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Research on Dynamic Intelligent Information Processing Method for Distributed Generation Systems Based on Multi-Agent Techniques

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Abstract

Distributed renewable energy generation is lack of intelligent information processing and decision-making section. The above problems can be solved effectively by the means of intelligent information processing technology based on the dynamic structure of multi-agent for distributed renewable energy. In order to solve the problems of less data and poor information, this paper puts forward fuzzy hyperbolic model and attempts to use dynamic intelligent information processing technology based on multi-agent to change the unreliable, inaccurate information into be full, reliable and accurate. And then the information we have obtained could be intelligent fitted, filtered and decided. The self-organizing self-learning and reasoning ability of multi-agent are considered when the information processing. The intelligent information processing section is comprised of three layers and two kinds of agents. The two kinds of agents are Bus Agents and Coordination Agents, and the three structural layers are the data layer, the filter layer and the policy making layer. Moreover the information have been processed could be utilized.

Keywords: *Distributed Renewable Energy Generation Systems, Fuzzy Hyperbolic Model, Multi-agent, Intelligent Information Processing*

1. Introduction

Distributed renewable energy has a lot of advantages, such as save energy, reduce grid expansion cost, reduce energy loss and enhance power reliability. Recently the mode of electric power system has changed from centralized to hybrid supplied, that means the main power system and distributed power systems are coexist, intelligent information processing of distributed renewable energy is one of the key fundamental problems. The model of a hybrid system composed of photo-voltaic and micro turbine was established [1], specify their joint output power constant at grid or islanding. But it can't change follow the load when islanding, has some limitations. Multi-agent information collection system was used to manage and restore the power system after a failure in [2]. But it not introduce the working process of the multi-agent, and not classify and layer the multi-agent. The information of distributed renewable energy generation system is intermittent, random and complex. As the time and resource is constraint, the coordination and cooperation becomes particularly important when solving the problems that allocate resource, schedule task, coordinate behavior and resolute conflict. This paper uses the ability of multi-agent to intelligent process the dynamic information of distributed renewable energy, firstly fuzzy hyperbolic model is presented to simulate the information of distributed renewable energy generation system. Moreover the information processing section is divided into three layers, they are the data layer, the filter layer, and the social

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layer. The data layer fuse the information data transmitted from sensors, and store the results in the database. The filter layer filter the feature data through Belief Revision Function. The policy making layer perform information reasoning and data fusion through the knowledge model of knowledge base, and achieve information sharing, self-learning and modeling by collaboration and coordination among multiple CA. Finally the information we want was obtained.

2. Fuzzy Hyperbolic Model of Distributed Renewable Energy Power Generation System Building

For the foundation of the entire theoretical system research, the accurate mathematical mode is difficult to obtain because of the multi-source combined distributed renewable energy generation system is a nonlinear multivariable object. Reference [3] proposed a new nonlinear space model called fuzzy hyperbolic model which can solve the problem of the establishment of systems model effectively.

As the fuzzy hyperbolic model is a kind of global model, optimal controller according to this model could make the system achieve optimal performance. Compared with other fuzzy models, fuzzy hyperbolic model is more suitable for the multivariable nonlinear objects which knows little about the objects controlled. It is seen by the following, we can get the models as we know the fuzzy inference relationship between the derivative of state variables, state variables and input variables.

Meanwhile fuzzy hyperbolic model can be seen as an extension of the linear model. If a linear system is robust stable, the corresponding hyperbolic tangent system is also asymptotically stable. Therefore, we can convert a hyperbolic tangent problem into a robust stability problem of linear system which is easy to be solved.

