Dual layered multi agent system for intentional islanding operation of microgrids

A.L. Kulasekera[1], R.A.R.C. Gopura [2], K.T.M.U. Hemapala[3], N. Perera[4], and Achala Pallegedara[5]

[1,2]Dept. of Mechanical Engineering, University of Moratuwa, Katubedda, Sri Lanka
[3,4]Dept. of Electrical Engineering, University of Moratuwa, Katubedda, Sri Lanka
[5]Dept. of science and technology, Graduate school of science and technology, Saga University, Saga, Japan

[3]udayanga@elect.mrt.ac.lk

Abstract: The paper focuses on proposing a dual layered, multi agent based control system for distributed control of a microgrid aimed at intentional islanding. The architecture consists of two layers; primary layer and secondary layer. The primary layer includes a User agent, a Distributed Generator (DG) agent and a Control agent. The secondary layer consists of a Low Voltage (LV) agent and a Load agent. The Control agent is capable of supervising the secondary layer agents. The proposed multi agent based control architecture is developed using the JADE platform and it is used to control a microgrid simulated in MATLAB/SIMULINK. In order to validate the effectiveness of the proposed method, investigations are carried out for islanding scenarios simulated on the test network. The results of this study show the capability of developing a reliable control mechanism for islanding operation of microgrids based on the proposed concept.

Keywords: distributed control, intentional islanding, microgrid, multi agent systems.

1 INTRODUCTION

Legacy power distribution systems are facing a tough challenge in meeting the needs of the rapidly evolving electricity market. Time is ripe for a smarter grid capable of meeting the present and future power delivery requirements. The looming dangers of climate change is also demanding a paradigm shift from large scale fossil fuel based sources towards small scale lower emission systems. The incorporation of smaller distributed generation (DG) units with maximum renewable energy penetration is vital in meeting all these demands.

This requires the ability to handle active generation and loads, which had not been addressed in existing legacy system designs. Smaller microgrids comprising local generation is a concept put forward to cater this requirement. These microgrids can be operated either in island mode, where the local loads are fully supplied by the local generation, or in grid connected mode, where the microgrid is either exporting or importing power from the main grid.

With the local generation and loads coming into the picture, local distributed control is essential for the local grid stability. Microgrid can survive from an upstream outage in the main grid by switching to island mode and maintaining supply to the most critical local loads. Load shedding has to be carried out rapidly when the microgrid is switched to island mode as the local generation capabilities might be limited.

In order to provide these local distributed control capabilities, development of distributed control systems are essential. Multi Agent Systems (MAS) is a technology coming forward in this aspect. MAS have been developed for a wide range of applications in power systems [1]. The use of MASs in microgrid applications has been evolving over the last decade with considerable amount of work being carried out regarding distributed control applications for microgrids [2].

This paper proposes a novel dual layered MAS capable of distributed control of a microgrid. The MAS is developed in JADE platform and it is used to control a microgrid simulated in MATLAB/SIMULINK. A brief outline of micro grids is presented in section 2. An overview of multi agent systems is presented in section 3. The proposed dual layered multi agent system architecture is presented in section 4. Section 5 describes the simulations carried out and their results. Finally the conclusions are given in section 6.

2 OUTLINE OF MICROGRIDS

Microgrids can be created by embedding small-scale conventional generation units or Non-Conventional Renewable Energy Sources (NCRES) to existing electrical infrastructure. These NCRES can be mini-hydro, solar photo-voltaic (PV), wind, geo-thermal, small internal combustion (IC) engines, biomass or waste-to-energy systems. Such embedded systems will provide the microgrid with DG capabilities. A conceptual model of a microgrid is presented in Fig. 1.

Once an upstream disturbance takes place on the main grid, the microgrid can separate from the main grid at the point of common coupling and isolate the local loads from any outage, providing a higher level of service, with minimum effect to the stability and the integrity of the main grid. This capability of intentional islanding will deliver a higher reliability than legacy power systems [3]. Thereafter, the microgrid has to manage the local loads to make sure that the most critical loads are supplied by the available limited local capacity. This would require priority based load shedding.

3 OVERVIEW OF MULTI AGENT SYSTEMS

Multi agent systems are complex systems composed of several autonomous agents with only local knowledge and limited abilities but are able to interact in order to achieve a global objective [1]. Their ability to act as a container for conventional control methodologies as well as artificial intelligent based techniques and expert systems has become an additional advantage in building hybrid controllers in microgrid.

