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# Coordination and Control of Multiple Microgrids Using Multi-Agent Systems

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***Abstract*– As distributed renewable generation sources continue to be integrated into the power grid, the concept of Microgrids has gained traction. Here, the integration challenge is not just in the control of an individual Microgrid but also in their coordination. This short communication presents a novel approach to inter-Microgrid coordination and control based upon Multi-Agent systems. An architecture based upon physical agents is presented and is implemented on a dual platform of JADE (environment for developing agents) and Matlab-Matpower (power system analysis tool). The implementation is demonstrated for a reconfiguration scenario involving the preservation of vital loads. The work presents many opportunities for future developments in the domain of resilient self-healing power grids.**

## I. Introduction

The motivation of this project is the place of Microgrids in the future of the electricity grid. In [1], it is realized that Distribution Systems increasingly coming to resemble Transmission Systems, both trending towards real-time controlled Smart Grid and with the introduction of Variable Energy Resources. Thus, Distribution Systems will form temporary semi-autonomous Microgrids, as shown in Figure 1.

The Microgrids benefits are congestion relief, postponement of new generation or delivery capacity, response to load changes, local voltage support, promote high penetration of renewable sources, dynamic islanding, and improved generation efficiencies through the use of waste heat [2], [3], [4].

Due to these benefits the power grid will deal with systems with multiple microgrids. It is required advanced modeling and the development of control systems working with inter-Microgrid coordination, this short communication proposed the first approach of an innovative technique for that.

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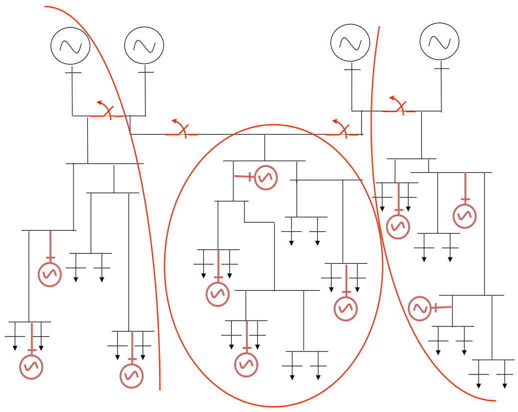

Figure 1: Semiautonomous Microgrids.

In Section II is presented a review of the academic literature of Coordination and Control of Microgrids, in Section III is presented the proposed MAS approach. A case study, in order to solve the load supply and self-healing problem of multiple Microgrids, is addressed in Section IV and the conclusions are in section V.

## II. Coordination and Control of Microgrids

The Coordination and Control of a Microgrid needs to ensure [1]:

- New microsources can be added to the system without modification of existing equipment.
- The Microgrid can connect to or isolate itself from the grid in a rapid and seamless fashion.
- Reactive and active power can be independently controlled.
- Microgrid can meet the grid's load dynamics requirements.

In order to insure the before, the Microgrids use the 2 following physical control methods given by the injection of power of the microsources into it [2]:

1. The first physical control method is the voltage regulation through droop, where, as the reactive current generated by the microsource becomes more capacitive, the local voltage set point is reduced.
2. The second physical control method is the frequency regulation through droop. When the Microgrid separates from the grid, the voltage phase angles at each microsource in the Microgrid change, resulting in a reduction in local frequency, this frequency reduction is

coupled with a power increase but the microsources have a maximum power rating.

The Control Methods can be handled by an architecture where there are 3 main components: Microsource Controller. This architecture normally has a control system with a Hierarchical Structure with 3 levels [6], [7]:

- Primary control: ensuring reliable operation.
- Secondary control: power quality optimization (minimize the average of all voltage and frequency deviations).
- Tertiary control: economic optimization (improves the economics of the supply and demand balance).

The academic literature is widely developed and devoted to the primary control; in particular to the conventional droop control method and its modifications, there are important research needs in the levels of secondary and tertiary control.

