AN INTELLIGENT CONTROL HYDROPOWER SYSTEM BASED ON MULTI-AGENT THEORY

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ABSTRACT

In order to achieve the potential of existing power stations, increase the efficiency of waterpower, and change the running of power stations from an individual plant basis to centralization, many people have researched the automation of power stations over the years with excellent results. However, in reality there are no power stations that have been fully automated. This paper proposes a control system based on Multi-Agent Theory, including a management agent, communication agent, control agent, echo agent, and so on. These agents are able to harmonize automation and intelligence to provide effective control of the running of a hydropower station. The end goal is a real control system that can operate independently of human intervention.

Keywords: Multi-agent, Intelligent control system, Management agent, Communication agent, Function agent, Power plant control

1 INTRODUCTION

Power systems are the most important and most extensive of the modern social pillar industries. Because of the ease and diversity of electrical energy production, transmission, distribution, and use, electrical energy is increasingly playing an important role in all aspects of social life and has become a major energy source in the development of modern society. However, because today's modern industrial and social development requires large amounts of electricity, there are serious waste problems in the production of electrical energy because of the absence of good control systems. In order to solve this problem of wasted resources, many researchers have proposed that hydropower stations should put economic operations in practice and have researched this academic and technical problem in-depth. Many algorithms for the optimal distribution load of power stations and automatic control methods of operation have been produced, but they do not combine the positive results of two aspects: intervention and correction for imperfect communication are still needed for coordination of the automation process.

Along with the development of science and technology, man's understanding of his own behavior and the social colony is constantly deepened. Scholars in the field of distributed artificial intelligence have abstracted divisions of the collaborative nature of social behavior into Agent and Multi-Agent Theories. Generally speaking, an agent is a kind of independently-calculated entity or procedure that can perceive the environment under a specific social environment and can flexibly and independently operate to achieve a series of design objectives. A Multi-Agent System (MAS) (Xiao & Cai, 2006; Zhou & Gao, 2004; Zhou & Sun, 2003; Jennings et al., 1998;

Shen, 1998) refers to a computer system that uses multiple agents to complete certain tasks or achieve certain goals by cooperation. These agents cooperate to solve problems above their individual capacities; they are autonomous and distributed operations. There are cooperation and the sharing of services between every two agents. The objectives and conduct often have contradictions and conflicts. Through competition or consultation to solve these problems, the agents complete a task. A multi-agent system requires that the exchanges among agents in the system have the capability of intelligence or auto-organic activities, such as reasoning, planning, learning, etc.

Once the Multi-Agent Theory was put forward, it was quickly and widely used in various fields of study and achieved fruitful results. However, in the field of electrical systems closely linked with automation and control, the combination and application of multi-agent and automatic control theory are very few, particularly for hydropower station operations. Thus, creating a hydropower station operating control system based on the multi-agent systems theory, to control the operations, will provide an important basis for achieving intelligent control.

2 INTELLIGENT CONTROL SYSTEM OF CONTROL SYSTEM OF HYDROPOWER BASED ON MULTI-AGENT THEORY

In an intelligent control system for hydropower operation based on Multi-Agent Theory, in accordance with the requirements of control, the system is divided into a number of agent subsystems and agent modules based on functionality. These subsystems and modules are scattered geographically and are relatively independent of the function of each module, but each module's sole function is to serve the entire system. Intelligent modules in the system share system resources and communication, as well as coordinate with each other to control the whole system. Furthermore, an intelligent control system of hydropower stations operating on a multi-agent theory is different from the traditional system of modular and simple distributed control. The traditional modular system only requires each system module to have the ability to do conventional calculations and control rather than to be autonomous and intelligent. Simple distributed control only emphasizes that functions will be scattered, but each part after scattering does not have mutual communication and coordination functions. Only the control module with independence, intelligence, and communication coordination is, in the real sense, an intelligent control agent.

