# 멀티 마이크로그리드 최적 운영을 위한 멀티 에이전트 시스템 적용

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# Applying Multi-Agent System for Optimal Multi-Microgrids Operation

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**Abstract**

This paper analyzes the capabilities of multi-agent system (MAS) technology for the optimal multi-microgrids (MMGs) operation in grid-connected mode. In this system, communication among microgrids (MGs) is realized by developing a modified contract net protocol (MCNP) based on agent communication language (ACL) messages. Moreover, a two-stage mathematical model is proposed based on mixed integer linear programming (MILP) for local optimization in each MG, and global optimization in energy management system.

## 1. Introduction

A microgrid (MG) is a small-scale distribution power system, which usually contains several components, such as controllable distributed generators (CDGs), energy storage systems (ESSs), renewable energy sources (RESs), and local loads [1]. In order to increase system reliability, several MGs are connected to form a multi-microgrid (MMG) system. Communication between each component in MG as well as with other MGs plays an important role in MG/MMGs operation. Nowadays, multi-agent system is considered as a good alternative to overcome these problems.

Multi-agent system (MAS) is composed of several agents, which can work together. Each agent pursues different tasks to achieve the system's goal. Nowadays, MAS has become a powerful tool for designing complex systems including advantages of agent characteristics, such as autonomy, local view, and decentralization [2, 3]. Recently, multi-agent technology has become an emerging technology for the microgrid operation and control.

In this paper, an energy management system (EMS) is developed for optimal multi-microgirds (MMGs) operation. In the proposed model, the interaction among agents is implemented by using an MAS. Moreover, a mathematical model based on mixed integer linear programming is also proposed for minimizing the total MMG's operation cost.

## 2. Multi-Agent System Approach

Nowadays, MAS has been widely applied to MG operation. Each component in the MG is represented as an autonomous agent aimed with its goal, which can communicates with other agents [4, 5]. In this study, an MAS is developed for MMGs operation in grid-connected mode.

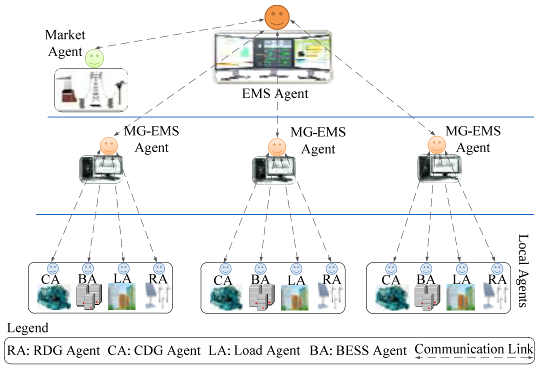


Fig 1. Microgrid communication based on MAS

Fig. 1 depicts interaction among agents for MMG system. In order to carryout communication among agents, a modified contract net protocol (MCNP) is used based on agent communication language (ACL) messages. Fig. 2 gives the interaction between different agents.