In this paper, we use fuzzy hyperbolic model to describe the model of a variety of distributed renewable energy generation system, the simplified equation:

$$\dot{x} = A \tanh(Kx) + Bu \tag{1}$$

If you know a fuzzy hyperbolic model, define a new state variables and input variables:

$$y_i(t) = m_i x_i(t),\ m_i > 0, i = 1,2,\cdots n \tag{2}$$

$$v_i(t) = n_j u_j(t),\ n_j > 0,\ j = 1,2,\cdots p \tag{3}$$

A new model can be obtained as follows:

$$\dot{y} = M\dot{x} = M\ (A \tanh(Kx) + Bu) = M\ (A \tanh(KM^{-1} x) + MBN^{-1} v) \tag{4}$$

$$\mathrm{M} = \mathrm{diag}\ (\mathrm{m}_1, \mathrm{m}_2, \cdots \mathrm{m}_n),\ \mathrm{N} = \mathrm{diag}\ (\mathrm{n}_1, \mathrm{n}_2, \cdots \mathrm{n}_n).$$

By defining the appropriate membership function, fuzzy and clear methods, fuzzy rule base is equal to fuzzy hyperbolic model. If a set of hyperbolic tangent type fuzzy rule base is given， we define membership function of P_2 and N_2 (In which z is an arbitrary state variable or input variable):

$$\mu_{P_Z}(x) = e^{-\frac{1}{2}(x-k_Z)^2} \tag{5}$$

$$\mu_{N_Z}(x) = e^{-\frac{1}{2}(x-k_Z)^2} \tag{6}$$

k_Z is a constant greater than zero, the mathematical model can be result according to this rule:

$$\dot{x} = A \tanh(Kx) + B \tanh(k_u u) \quad (7)$$

$k_x = \mathrm{diag}(k_{x_1}, \cdots k_{x_n})$, $k_u = \mathrm{diag}(k_{u_1}, \cdots k_{u_p})$.

3. Dynamic Intelligent Information Processing Based on Multi-Agent of Distributed Renewable Energy Generation Systems

The intelligent information processing system considered in this paper is comprised of three layers and two kinds of agents. As is shown in Figure Two, two kinds of agents of system are Bus Agent (hereinafter to be referred as BA) and Coordination Agent (hereinafter to be referred as CA), three structural layers are the data layer, the filter layer and the social layer.

BA: Bus Agent, a BA corresponds to one node, always resist in the power system;

CA: Coordination Agent, which excited to exist when the information is proceed intelligent, automatically disappear when the task finished;

The data layer: the BA working in this layer fuse the information data transmitted from the sensors and store the results in the database.

The filter layer: the CA working in this layer filter the feature data by the Belief Revision Function.

The policy making layer: The CA working in this layer use the knowledge model of knowledge base to perform information and fuse the policy-making layer data. It can also achieve information sharing, self-learning and modeling by the collaboration and coordination between the multiple CA. The dynamic intelligent information processing structure is shown below:

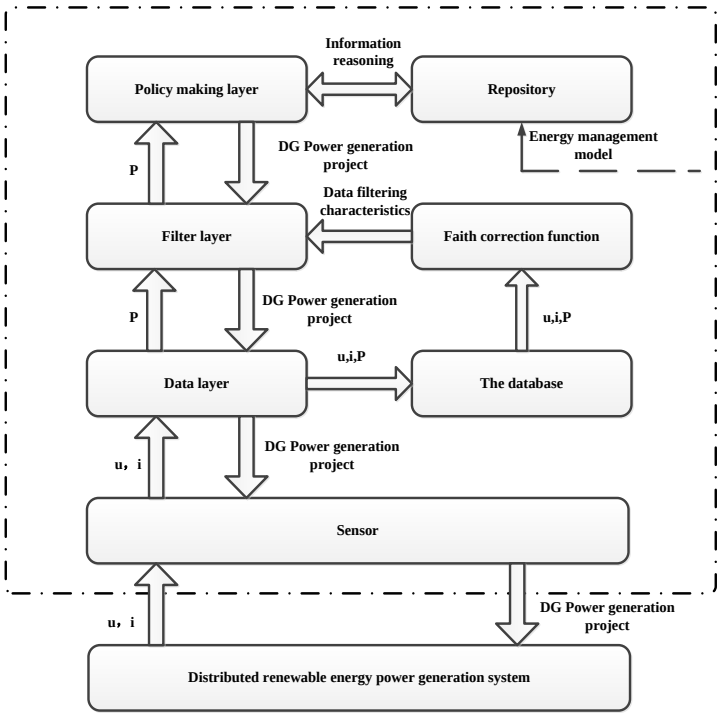

Figure 1. Dynamic Intelligent Information Processing Structure

This section of dynamic intelligent information processing based on multi-agent characterized by:

(1) The architecture of dynamic multi-agent system could be adjust between the distribute architecture and multi-level structure according to the complexity of processing intelligent information tasks.