2.1 Model of an intelligent control system of hydropower based on Multi-Agent Theory

A control system uses different control types. According to the operational characteristics of hydropower stations, the whole system uses hierarchical control types, with each subsystem under the central control. According to the requirements of hydropower operational control, the station operational control system based on Multi-Agent Theory can be divided into three types: a **communication module** to establish contact with the network and receive and send information from and to the network; the **agent federation module** composed of several sub-modules (agents) to achieve economic operation of the station, by determining the optimal load distribution among the units through coordination and communication; the **federal agent module**, which controls each unit and ultimately puts the optimized parameters into practice for each individual unit. In each unit, the federal agent composed of several functional sub-agents to control the operation of the units, simultaneously working with the upper level agent. The specific model is shown in Figure 1.

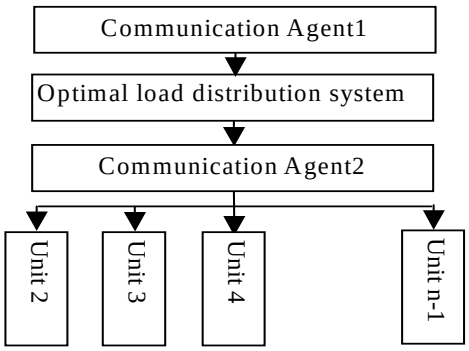

Figure 1. System level structure chart

2.2 The categories and basis functions of agents in the system

In the model, the entire system can be divided into three categories: **communication agent, management agent,** and **function agent**. The **communication agent** is primarily used to coordinate communications among agents. In a multi-agent system, every agent communicates with the others, and if we do not categorize like agents together to simplify communications among agents, the entire system would be a very complex communications network. The use of the communication agent makes the entire system of communications very simple, rapid, and efficient. The communication agent receives information, classifies accepted information, and sends the information to agents with different functionalities.

The **management agent** is the central control unit of the entire system. The entire system has three levels of management agents. The top management agent is used to coordinate and manage the optimal load distribution system and the optimal start-and-stop-sequence-confirm system. It is very easy to locate in the level chart of system. There are two levels of management agents in an optimal load distribution system: the optimal start-and-stop-sequence-confirm system internal management agent and the unit control system management agent. The main function of these two levels is to coordinate the functions among multi agents in each subsystem, distribute tasks to each function agent, and receive the results of their completed tasks. Then they analyze the results and ultimately determine whether the subsystem task has been completed, simultaneously transferring the messages that need to be sent to the other subsystems by the communication agent.

The final category is a **functional agent**. In addition to a management agent, which plays a control role in each subsystem's internal workings, there are a number of functional agent modules. Each functional agent has its own task in accordance with the different task name corresponding to it. Every functional agent receives its task from the management agent, accomplishes the task, and then returns the results to the management agent.

2.3 The composition of the agents

Each agent is composed of a generic agent kernel and many functional modules. The agent kernel consists of an internal database, communications coordinator, blackboards, and an executive. Among these, the internal database includes the information about itself (agent-self), the target muster, the world model, and so on. The agent communication processor provides the mechanism (language and codes) with which the agent communicates with the world and other agents. The blackboard supports the agent's internal communications

among the various functional modules. The executive completes the assigned tasks and acts as the functional module's implementation control. One agent can have many functional modules. These modules are pre-compiled and executable files, are relatively independent entities, and express some functional properties and functions also exhibited by the agent, which can have fully parallel implementation after being launched by the executive with work coordinated by the blackboard. The next subsection looks at the core structure of the agent.

2.3.1 Internal database of the agent

The internal database of an agent includes a description of the agent-self, a description of the state of the world, and a description of the state of the other agents.

2.3.2 Model of the agent world

Agents are located in a group called the agent world. Every agent needs to have a description of the agent world in order to communicate and collaborate with other agents. The description is not a complete description and only describes the sensory information of the agent. This information is located in the agent's internal database. It is not pre-defined by system development personnel, but is built during the agent's active use.

2.3.3 Executor of the agent

The function of this part is similar to the process management in an operating system, but its management is done with functional modules. Each agent executes the same control loop.

2.3.4 Joints linking the agent with functional modules

Communication between the agent kernel and the function modules is completed through the blackboard, which provides a set of standard programming joints for communication between the kernel and the functional module and allows for convenient communication between the agent and the modules.