A MAS in essence is an abstraction of the role of agents in real life into intelligent control systems. These agents are able to act as autonomous social entities which react to changes in their environment and take intuitive actions in order to realize their individual goals. The aim of a multi agent based control system is to apply this individual goal seeking in a manner such that the overall target required by the user is achieved efficiently and effectively as possible.

Since Fast communication facilities such as fiber-optics, 3G, GSM/GPRS have become an integrated part of power systems [4], it is easier and more feasible to integrate multi-agent systems into power system applications.

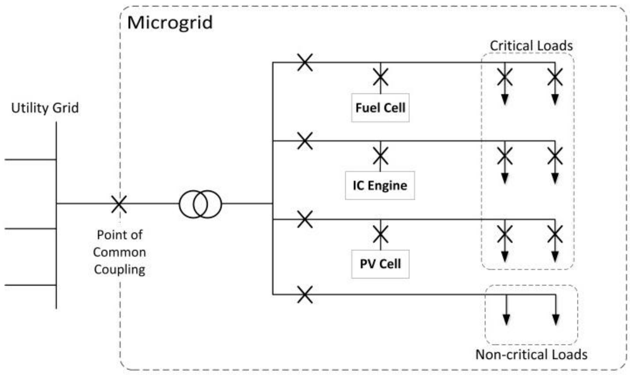

Fig. 1. Conceptual model of a microgrid

In a microgrid, an individual intelligent agent can be assigned to each entity (circuit breaker, generation unit, loads, users etc.). This assignment determines the architecture of the MAS. Several different multi agent architectures have been presented in [5]-[8].

4 DUAL LAYERED ARCHITECTURE OF MULTI AGENT SYSTEM

Fig. 2 shows the conceptual design of the proposed dual layered control architecture for microgrids. The MAS system is developed using the JADE platform [9]. The model presents a dual layer distributed control architecture. The primary layer comprises of three major agents; DG Agent, User Agent and Control Agent. The three major agents will be tasked with sensing and controlling the components of the microgrid. The DG agent will collect the information related to the DG such as; availability, connection status, power rating, energy source availability and cost of energy. The control agent is in control of a secondary layer comprising of a Load agent and a Low Voltage (LV) agent, overseeing the load control and microgrid connection control capabilities.

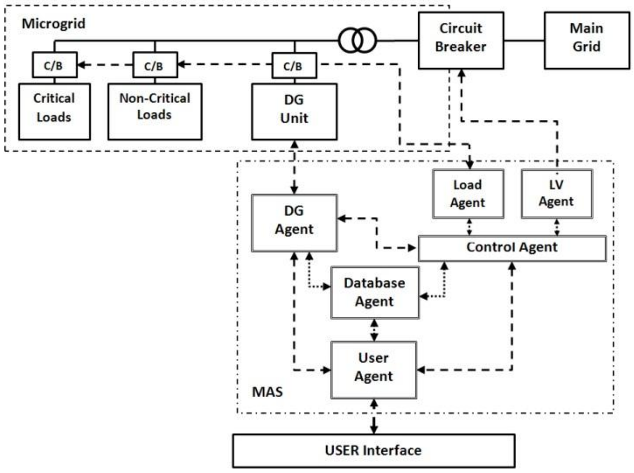

Fig. 2. Dual layered MAS architecture

During an upstream fault, the LV agent will island the microgrid, by tripping the circuit breaker at the point of common coupling, if the Control agent allows it. During island operation the load shedding will be taken care of by the Load agents to ensure that power is delivered to the most critical loads on the priority basis set by the Control agent. This will be implemented by Load agents opening circuit breakers at each of the controlled local loads.

The User agent behaves as the gateway for the user to interact with the system, to obtain real-time information and set system goals. A utility agent acting in the form of a database agent is utilized to store system information and the data and messages shared between the agents. The database agent will also be the access point for data for all the agents and users.

The control agent will be the center of the primary layer holding influence over the DG agent and controlling the LV and Load agents. The control flow chat followed by the control agent is given in Fig. 3. The operation of the control agent during the detection of an upstream outage is described in the next section.