In order to handle these control levels, the academic works are focused in MAS to coordinate Micrograms, normally they have the following levels [8], [9], [10], [11]:

- In the Grid Level are the Distribution Network Operator (DNO) -refers to the operational functions of the system- and the Market Operator (MO) –refers to the Market functions.
- In the Management Level are the Microgrid Central Controllers (MGCC), they are resposibles for the optimization of the Microgrid operation coordinating the Local Controllers (LC),
- In the Field Level are the LC's, they control the Distributed Energy Resources (DER), production and storage units, and some of the local loads.

## III. Proposed Multi-Agent Approach

The MAS approach´s goal is to control a very complicated system with minimum data exchange and minimum computational demands, in this way an agent has the following characteristics [13], [14], [15]:

- An agent can be a physical entity or a virtual one that acts in the environment or a virtual one.
- The agent changes its environment with its actions.
- Agents communicate with each other.
- Agents have a certain level of autonomy, to achieve this; they are driven by a set of tendencies.
- They have partial or none at all representation of the environment.
- An agent has a certain behavior and tends to satisfy certain objectives using its resources, skills and services. The way that the agent uses it characterizes its behavior; the behavior of every agent is formed by its goals.

According to the above, it is proposed to use as agents the following physically elements (Figure 2) of each Microgrid:

- Deterministic Generation
- Stochastic Generation
- Deterministic Load
- Stochastic Load
- Energy Storage Systems

Figure 2: Physically elements in Microgrids.

The proposed system consists of two layers (Figure 3). One layer is the power network and the other layer is the MAS layer with software agents.

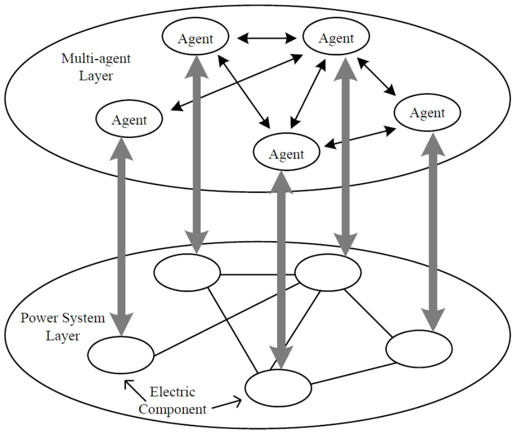


Figure 3: System Infrastructure.

This two layers system can get several Coordination and Control functions by drawing together, in a platform, two modeling tools used extensively in their respective communities: JADE (environment for developing agents) and MATPOWER (MATLAB tool used to get the physical behavior of the electric network).

Since MATLAB is a single threaded programming, it cannot execute two or more programs in parallel, run time changes are not allowed and storage of data more than once is not possible. Due to its single threading nature, peer-to-peer message transfer neither is possible [16].

In order to solve the above, the developed platform works with "matlabcontrol", which is a Java application programming interface that allows for calling MATLAB from Java, supporting multithread simulation.

In this way, "matlabcontrol" would be a communication middleware allowing the MAS to send/receive data to/from the multiple Microgrids network modeling in MATPOWER; thus, it is possible to know the electric status of the components to take the necessary control actions.