(2) When the system does not detect the intelligent information processing tasks, just a small portion of agents to be used to daily data storage operations; Once detect the task occurrence signal, corresponding agent is activated immediately;

(3) According to the varying complexity of the intelligent information processing tasks, system is available to provide effective topical CA solutions or global CA solutions to make the "partial information" change gradually into complete, reliable, accurate, consistent and certain information.

3.1. Working Process of Data Layer

A BA is a static agent and permanently associated with a physical bus. A BA will be eliminated only when its corresponding physical bus is removed from the power system. A BA monitors the status of the physical bus.

Monitoring data of distributed renewable energy are the output voltage and current of the distributed power supply. Each supply are installed by a current sensor and a voltage sensor. Firstly, the data level fusion, direct to fuse the raw data collected by the sensor, achieve the fusion estimation method of a single sensor based on the time [4].Unified the multi-sensor information into a common temporal reference system, change the various kinds of information at the same level to the same form of expression. We use the test information and data exchange standards based on Extensible Markup Language-Automated Test Markup Language to describe the basis of measurement data obtained, achieve interaction of each agent in information processing and sharing [5]. Finally, the data have been fused in the data base agent. The agent is mainly engaged in database queries and assist other agents to access the database quickly and efficiently and then obtain necessary data and knowledge in time.

3.2. Working Process of Filter Layer

The distributed renewable energy generation system is less of data, poor information, uncertain, spatial dispersion and randomness. These shortcomings results to the incomplete, unreliable，inaccurate, inconsistent and uncertain of the information stored in database of data layers. So we need to conduct BDI (Belief-Desire-Intention) model of agent construct belief revision function to filter the data of database, obtain the characteristic data required. The CA working in the filter layer receives the task information from the data layer.

3.2.1. BDI Modeling: The agent describe the information of the multi-agent system through data representation, the internal data of agent can be attributed to agent's mental status. Mental status is the key factor to decide the agent's behavior and performance. The research by Bratman, Rao and Georgeff have seen the system as a rational agent, it has belief, desire and intention and other mental states. We call this model as the BDI model. It try to establish a relative complete symbolic representation system, obtain independent thinking and decision-making ability by knowledge reasoning.

Belief, desire and intention, as the main mental state, play different roles in the determination of the subject behaviors.

(1)Belief is a collection including the world beliefs and self-beliefs. Belief is the perception of the world, it contains the data that describe environmental characteristics and the function itself, is the basis of agent thinking activities. Belief is different from knowledge, or you can say, knowledge is the true belief. Belief presents an agent's information of the world, however, it is not a true proposition, both can be confirmed also be disproved (This information is incompletely or wrong).

(2) Desire is the primary motivation of the main agent. It is a collection of its desired state or the state want to keep. The state can stimulate the planning and action of the system. Generally, desire can be expressed as a kind of expectation and judgment of the

agent to the environmental state. That is by determining whether the state is set up as the signal to achieve the desire. Agent may have desire incompatible, and do not need to believe it can absolutely achieved.

(3) Intent is selected from the aspirations which commitment to achieve, the aspiration is the most needed or the best suite to achieved. It is the intention of the state of thinking, the current intention guide to the current action.

Desire and intention both are the state of a subject desired, generally considered, the differences are: Intent is a measure of commitment, it will guide and control the future activities of main object. It plays a vital role in the practical reasoning. Desire is the goal that the main try to achieve, this target subject may have the opportunity to achieve, or never to achieve. As long as the main produce a certain intent according to the promise or collaborative knowledge, the intention will drive the main to find the right means to achieve this intention, until this intention end. The most obvious nature of intention is that it will lead to behavior [7].