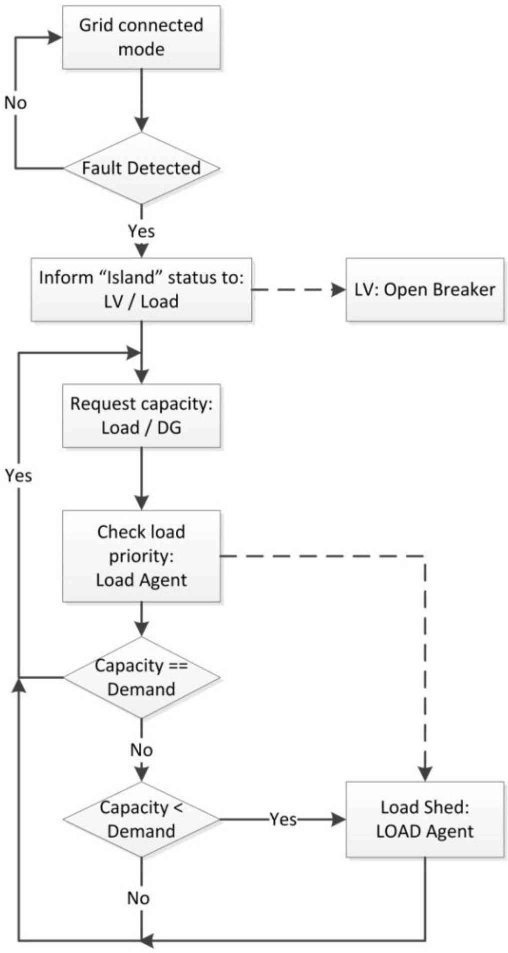

Fig. 3. Control flow chart of Control agent

5 SIMULATION AND RESULTS

The microgrid test bed used for the simulations (Fig. 4) consists of an embedded generator, acting as a DG unit, supplying part of the local demand, and several critical and non-critical loads. It is assumed that the DG unit can operate at full capacity without fuel limitations during any outage. This simulation test bed is modeled using MATLAB/SIMULINK. An external TCP/IP server [10] is used to connect the MAS to the simulated test bed.

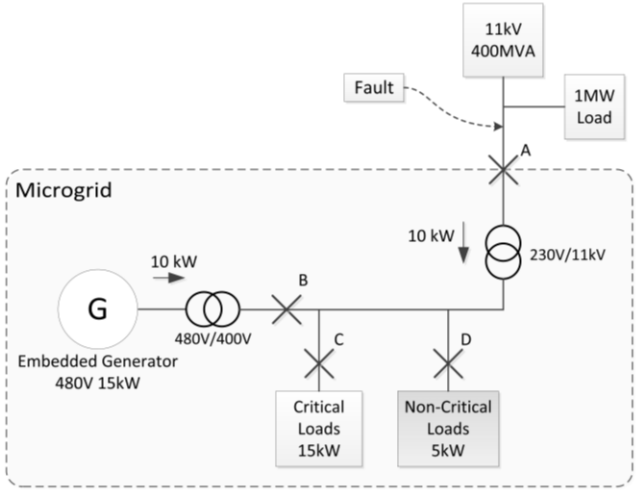

Fig. 4. Microgrid simulation model

The objective of the test setup is to demonstrate the ability of the proposed MAS to island the microgrid after an upstream fault is detected. Initially the microgrid is operating in the grid-connected mode, with the embedded generator is supplying only part of the local loads while the rest is supplied by the utility grid. The demands supplied by the DG and the grid are depicted in Fig. 4. At the beginning of the simulation breakers A, B, C and D are all closed.

While the microgrid is in grid connected mode and upstream fault is introduced at 0.05 s as seen in Fig. 5 and is switched to island mode thereafter. Line-to-line voltages are measured from points C and D shown in Fig. 4.

5.1 Grid connected mode

While the microgrid is in grid-connected mode, the total demand is 20 kW, with 15 kW critical loads and 5 kW non-critical loads. During the grid-connected mode the embedded generator only provides 10 kW output, 50% of the total demand. Another 10 kW is required from the main grid to supply the microgrid.

5.2 Transition period

When the upstream outage is detected at t = 0.05 s the control agent informs the LV agent and the Load agents to switch to island mode operation. Upon receiving the islanding order the LV agent trips the main circuit breaker A, at the point of common coupling, isolating the microgrid from the utility (Fig.5(c)). The Control agent then queries the DG agent and the load agents regarding their available capacities the DG can provide to the microgrid and the power requirements of the connected loads.

As the total load of 20 kW exceeds the available maximum capacity of 15 kW, the control agent commands the load agents to shed the 5 kW non-critical loads to match the DG capacity. Soon as the microgrid is put to island mode the supply to the critical loads is maintained (see Fig. 5(a)). The load agent at the non-critical loads sheds them from the system by opening breaker D (see Fig. 5(b)).