2.4 The communication and coordination between agents in the system

In the whole system, the functions of the communications agent are the simplest. Those functions, which link communication between the upper and lower federal agents, receive and classify sent information, so this agent's communication with the other agents is simple and not elaborate. According to the level structure chart, (Figure 1) the main communication and coordination tasks focus on load optimal distribution. as discussed below.

2.4.1 Communications and coordination between the load optimal distribution system and the unit agent federation.

The main function of the load optimal distribution system is, after receiving the load task from the management agent, to determine the optimal load distribution and then send the results to each unit's agent federation. After the agent federation of each unit has received the information, the status of every unit is measured to determine whether it can perform the task assigned by the load distribution system. If it cannot, then this information is returned to the load distribution system. Because every hydropower station consists of at least two units,

according to the usual mode of communication, the load distribution system creates a communications network between the generating units. In order to communicate quickly and efficiently between the load distribution system level and the unit control system level, a communications agent is used. The received message from the load optimal distribution system level, which is classified and analyzed by the communication agent, is then sent to the corresponding unit control system.

2.4.2 Load optimal distribution system

The load optimal distribution system is a multi-agent center control system consisting of a management agent and three functional agents. The management agent manages and coordinates the work of several functional agents and links with the outside world. It accept the tasks for these sub-systems from the outside world and then sends a message to a chosen functional agent, waits for the task to be accomplished, and receives a reply from the agent that the task has been accomplished. This process continues until the tasks of the entire sub-system have been completed and the management agent finally sends the result message to the lower units of the operation control system. The function of each functional agent is to receive the task information from the management agent and to fulfill this task, then inform the management agent that the task is completed. The specific communication and coordination are shown in Figure 2.

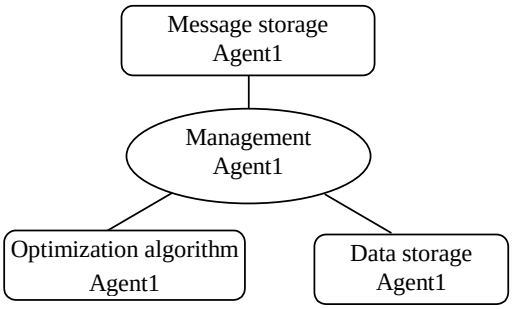

Figure 2. The structure chart of a load optimal distribution system

2.4.3 Federal agent units

Each unit in a multi-agent central control system consists of one management agent and several functional agents. The functional agents include: data storage agent, message storage agent, optimization algorithm agent, state detection agent, and operation control agent. In all agents, the functions of the management agent are coordinated with the top agent to receive and deliver information, to manage and coordinate internal communications within the agent world, and finally to complete the tasks of the subsystem.

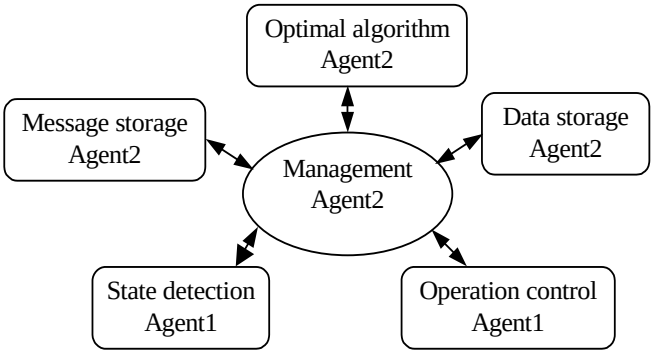

Figure 3. The federal agents of unit control

3 CONCLUSIONS

The problems of the economical operation of hydropower plants have a very long history. Despite the existence of much research, most generate theoretical results, which have never actually been put into practice. In order to carry out the results of theoretical studies, it is essential to create a control system for the economical operation of a hydropower station. This article discusses how Intelligent Multi-Agent Theory can create an intelligent control system for hydropower stations. This intelligent control system is very different from previous approaches. It combines optimized computation of a station's economical operations with automatic control of the power plants and introduces a multi-agent, intelligent control system to improve a hydropower station's efficiency. In this multi-agent system, agents with different objectives all work together with mutual coordination and consultation to improve operations. Combining multi-agent theory and optimization to create a more economical hydropower station operation control system will greatly improve efficiency and reduce the operating costs.

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