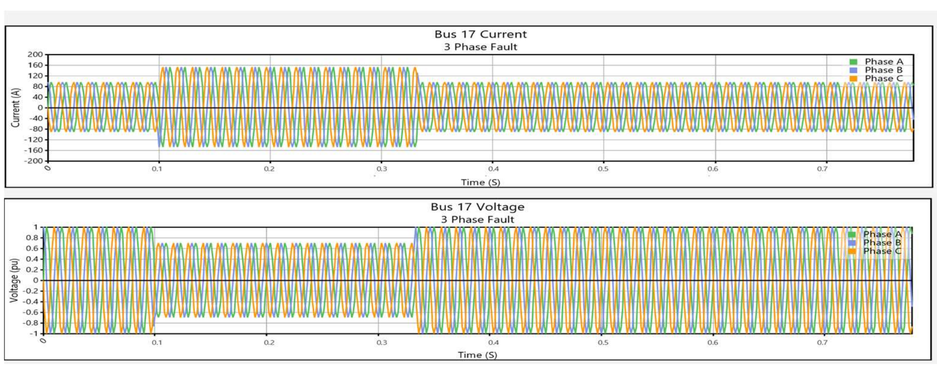


*Figure 12: Three Phase Fault Current and Voltage at Bus 17*

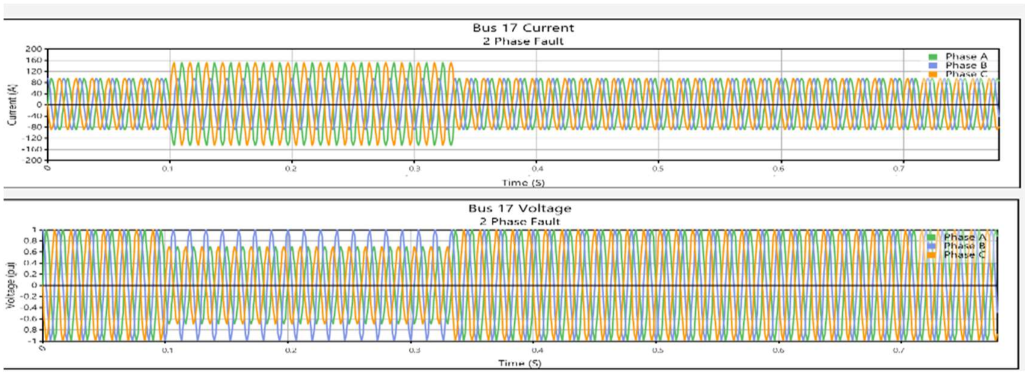


*Figure 13: Double  Phase Fault Current and Voltage at Bus 17*

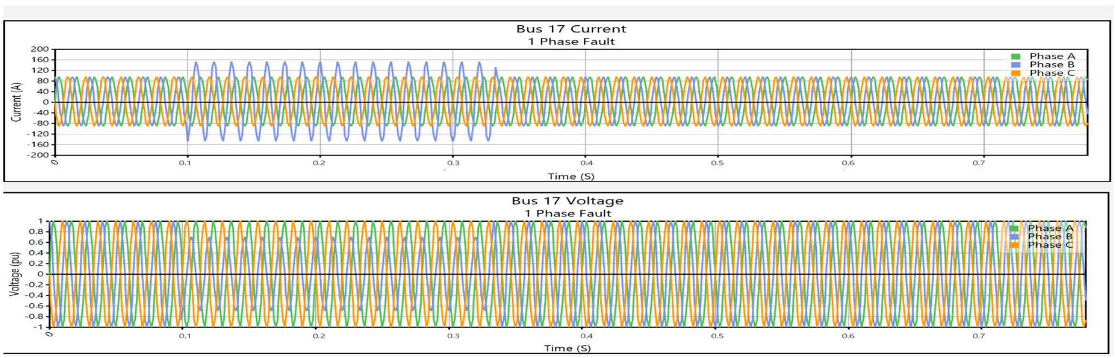


*Figure 14: Single Phase Fault Current and Voltage at Bus 17*

Fault was at B17, CB16, CB17,CB18 and CB28 was opened to isolate the fault, then CB16 and CB18 was closed to restore power to the healthy part of the network with DG.In the duration of 0.225 seconds control agents senses the changes and provide the information between the agents and immediately a main breaker is opened due to a control action. The fault occurs at 0.1 seconds and cleared of the fault is at 0.325 second to restore the fault free zone. In figure 12, a three-phase fault occurred, it can be seen that the voltage drops to almost 0.65pu while the current increases to 180A.also in figure 13, a Double phase fault occurred, the result indicate that the fault current increases to 178A and the voltages to 0.66 pu. In figure 14, a single-phase fault occurred showing only one phase faulty.

