ISSN 2250-3153

# Collaboration among Agents to Detect Fault in Power Distribution System

**Ali Aliyuda and Muhammed Kabir Ahmed**

Department of Mathematics, Computer Science Unit, Gombe State University, Gombe, Nigeria.

***Abstract-*** In this Paper, a Multi-agent System platform that will allow agents to detect and report fault in Power Distribution System (PDS) with the minimum time delay is presented. Multi-agent System Engineering (MaSE) methodology was used to demonstrate how agents will be able to manage the complexity of PDS. The simulation of the framework in MatLab/Simulink indicates that Multi-Agent System technology can be applied to detect and report fault in Power Distribution System with the minimum time delay.

***Index Terms***- Agent, Multi-Agent System, Power Distribution System, Multi-agent Software Engineering (MaSE)

## I. Introduction

Agent-based computing is one of the powerful technologies for the development of distributed complex systems [15]. The authors in [5] presented agents as new paradigm for software development since object-oriented design, and the concept of intelligent agents has already found a diverse range of applications in manufacturing, real-time control systems, electronic commerce, network management, transportation systems, information management, scientific computing, health care, and entertainment, etc. The reason for the growing success of agent technology in these areas is that the inherent distribution allows for a natural decomposition of the system into multiple agents that interact with each other to achieve a desired global goal.

Agents can operate without the direct intervention of humans or others [13]. This feature helps agents to monitor and detect fault in power distribution system in a particular area. In Multi-Agent System (MAS), agents communicate with other agents in a system to achieve a global goal. Agents can also perceive their environment and respond in a timely fashion to environmental changes [9].

### *A. An Agent*

An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives [2].

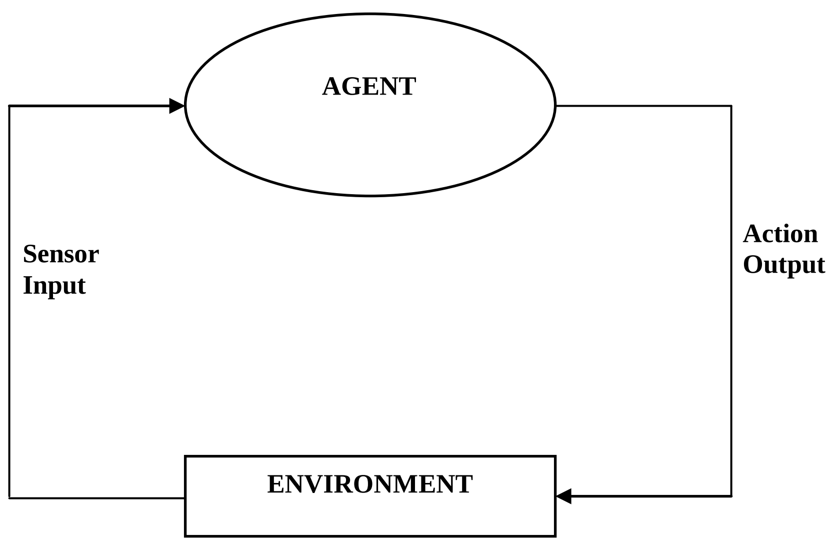


Figure 1.1: An Agent in Its Environment.

Figure 1.1 gives an abstract view of an agent. In this diagram, the agent takes sensory input from the environment, and produces as output actions that affect it. The interaction is usually an ongoing, non-terminating one. We can see the action output generated by the agent in order to affect its environment. In most domains of reasonable complexity, an agent will not have complete control over its environment. It will have at best partial control, in that it can influence it.

*B. Multi-Agent System (MAS)*

The authors in [5] defined multi-agent system as a group of agents which sense the environment and act in order to achieve specific objectives. MAS can therefore be seen as a network of interacting software modules that bring together dispersed systems that collectively manage complex tasks that are beyond the capacity of any individual system on the network.

The authors in [14] described that, the term multi-agent system implies more than one agent interacting with each other within an underlying communication infrastructure where individual agents are often distributed and autonomous. Multi-agent systems are based on the idea that a cooperative working environment can cope with problems which are hard to solve using the traditional centralized approach to computation. Agents are used to interact in a flexible and dynamic way to solve problems more efficiently.