3.2.2. Construction of Belief Revision Function: Firstly, deliver the data stored in the database of the data layer to belief revision function in the filter layer, CA establish the belief according to the data transferred to represent the voltage, current, power values of physical bus at time t. A desired portion section represent the theoretical expectations of the bus, then CA use belief revision function to filter by comparing its beliefs and desires, finally, we get the voltage, current, power which can represent actual state of the physical bus.

Belief revision function is defined by Wooldridge in this paper:

$$brf\ (\text{belief revision function}) : p(Bel) \times percept \rightarrow p(Bel)$$

$$deliberate : p(Bel) \rightarrow p(Int)$$

$$plan : p(Bel) \times p(Int) \rightarrow Plan$$

So the deliberative process of agent will be divided into two steps:

1. Generation Options: Agent generated a collection of possible options what want to do:

$$options : p(Bel) \times p(Int) \rightarrow p(Des)$$

2. Filtration: Agent selected from competitive options and promised to complete.

$$filter : p(Bel) \times p(Des) \times p(Int) \rightarrow p(Int)$$

3.3. Working Process of Policy Making Layer

The CA working in policy making layer is not always present, it get activated when get the task request, after the work procedure finished, the CA in a dormant state, always ready for the next activation. Reach the goal that adjust the structure between the distributed and the multi-level according to the complexity of the task, greatly reduce the cost of the system. There is not only one CA during the operation, it can exist multiple CA, and process information through collaboration and coordination between multiple CA. Finally we get complete, reliable, accurate, consistent and determined information.

3.3.1. Information Reasoning Based on the Knowledge Model of Knowledge Base: The Agent response to the information received based on the model of knowledge base directly, that is Cognitive Agent or Reactive Agent. Cognitive Agent which also called deliberative agent has the ability of intelligent behavior and environment reasoning. Each knowledge model can be used to accomplish the specific problem-solving capabilities.

The Reactive agent use a plurality of reactive agents as the internal entity of system. This method receive the external environmental information by the sensors, analysis and process the external information, then act on the external environment in the form of "condition - action" according to the rule of predetermined.

This paper use multi-agent situation reasoning algorithm based on the information entropy [8], each individual agent iterations each state select the inference result that make the entropy minimum (that is the most informative) of inner system of agent based on the current state.

The state selection of multi-agent system is much more complex. It require cooperation of multi-agent, and each agent of system predict the environmental changes associated with its own by reasoning, then choice behaviors according to the information obtained from the environment. The reward of the system is a maximum of total returns of all the agents. The behavior that agent selected the maximum expected utility is a performance of ration. The principle of maximum return is a basis of rational agent to choice correct behavior.

3.3.2. The Data Fusion Based on Multi-Agent Cooperation: As the limitation in resources and ability of single agents, it needs the cooperation between multiple agents to complete the task. In an open, dynamic and multi-agent environment, multiple agents with different targets must coordinate to its target, coordinated use of resources to guarantee the orderly collaboration. How to coordinate the agent's behavior multi-agent coordination is the key to realize the work coordination, conflict resolution, conflict management. We can say, the coordination is an important means to realize the coordination, and the cooperation is the ultimate goal of the coordinated. There are two main negotiation models:

1 Contract-net Negotiation

Contract- net protocol is a typical representative of the consultation model [9]. Contract-net negotiation is a kind of distributed problem solving framework negotiation model based on negotiations, which is raised by R. Davis and R.G Smith in 1951. Its main idea is to negotiate every problem solved by the means of communication, namely that through tendering, bidding, bid processing between the nodes to distribute the tasks, solve the resources and the knowledge conflict.

2 Game-theory Negotiation

The model based on game-theory negotiation was firstly raised by Rosenschein. He was the first to use the game-theory to analyze the MAS negotiation process. In game-theory as the basic theory, he set up a rational agent, and the static model of interaction. It's the formal theoretical basis of multi-agent coordination and collaboration.