**Table 1: Summary of Simulation Results with DG**

| Cases | Fault location | Faulted Bus | Switching action | Number of switching |
|---|---|---|---|---|
| **Case 1** | Bus 1 | B2- B34 | DG on and corresponding CBs reclosed to restore power to the network | 2 |
| **Case 2** | Bus 12 | B9-B11, and B15-B34 | DG on and corresponding CBs reclosed | 2 |
| **Case 3** | Bus 17 | B18 – B34 | DG on and corresponding CBs reclosed to restore power to the network | 2 |

Table 1 above shows the summary of the result of network with DG after applying MAS. The faulty buses are bus 1, 12 and 17.as a result of fault at bus 1, bus 2-34 loss supply from the feeder. With action of MAS the DGs will be ON and corresponding CBs will reclosed to restore power to the fault free areas, and switching the DGs and reclosing of the CBs gives the number of switching to be 2.similarly for bus 12 and 17 follows same operation.

**Table 2: CB Status for fault at Bus 1 with DG after Restoration**

| CB | Status | CB | Status | CB | Status | CB | Status | CB | Status |
|---|---|---|---|---|---|---|---|---|---|
| **1** | OFF | 8 | ON | 15 | ON | 22 | ON | 29 | ON |
| **2** | ON | 9 | ON | 16 | OFF | 23 | ON | 30 | ON |
| **3** | ON | 10 | ON | 17 | ON | 24 | ON | 31 | ON |
| **4** | ON | 11 | ON | 18 | ON | 25 | ON | 32 | ON |
| **5** | ON | 12 | ON | 19 | ON | 26 | ON | 33 | ON |
| **6** | ON | 13 | OFF | 20 | ON | 27 | ON | 34 | ON |
| **7** | ON | 14 | ON | 21 | ON | 28 | ON | | |

**Table 3: CB Status for fault at Bus 12 with DG after Restoration**

| CB | Status | CB | Status | CB | Status | CB | Status | CB | Status |
|---|---|---|---|---|---|---|---|---|---|
| **1** | ON | 8 | ON | 15 | ON | 22 | ON | 29 | ON |
| **2** | ON | 9 | ON | 16 | OFF | 23 | ON | 30 | ON |
| **3** | ON | 10 | ON | 17 | ON | 24 | ON | 31 | ON |
| **4** | ON | 11 | ON | 18 | ON | 25 | ON | 32 | ON |
| **5** | ON | 12 | OFF | 19 | ON | 26 | ON | 33 | ON |
| **6** | ON | 13 | OFF | 20 | ON | 27 | ON | 34 | ON |
| **7** | ON | 14 | ON | 21 | ON | 28 | ON | | |

**Table 4: CB Status for fault at Bus 17 with DG after Restoration**

| CB | Status | CB | Status | CB | Status | CB | Status | CB | Status |
|---|---|---|---|---|---|---|---|---|---|
| **1** | ON | 8 | ON | 15 | ON | 22 | ON | 29 | ON |
| **2** | ON | 9 | ON | 16 | ON | 23 | ON | 30 | ON |
| **3** | ON | 10 | ON | 17 | OFF | 24 | ON | 31 | ON |
| **4** | ON | 11 | ON | 18 | ON | 25 | ON | 32 | ON |
| **5** | ON | 12 | ON | 19 | ON | 26 | ON | 33 | ON |
| **6** | ON | 13 | ON | 20 | ON | 27 | ON | 34 | ON |
| **7** | ON | 14 | ON | 21 | ON | 28 | ON | | |

Table 2, 3 and 4 shows the status of circuit breakers at the buses after restoration.in table 1 it can be seen that the circuit breaker of the faulty bus is OFF indication the fault condition. From bus 2 to 12 is ON indicating restoration of the network, while bus 13 and 16 are OFF. Also in table 3, the status CB 12, 13 and 16 are OFF while all CBs are ON to restore power to the network. In table 4 CB 17 is OFF after the restoration.

**5.0 Conclusion**

The work presents a decentralized multi agent system (MAS) which works in real time with a power distribution system for fault isolation and restoration applications. The multi-agent system consists of a control agent, a feeder agent, switch agent, DG agent, and a Bus agent.

The results of the simulation cases of different fault locations and DG existences as well as feeder reconfiguration verified in realizing different restoration scenarios. Simulation results reveals that faults can be located, isolated and restored by the control action of the multi agent system. The MAS applied on an existing 34 bus distribution network and effectively locate, isolate and restored power to the network.Number of switching operation in each bus were obtained as in the tables above, status of circuit breakers in opening and closing of the network were also recorded and finally, agent are built to clear the fault within shortest time and has been achieved.

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