## II. BACKGROUND

For the design of our Agent-based framework we revised the state of the art of MAS platforms in relation to power distribution systems [12], [6], [4], [10], [3] and [14]. We also revised the state of the art of Agent-Oriented Software Methodologies [7] and [11]. The purpose of this revision is to select the most appropriate and suitable agent platform and agent-oriented software methodology for this work.

In [6], a conceptual framework for a power system self-healing infrastructure is examined. In [12] and [4], the authors presented a MAS designed for distribution systems restoration. These works abstract network buses as agents, along with a facilitation agent who is responsible for aiding negotiation processes among bus agents. In [1], agents have hierarchical levels and higher level agents coordinate a group of lower level agents. In [8], each agent is considered to have its special functionalities e.g. acquiring data, analyzing data, managing situations, etc. In other words each step of decision making is done by a special agent. An intelligent agent-based environment to coordinate maintenance schedule discussions is introduced in [10] and autonomous regional active network management system is introduced and discussed in [3].

In general, the above literatures consist of a master agent which makes the final decision based on the data received from other agents. This cannot be considered as distributed control since the master agent is behaving like a control center.

The authors in [14] proposed an agent committee approach to push the technology to some extent in solving the power restoration problems in a more distributed and efficient way. The idea is to allow neighboring switch agents to be organized into a local power committee whose responsibility is to ensure that the local power demand can be satisfied as well as reconciled with an optimal solution to the conflicting issues proposed among committee members who are responsible for identifying a feasible power source to the local power demand problems. The advantage of this approach is to localize the global problem solving ability to a local committee of agents who could coordinate with neighboring committees to achieve an agreement that satisfies the global objective of the distribution system without relying on a pre-determined centralized optimization algorithm as traditional approaches. The authors illustrated a committee-based multi-agent system whose objective is to find a solution of power restoration problem that can maximize the service zones while minimizing the number of switch operations under the topological and operational constraints of power distribution systems.

While this approach contributed in pushing the technology to some extent, however, since a committee is an organization of agents, it requires a leader to actually conduct the decisions of the committee and communicate with its committee member and other committees. For this purpose, the system will encounter a problem whenever a break in communication occurs between the Local Power Committee leader and the central unit of the system.

## III. MULTI-AGENT SYSTEM FRAMEWORK

In order to design a framework for our case study which is Gombe State University Power Distribution System (GSUPDS), we selected the MaSE methodology which is a general purpose methodology for developing multi-agent systems that is founded on the basis of software engineering principles [7]. MaSE divides the development process into two major phases: the analysis phase and the design phase [11]. The analysis phase consists of the following stages: capturing goals, applying use cases, and refining roles and the design phase consists of the following stages: creating agent classes, constructing conversations, assembling agent classes, and system design. For each phase, MaSE provides a set of stages need to be performed. The main goal of MaSE is to guide a designer through the software lifecycle from a documented specification to an implemented agent system, with no dependency of a particular MAS architecture, agent architecture, programming language, or message-passing system.

ISSN 2250-3153

*A. Collaboration among Agents in MAS*

Our framework consists of the Switch Agent (SA), the Zone Agent (ZA) and the Control Center (CC). After the SA, ZA and the CC specifications, the next step involves the formalization of agent roles and interactions applied to the problem at hand. To accomplish this task, a collaborative diagram which defines the interaction among agents and their interaction with the environment needs to be defined. The collaborative diagram of MAS is shown in Figure 3.1. The diagram illustrates two agents (SA and ZA) and their interactions with each other and the environment. The SA interacts with the environment and communicates with the ZA which in turn forwards the state of the environment to the CC. The CC receives copies of all messages exchanged within the MAS and is responsible for interpreting and displaying these messages to users for appropriate action. In Zeus, all messages received and their respective source addresses are automatically stored in the resource database. All messaging exchanges among agents are established via the Transmission Control Protocol/Internet Protocol or TCP/IP.