When the information fusion technology is applied in multi-agent systems and the local information data perceived by other intelligent agent of the space distribution by the means of data fusion based on multi-agent cooperation is fused, then a complete situation assessment will be gotten. Implementing a way of data fusion based on multi-agent cooperation, and at the same time planning and coordinating the multi-agent system cooperation behaviors with fused information.

Obtaining comprehensive and complete information used multiple sources mainly reflected on the fusion algorithm. There are main points for information fusion method to operate the categories of data directly, such as weighted average, neural network and so on; using statistical characteristic of the object and the probability model to operate ,such as Kalman Filter, Bayesian Estimation, Bayesian Estimation, Statistical decision Theory *etc.* The methods based on rule reasoning, such as Fuzzy Reasoning, Evidence Reasoning, and Production Rules *etc.* In information fusion algorithm, the main consideration is how to choose appropriate and effective algorithm to achieve the optimal expectations for the

practical application system. Different algorithm is suitable for different fusion system, we should make a reasonable compromise choice for the real-time, accuracy and robustness of the algorithm according to the practical problems is very important [10]. At the same time as we can see, the fusion algorithm is essentially the forward algorithm namely from junior to senior, low-level sensors to collect information, extract information, high-level fusion center to the fusion and judgment, to make decisions. Then each agent obtained the feedback from the fusion center, and the purpose is to maximize the decision-making accuracy of the information fusion system.

After the introduction of information fusion technology, there are two types of multi-agent system's agent:

(1) The Management agent: Collecting and processing information from collaboration agent, at last using the information fusion result to make team planning, including the definition of the decomposition and the order of the task. Management agents could communicate with each other directly.

(2) The Coordination agent: Collecting the environmental information and sending to management agent, and completing the task according to the planning management agent. At the same time, cooperation agent has a certain capacity for independent decision making, in the case of not receiving MA instructions, it will be in accordance with their own decisions. Coordination agent can communicate with the corresponding management agent directly.

In this paper, the concept of management agent of reinforcement learning has been introduced [11], the reinforcement learning comes from behavior psychology. The behavioral learning is seen as a process of trial and error. Thus the environment state is mapped into the corresponding action. Reinforcement learning is a learning method between supervised learning and unsupervised learning, and it has gained more and more applications. In reinforcement learning, learners were not told what actions to take like most of the study, but to get the maximum reinforcement signal by trying to find all kinds of behavior. The reinforcement signal is a review of the information fusion results. Through the reinforcement signal, the information integration system can get more effective information for environment, ongoing self-adjustment, gradually adapt to the environment, and reach the expected goal. Each management agent receives messages from the collaboration agent, gets the feedback from the fusion center and used the method of reinforcement learning to maximize information integration system of decision-making accuracy. Reinforcement learning process not only can improve the performance of the system, but for each management, the individual performance can be improved after the continuous reinforcement learning process.

At the same time in order to enhance the system's fault tolerance and adaptive ability, multiple management agents are set up based on the system size, and each management agent is responsible for a certain number of collaboration agent. Collaboration agent can use its decision-making algorithm to pretreated, then send management agent the characteristics of the information raised. Management agent uses Markov model [12] to make decision and then realize the information fusion.

3.3.3. Communication Mode Between Multi-agent and Improvement of Communication Model: The communication mode between multi-agent always be wireless，in the multi-agent system, communication is the basis of the communication and organization among agent. Communication topology of multi-agent is similar to computer network, roughly divided into a star, ring, tree, bus, mesh and so on. Bus architecture is the most used topology form in multi-agent communication system, the advantage of it is its better robustness. Capability of communication is an important feature of Agent.

According to the communication mode, agent communication is divided into: blackboard system, federal mode, radio mode, point to point mode. The following were introduced:

1 blackboard system

Blackboard model structure is a model to solve the cooperation among many entities to complete the task parallel and distributed computing in different physical environments. The model enables the integration of heterogeneous knowledge sources. The model of it is usually composed of three main parts: the blackboard, knowledge source, control mechanisms, as shown below.