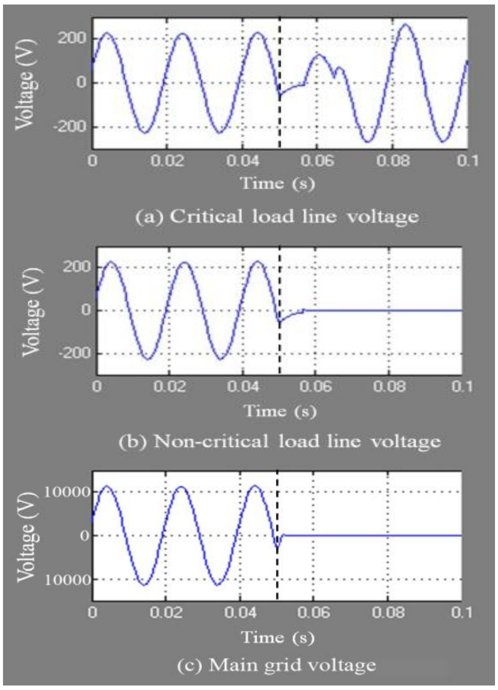

Fig. 5. Simulation results during intentional islanding. (a) Line to line voltage across critical load at 'C', (b) Line to line voltage across the non-critical load at 'D', (c) Line to line voltage at breaker 'A'.

5.3 Islanded mode

At t=0.05s the microgrid is separated from the main grid and the load agents balance the local demand. After the microgrid switches to island mode the total local demand is met by the embedded generator supplying 15 kW.

All agent operations are carried out rapidly, from detecting fault, opening the main breaker, connecting the local source and shedding loads, to stabilize the microgrid within 0.02 s. Therefore the system is able to disconnect from the main utility grid and maintain the supply to the critical loads without suffering a brownout and/or blackout.

6 CONCLUSION

A dual layered MAS for intentional islanding operation of microgrid is proposed in this paper. The agent architecture was developed using the JADE platform. Time domain simulations were carried out using a test system simulated in MATLAB/SIMULINK. The test bed was simulated for 0.1 s with the introduction of an upstream fault at 0.05 s. the MAS was able successfully restore supply within 0.02 s to the critical loads by islanding the microgrid and shedding non-critical loads. The results show the capability of the Multi Agent System to safely island and maintain the supply to its critical loads. These results validate the effectiveness of the MAS in controlling DG units to protect and control a microgrid. In the future the MAS will be implemented on a physical test bed to further validate the results.

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REFERENCES

[1] Mcarthur SDJ, Davidson EM, Catterson VM, et al (2007), Multi-agent systems for power engineering application Part I: Concepts, approaches, and technical challenges, IEEE Trans. on Power Systems, vol. 22, no. 4, pp. 1743-1752.

[2] Kulasekera AL, Gopura RARC, Hemapala KTMU, et al (2011), A Review on Multi-Agent Systems in Microgrid Applications, In: Proceedings of IEEE PES Conference on Innovative Smart Grid Technologies India (ISGT 2011), Kollam, Kerala, India, December 1-3, 2011.

[3] Lasseter RH, Paigi P (2004), Microgrid: A Conceptual Solution, In: Proceedings of IEEE 35th Annual Power Electronics Specialists Conference, (PESC '04), June 20-25, 2004, vol.6, pp. 4285 - 4290

[4] Wissner M (2011), ICT, growth and productivity in the German energy sector - On the way to a smart grid?, Utilities Policy, vol. 19, no. 1, pp. 14-19.

[5] Aung HN, Khambadkone AM, Srinivasan D, et al (2010), Agent-based intelligent control for real-time operation of a microgrid, In: Proceedings of 2010 Joint International Conference on Power Electronics, Drives and Energy Systems & 2010 Power India, New Delhi, India, pp. 1-6.

[6] Zheng W and Cai J (2010), A multi-agent system for distributed energy resources control in microgrid, In: Proceedings of 2010 5th International Conference on Critical Infrastructure (CRIS), Beijing, China, pp. 1-5.

[7] Jian Z, Qian A, Chuanwen J, et al (2009), The application of multi agent system in microgrid coordination control, In: Proceedings of 2009 International Conference on Sustainable Power Generation and Supply, Nanjing, pp. 1-6.

[8] Cai N and Mitra J (2010), A decentralized control architecture for a microgrid with power electronic interfaces, In: Proceedings of 2010 North American Power Symposium, Arlington, TX, USA, pp. 1-8

[9] JADE agent development toolkit (2011) [online], Available: http://www.jade.tilab.com

[10] Zimmermann W (2011), IOlib – Hardware input / output library module for matlab and sim ulink [online], Available: http://www.it.hs-esslingen.de/~zimmerma/software/index_uk.html