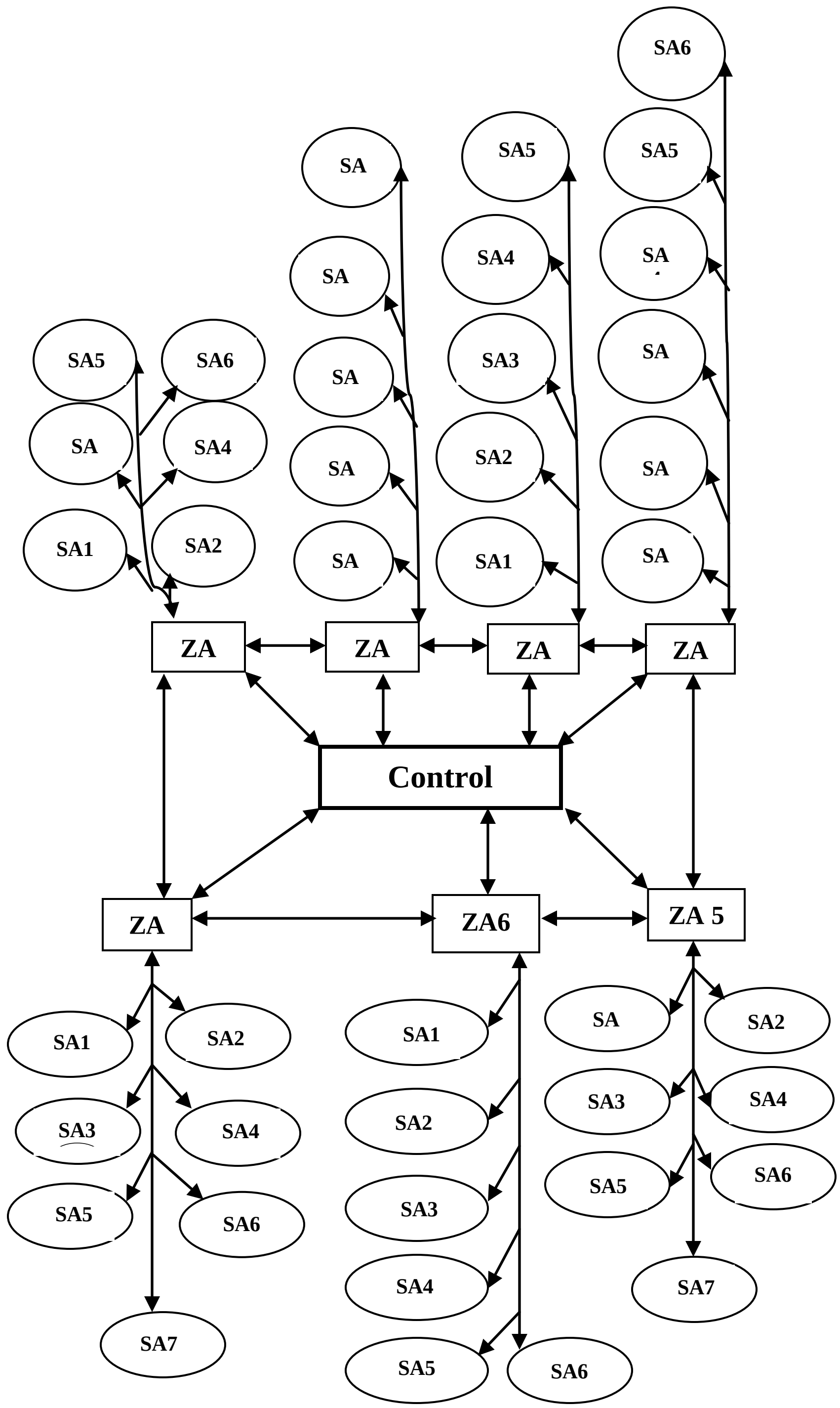


Figure 3.1: MAS Collaboration Diagram

The initialization of the MAS is performed by the CC, the SA and the ZA notifying the CC of their presence. This includes notifying the CC of their names and IP addresses; the CC then updates its resource database and fulfills the required procedure for agent registration.

In order to demonstrate the proposed MAS, a simulation test model is developed in Matlab/Simulink as a simplified distribution circuit that comprises: a step block as a SA, a transfer function block as a ZA and a scope block as the CC as shown in Figure 4.1. A fault is applied to the circuit at 0.1 second after the simulation starts. Measurements are voltage and current waveforms which represent voltage and current outputs produced from the power distribution system. The circuit depicts a single path of the entire distribution system. That is, a path from a single SA to the CC.