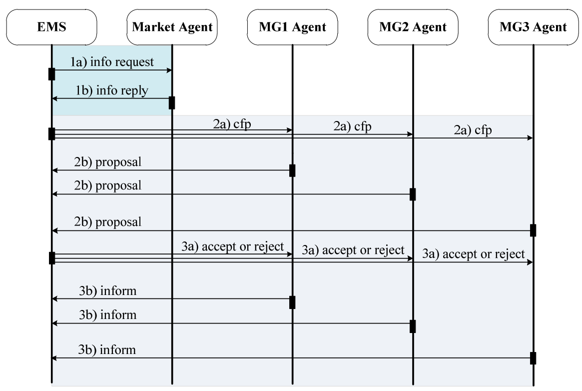


Fig. 2. Modified contract net protocol

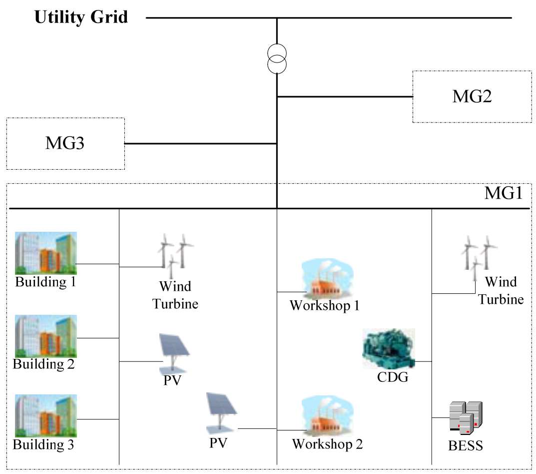


Fig. 3. Multi-Microgrid configuration

## 3. Case Study

### 3.1. Multi-Microgrids Configuration

The proposed model is tested on a multi-microgrid (MMG) system for minimizing the operation cost, which contains three individual MGs as shown in Fig. 3. Each MG is composed of several components, such as renewable distributed generators (RDGs), controllable distributed generator (CDG), battery energy storage system (BESS), and local loads.

### 3.2. Two-Stage MILP-based Model Formulation

A day-ahead scheduling model is presented in this paper for minimizing the total operation cost of MMG system by performing two-stage optimization. In stage 1, each MG performs local optimization to minimize its cost. While, global optimization is performed by EMS in stage 2.

$$\min \sum_{i\in I}\sum_{t\in T}\left(C_i^{CDG}\cdot P_{i,t}^{CDG}+y_{i,t}\cdot C_i^{SU}\right) + \sum_{t\in T}\left(PR_t^{Buy}\cdot P_t^{Short}-PR_t^{Sell}\cdot P_t^{Sur}\right) \quad (1)$$

$$P_t^{RDG}+\sum_{i\in I}P_{i,t}^{CDG}+P_t^{Short}+P_t^{B-}=P_t^{L}+P_t^{Sur}+P_t^{B+} \quad (2)$$

$$\min \sum_{k\in K}\sum_{t\in T}\left(PR_t^{Buy}\cdot P_{k,t}^{Buy}-PR_t^{Sell}\cdot P_{k,t}^{Sell}\right) \quad (3)$$

$$\sum_{k\in K}P_{k,t}^{Buy}+\sum_{k\in K}P_{k,t}^{Sur}=\sum_{k\in K}P_{k,t}^{Short}+\sum_{k\in K}P_{k,t}^{Sell} \quad (4)$$

The objective function of individual MGs is given by (1) for local optimization. Constraint (2) represents power balancing in each MG. The amount of surplus/shortage power is proposed to EMS for performing global optimization. In stage 2, the cost objective function for minimizing operation cost of trading power with utility grid, which is given by (3). Constraint (4) ensures that the amount of shortage to be fulfilled by either receiving surplus power from other MGs or buying from utility grid.

## 4. Simulation Result

In this section, we developed an MAS for communication as well as optimization of operation cost of MMG system. The model has been implemented in Java integrated JADE (java agent development framework) and CPLEX libraries.

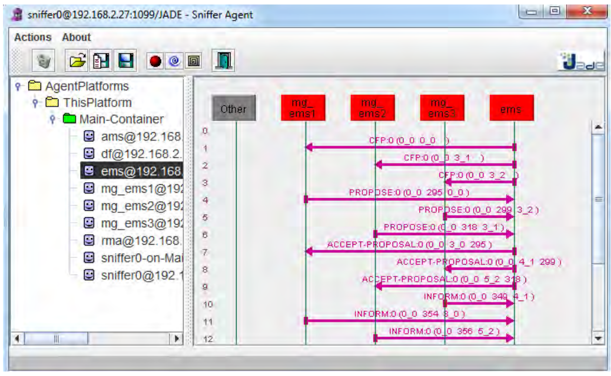


Fig. 4. Message flow among agents

Fig. 4 demonstrates message flow among agents in each stage of optimization. Firstly, EMS agent sends a cfp to each MG agent and receives a proposal (the amount of surplus/shortage) from each MG after performing local optimization. EMS accepts/rejects proposals based on global optimization results and informs each MG. Finally, each MG has to reschedule its local resources based on EMS information and inform EMS at the end of the processing.

## 5. Conclusion

In this paper, an MAS has been developed for optimal MMGs operation. The communication among agents has been implemented by using JADE software. Moreover, the MILP-based mathematical model has been developed for day-ahead scheduling of MMG's operation and the model has been realized by using Java under CPLEX.

## Acknowledgements

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