An Agent-based Approach for Decentralized Control in a Heating Grid

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***Abstract*—The objective of this paper is to discuss the design and implementation of an agent-based model that provides decentralized control of a heating grid – a heating grid consisting of basic CHP plants, boilers, storages and residential loads. An agent-based application development involves model design, agent specification, application design, application implementation and case studies. This application uses JADE to develop the agents and MATLAB/SIMULINK to provide a simulated environment. The simulation results indicate that the proposed agent-based application can operate each heat production unit to meet the future heat consumption by using a priority-based decentralized control.**

Keywords—agent-based model, heating grid, priority control, JADE platform

I. INTRODUCTION

By a significant proportion of district heating in the German energy network, the control aspect towards the operation of heat units are of high importance. Given this fact, an agent-based approach is well suited for providing energy control and management systems in heating grids. A centralized control method is mostly used to operate each DG (Distributed Generator). To improve the robust and flexibility of the whole heating grid, a decentralized control is introduced in this agent-based model.

Agent-oriented software engineering is at an early stage of evolution. Since 1980s, software agents and multi-agent systems have grown into what is now one of the most active areas of research and development activity in computing generally. The most important reason for the current intensity of interest is that the concept of an agent as an autonomous system, capable of interacting with other agents in order to satisfy its design objectives. [1]

Recently multi-agent system technology is taking greater roles in Power System. Zhang Jian et al in [2], discussed the framework of MAS and presented an agent control model aiming at maximizing efficiency of Microgrid. M.Pipattanasomporn et al in [3], demonstrated the design and implementation of the multi-agent system for use in an Intelligent Distributed Autonomous Systems (IDAPS) microgrid.

II. CURRENT WORK

The heating grid usually consists of heat generation, heat storage and insulated pipes and loads.

The heat is often obtained from boiler units, a geothermal source or power plant designed for combined heat and power (CHP) which has a high level of energy utilization efficiency. Heat storage allows the transfer and storage of heat energy. After generation, the heat is distributed to the customer via a network of insulated pipe.

In this paper, a simple structure of heating grid is shown below.

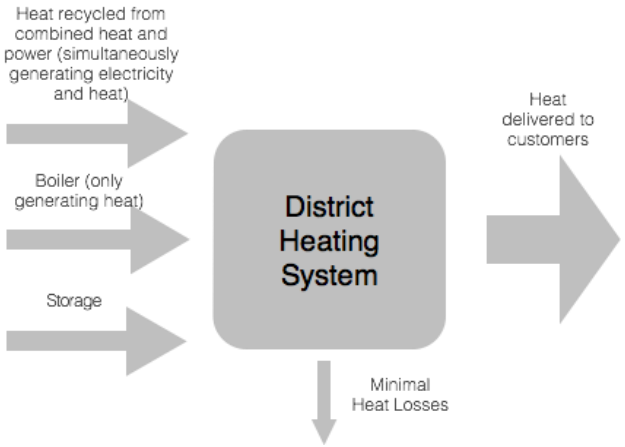

Fig. 1. Overview of a heating grid

Agent-based model aims for simulating the actions and interactions of multiple agents in an attempt to re-create and predict the appearance of complex phenomena. [4] The idea behind an agent-based approach is to break down a centralized system into a decentralized system.

The architecture of an agent-based system is presented in Figure 2.

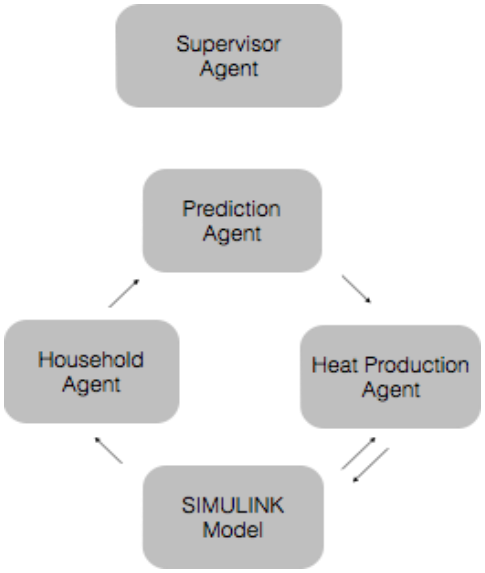

Fig. 2. The agent-based architecture in the paper

As shown, this agent-based system comprises four types of agents. They are household agent, prediction agent, heat production unit agent and supervisor agent. Each agent has unique objective and responsibilities. The whole system works in cooperation, it means these four types of agents will take its own task to achieve the overall goal of heating grid, which is to assign each generator's operation to meet the future heat consumption.

During the implementations, many agent platforms are found for developing agent-based system. It is very important to select an agent platform that is based on a well-known standard -- IEEE standard [5] on Foundation for Intelligent Physical Agents (FIPA). This will help to ensure interoperability among different systems and platforms so that the proposed multi-agent system can be universally accepted. [6]

In this study, JADE (Java Agent Development Framework) is selected for application development. It simplifies the implementation of multi-agent systems through a middleware that complies with the FIPA specifications and through a set of graphical tools that support the debugging and deployment phases.

The agent-based system development involves model design, agent specification, decentralized control design, application realization, and case study.

A. *Heating Grid Model Design*

Since this paper focuses on the design and implementation of agent-based model, CHPs (Combined Heat and Power), boiler, storage and household unit are simply defined.

1) **CHP** thermal output power is only considered to be either 0 MW or maximun MW according to the most common operations of CHP.

2) **Boiler** can be operated adjustable to meet the thermal power demand.

3) **Storage** has input parameters – charging amount and discharging amount. It has an attribute called thermal capacity which stansds for the state of heat storage and can be charged and discharged.

4) **Household** consumed power is based on authetic or realistic sources. Consumption recorded for one year are used in this paper.

B. *Agent Specification*

After the model design step, specifications of each agent are defined.

1) **Household agent** acts as a customer gateway to get data from SIMULINK model and pass the value to Prediction agent.

2) **Prediction agent** gets the weather data and consumption data from household agents, and predicts the future heat consumptions by using current weather data. Afterwards, it gives the data to each power generator agent.

3) **Heat production agent** is responsible for coordinating themselves to decide the operation mode by a priority-based decentralized method. After the decision, it will pass the final decision to supervisor agent and SIMULINK.

4) **Supervisor agent** is responsible for monitoring the whole grid, recording the operation mode and handling errors.

C. *Priority–based Decentralized Control*

In order to show a complete and reasonable interactions among heat production unit generator agents, four specified agents are defined: 2 CHP agents, 1 boiler agent and 1 storage agent. To realize the decentralized coordination among them, priority-based method is proposed by considering financial and environmental aspects.

III. CONCLUSION

This paper presents an agent-based approach for decentralized control in heating grid. The proposed system was developed using IEEE FIPA standards, and priority-based decentralized control displayed much potential for the autonomous operation of heating grid. It means that the highest priority agent has the right to decide its own operation first.

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