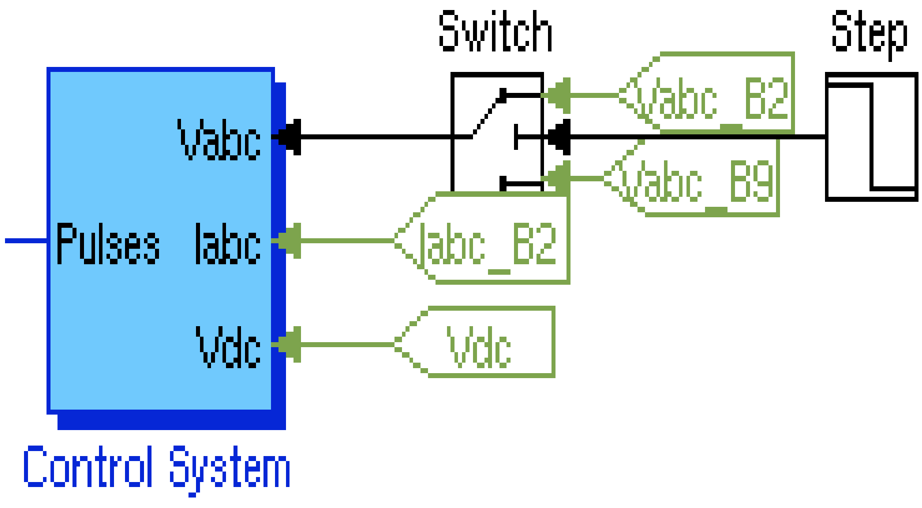


Figure 4.1: A Simple Circuit Simulation of the Power Distribution System in MatLab/Simulink

## IV. RESULTS AND DISCUSSION

The circuit as shown in Figure 4.1 is simulated for 0.2 second. The simulation result shown in Figure 4.2 illustrates the variation of voltage and current waveforms, before and after the upstream outage applied to the circuit at 0.1 second. As can be seen from Figure 4.2, the circuit is in the normal operation mode during the first 0.1 second and it is interrupted thereafter. During the normal operation mode, the circuit's voltage and frequency are controlled such that they follow the grid's voltage and frequency, which are roughly at 1 per unit and 60 Hz, respectively. During the normal operation mode, the circuit produces 240v internally. This can be seen from the measurements in Figure 4.2, i.e. the voltage output is 1 per unit and the current output is 0.5 per unit. During the transition, once the SA detects fault at t = 0.1, the SA informs the ZA which in turn forward the information to the CC in form of signal. The SA and the ZA both exchange information and the CC decides on the action to be taken. All agent actions from detecting the fault, sending message, and taking the appropriate decision can be accomplished within half an electrical cycle, that is, less than 0.008 second for a 60-Hz system. After fault occurred at 0.1 second, the flow of current along the circuit is interrupted. As can be seen in Figure 4.2, while the voltage is always kept constant at 1 per unit, the current increases from 0.5 per unit to 1 per unit during the transition. This implies that the power output of the circuit increases after fault occurred.