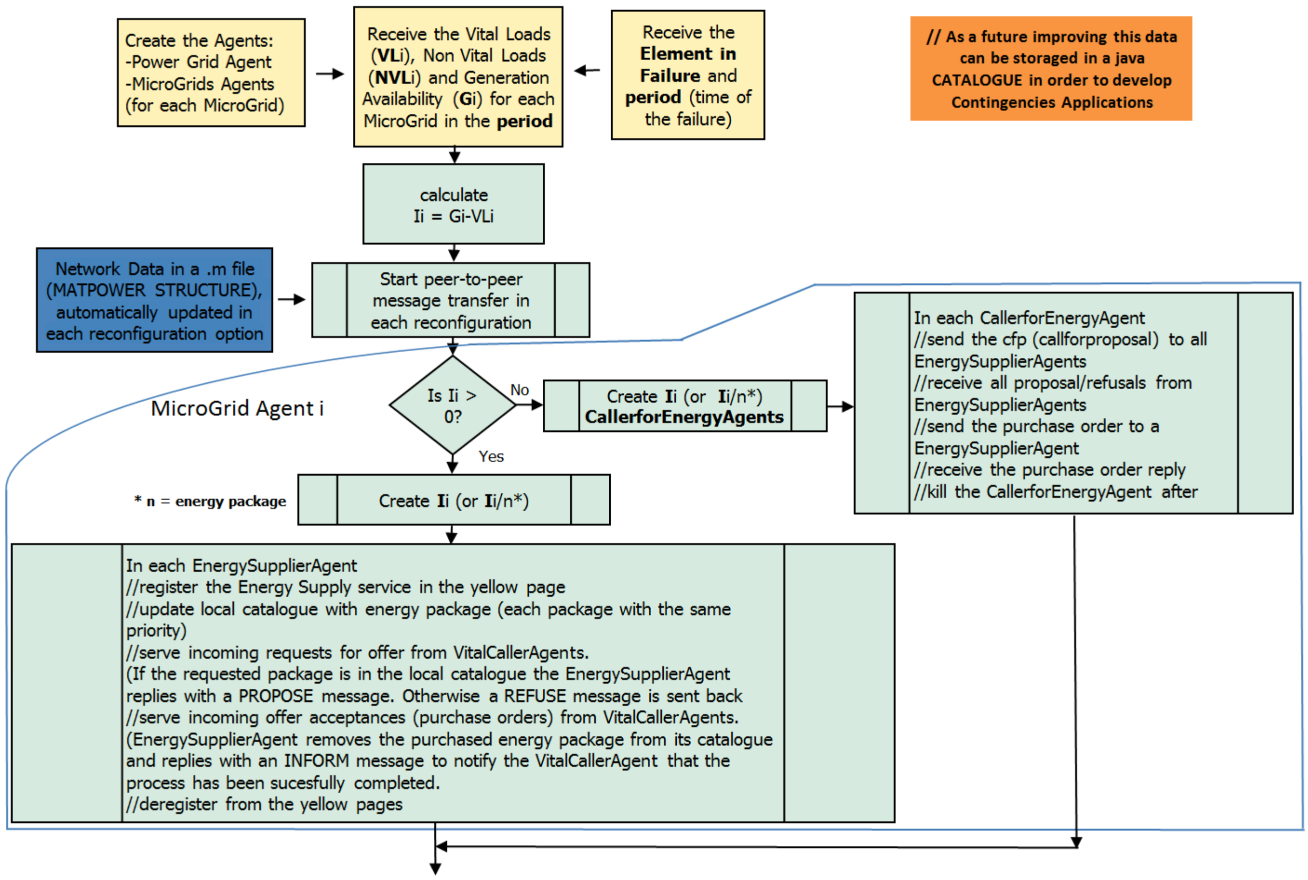


Figure 4: Flow chart with initial input data and vital load supply.

## IV. CASE STUDY: LOAD SUPPLY AND SELF-HEALING

The proposed architecture was applied to solve the problem of load supply and self-healing in a power network with multiple Microgrids under failures in its elements. For the purpose of demonstration the system experiences a contingency scenario with a component in failure; as a result the system must react and recover operations to the all possible vital loads, looking for the topology that can fit the voltage profile restriction and the lower losses.

The steps of the flow chart used are depicted in figures 4 and 5, the boxes in green are coded in JAVA (JADE), the boxes in blue are coded in MATLAB (MATPOWER) and called from the MAS through matlabcontrol, the yellow boxes are input data, and the orange boxes are future developments.

In order to test the proposed flow chart, a network with 5 nodes, 7 lines and 2 Microgrids linked to the power grid was used (Figure 6), the electrical data are from [17].

The developed platform is user friendly with simple graphical user interfaces (Figure 7), where can be introduced the vital loads and non-vital loads of each agent and the available capacity in the moment of the failure in each Microgrid since its variable nature.