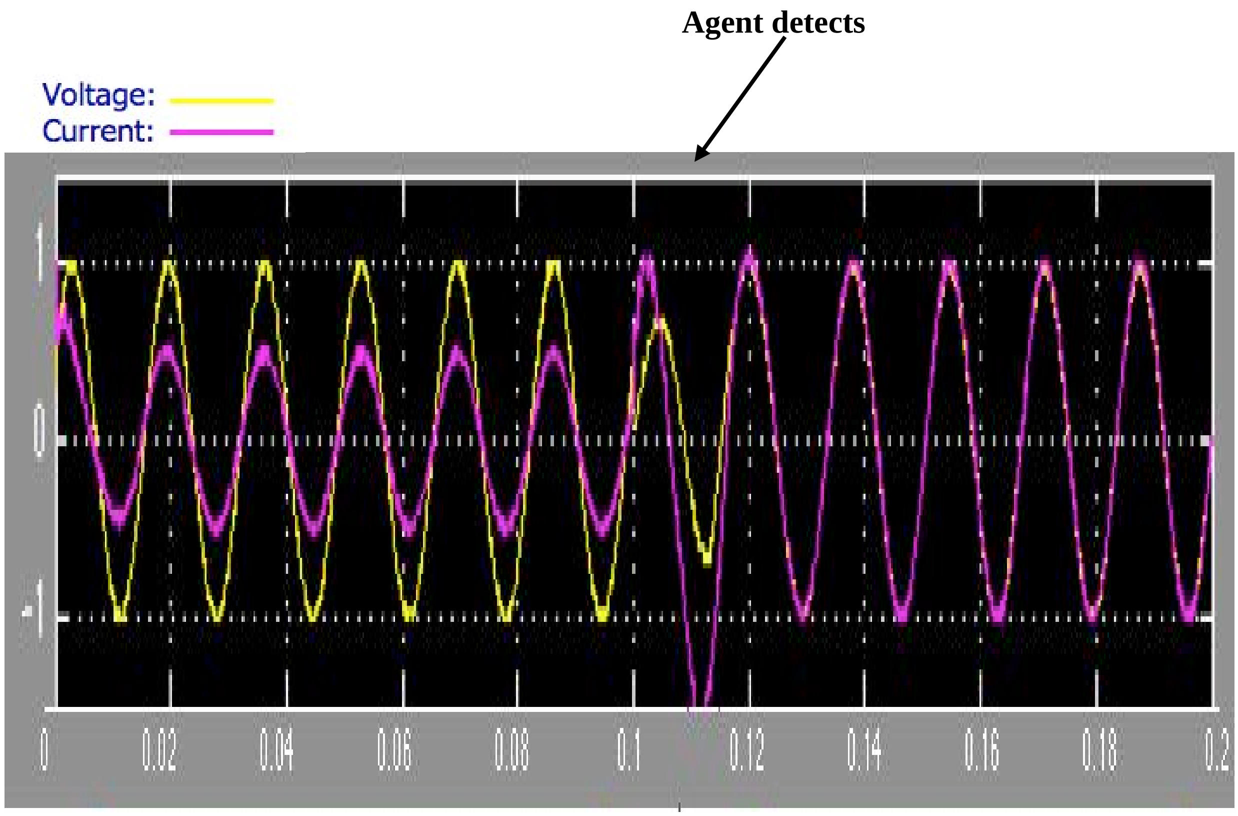


Figure 4.2: Simulation Result (Y-axis Represents Voltage and Current Waveforms; X-axis is the Simulation Time in Second).

## V. CONCLUSION

This research describes the design of distributed MAS architecture for detecting fault in Power Distribution System. The MAS consists of a SA, ZA and the CC. Agents exchange their messages via a TCP/IP protocol based on the IEEE FIPA standard to ensure the system interoperability. The application implementation process is illustrated through simulated case study, which indicates that the proposed MAS can respond to its environment when fault is detected.

## ACKNOWLEDGMENT

The authors are very thankful to Prof. H. S. Tantawy, a visiting Professor at Department of Computer Science, Usmanu Danfodiyo University, Sokoto,Nigeria for his interest to supervise this work and his provision of excellent computation facilities to carry out this work.. Appreciation also goes to Dr. Aminu Mohammed Head of Computer Science Unit Usmanu Danfodiyo University, Sokoto,Nigeria for his advice, moral support and help to carry out this research work.

## REFERENCES

[1] Adejumobi, I. A. and Pekum, A. J. (2009). "Software Application for Electrical Distribution System Reliability Studies: Box-Jenkins Methodology". *Pacific Journal of Science and Technology*. 10(2):377-387.

[2] Bo, C. R. and Harry, H. (2010). "A Review of the Applications of Agent Technology in Traffic and Transportation Systems". IEEE Transactions on Intelligent Transportation Systems, Vol. 11, NO. 2, pp 44 – 49.

[3] Chinwuko, E. C., Nwuba, U. and Mgbemena, C. O. (2011). "Optimum Reliability and Cost of Power Distribution System: a case of Power Holding Company of Nigeria". *International Journal of Engineering Science & Technology*, 12(5): 233 – 238.

[4] Deshmukh, R. K., Davidson, E. M. and McArthur, S. D. J. (2008). "Exploiting Multi-Agent System technology within an autonomous regional active network management system". Proceedings of the 14th IEEE International Conference on Intelligent Systems Application to Power Systems. Pp 57 – 61. New York.

[5] Dimeas, A. and Hatziargyriou, N. D. (2005). "Operation of a Multi-agent System for Micro Grid Control". IEEE transaction on power systems, Vol. 20, No.3, 48 – 53.

[6] Ioannis, S. B. and Dimitris, P. L. (2007). "Implementing Multi-Agent Systems Technology for Power Distribution Network Control and Protection Management". IEEE Transactions on Power Delivery, Vol. 22, NO. 1, pp 14 – 19.

[7] Maalal, S. and Addou, M. (2011). "A New Approach of Designing Multi-Agent Systems". *International Journal of Advanced Computer Science and Applications, Vol. 2, No. 11,* pp 67 – 72.

[8] Rosa, M. A., Miranda, V., Carvalho, L. and DaSiva, A. M. L. (2010). Modern Computing Environment for Power System Reliability Assessment". Proceedings of the 12th ACM Probabilistic Methods Applied to Power Sytems, Pp 29 – 35. Singapore.

[9] Rosa, M. A., DaSilva, A. M. L., Miranda, V., Matos, M. and Sheblé, G. (2009). "Intelligent Agent-Based Environment to Coordinate Maintenance Schedule Discussions". International Symposium on Intelligent Systems Applications to Power Systems, pp 22 – 27.

[10] Rumley, S., Elvira, K., Hugh, R. and Alain, G. (2010). "Multi-Agent Approach to Electrical Distribution Networks Control". 27th Annual IEEE International Computer Software and Applications Conference. Pp 62 – 68. New York

[11] Silaghi, G. C. (2005). "Software Engineering Approaches for Design of Multi-agent Systems". IEEE Transactions on Power Systems 17(2): 457–462.

[12] Tao, Y., Nagata, T., Kimura, K., Sasaki, H. and Fujita, H. (2004). A Multi-Agent Approach to Distribution System Restoration". Proceedings of the 47th IEEE Midwest Symposium on Circuits and Systems, Vol. 2, pp 51 – 58.

[13] Wang, F. Y. (2005). "Agent-Based Control for Networked Traffic Management Systems". IEEE Intell. Syst., vol. 20, no. 5, pp. 92–96.

[14] Wan-Yu Yu, V., Men-Shen, T. and Yen-Bo, P. (2012). "Coordinating a Society of Switch Agents for Power Distribution Service Restoration in a Smart Grid". IEEE Trans. on Power System, Vol. 25, No. 1, pp. 72 – 81.

[15] Zambonelli, F. and Parunak, H. V. D. (2003). "Signs of a Revolution in Computer Science and Software Engineering". In Proc. 3rd Int. Workshop Eng. Soc. Agents World, vol. 25, No. 9, pp. 13–21.

## AUTHORS

**First Author:** Ali Aliyuda has completed his M. Sc. in Computer Science from Usmanu Danfodiyo University, Sokoto, Nigeria in 2016 and B. Sc. in Computer Science from Gombe State University, Gombe, Nigeria in 2009. He is currently working as a Lecturer in Department of Mathematics, Computer Science Unit, Gombe State University, Gombe, Nigeria. His area of research includes Multi-Agent Systems and Empirical Software Engineering.
Email ID: aliyuda.ali6@gmail.com

**Second Author:** Muhammed Kabir Ahmed received his M. Sc. in Computer Science from Usmanu Danfodiyo University, Sokoto, Nigeria in 2016 and B. Sc. in Computer Science from Gombe State University, Gombe, Nigeria in 2010. He is currently working as a Lecturer in Department of Mathematics, Computer Science Unit, Gombe State University, Gombe, Nigeria. His area of research includes Multi-Agent Systems and Computational Intelligence.
Email ID: kabirmka@yahoo.com

**Correspondence Author:** Ali Aliyuda; Email: aliyuda.ali6@gmail.com; Contact: +2348061698643