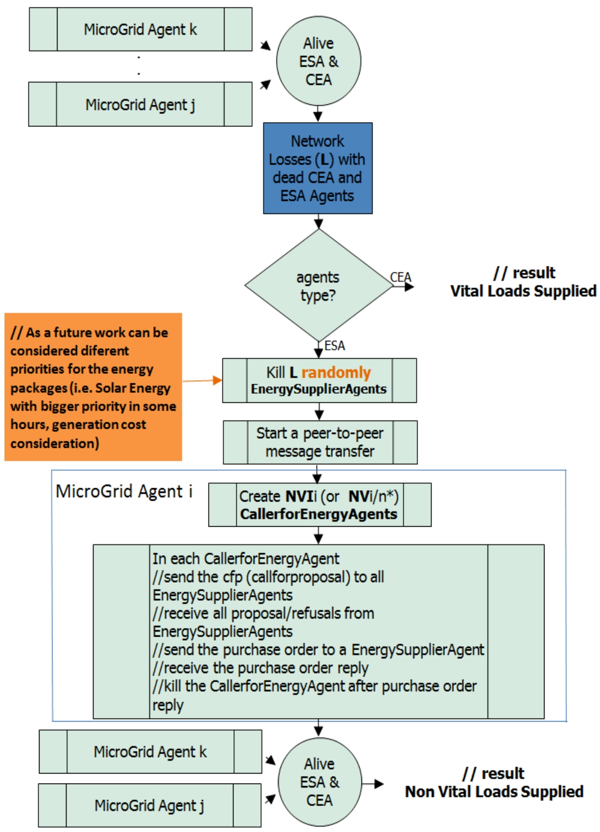


Figure 5: Non vital load supply.

For instance when the line 1 has a failure, the Microgrid agents are asked for available power in that instant and the vital and no vital loads in each node, after the communication between agents and the combinatorial reconfiguration in this case (as a future improvement will be code a bus ranking reconfiguration or artificial intelligence techniques), the platform suggested the reconfiguration with the active lines between the nodes: 1-2, 2-5, 4-5, 3-4 and 2-4, the supplied load is presented in the GUI of each vital and non-vital load.

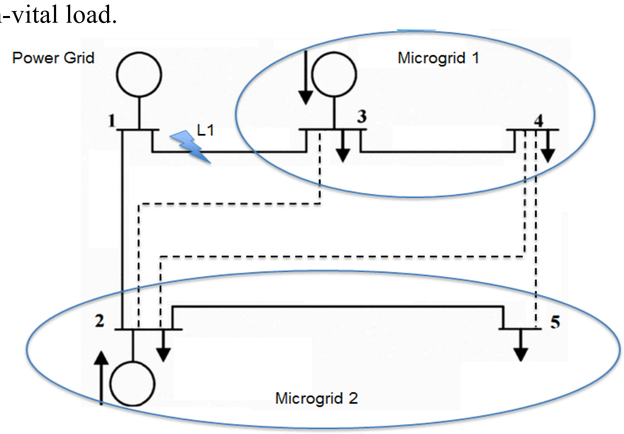


Figure 6: Sample network (2 Micrograds, 5 nodes, 7 lines).

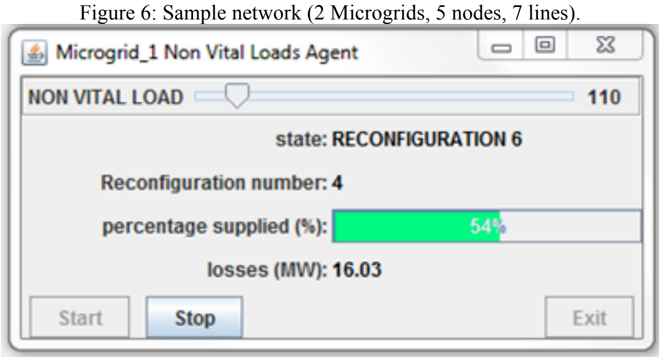


Figure 7: GUI for available capacity, vital and non-vital loads.

## V. Conclusion and Future Developments

The coordination and control task of multiple Microgrids is a decentralized problem that can be addressed through multi-agent systems. In this short communication a MAS platform was implemented and integrated with a power system analysis tool. The developed interface provides the means for advanced modeling and the development of multi-agent control systems, this allow that can be tested the network resilience. As a main future implementation, it is proposed to make a power system dynamics and stability analysis of the network using both JADE and MATLAB modeling tools.

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