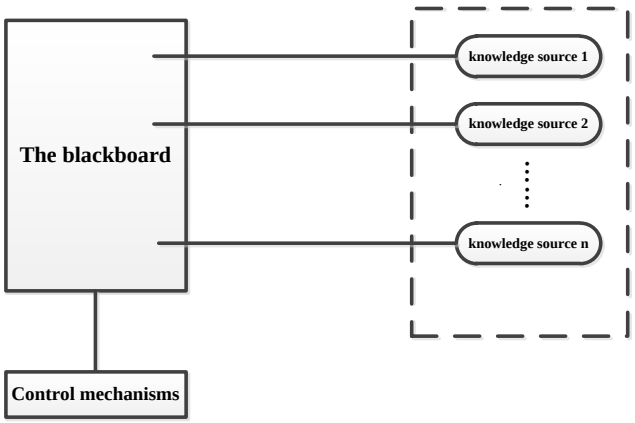

Figure 2. General Principles of Blackboard Model

The blackboard is used to store the raw data, part of the solution and complete solution in the problem solving process, it is a dynamic data base. An agent write information items on the blackboard, other agent in system can use it. Because agent will generally use the way that find keywords to find information about the current job when reading, thus, also present the corresponding requirements to the way that information record. In blackboard system, every agent is independent, they can ‘t transfer with each other directly, obtain the appropriate information required by the public service area, they can only communicate through a blackboard, each agent complete their sub-problems independently. The features of blackboard system are centralized control, share data, to solve a single task, and high efficiency. The disadvantage is that centralized control by the scheduler, the complexity of scheduler often become a bottleneck of system, the structure of shared data is difficult to use heterogeneous data sources flexible, solving a single task make blackboard system can't accomplish interconnected task effectively.

2 federal mode

When the number of the agent of system is quite huge, traffic and the cost of direct communication is quite amazing. A popular alternative is to organize these agent according to federal way, inside of each group are equipped with a meson agent, each agent only communicates with the media in their group directly, to receive, forward messages through the media, this greatly reduces the number of connection link between Agent.

3 radio mode

In this way, every message issued by every agent is received by all of agent Messages in this way are divided into two types, Public messages and direct messages. Public messages are sent to all of agent directed message is sent to an agent, other agent can also receive, but the Agent flagged in the message content, if the agent discover the flag, then

deal with it, other agent don't discover the flag, then ignored it. This approach is often used in the case when system is simple, and message type and number are less.

4 point to point mode

Generally use the TCP/IP protocol, to establish a physical connection link between the communicate agent. TCP/IP protocol can ensure the information package arrived safely, because it confirmed the end to end. Physical connection means that an agent must know the displacement of other agent in system, agent address either as apart of broadcast information received from the other or obtained from the object which is responsible for agent registration center in system.

Multi-agent often use Client/Server (C/S) and Peer-to-Peer (P2P) communication model, following will describe these two communication models.

1 Client/Server (C/S) model

In the communication system based on the C/S model， communications among computing inter process must be "transit" through communications server. There has a central server in system. All the client process and server process can communicate bidirectional, and no direct path between the client processes.

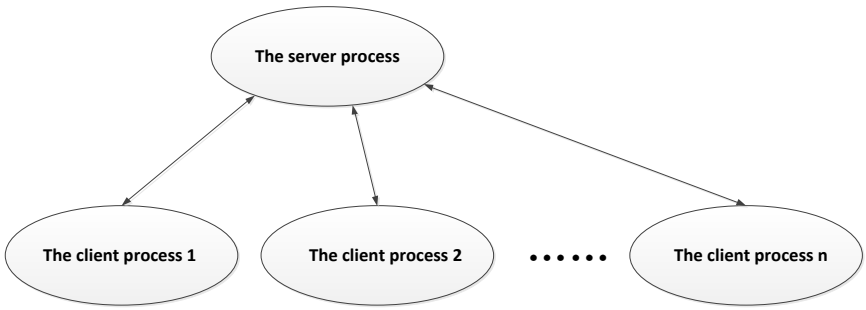

Figure 3. Block Diagram of C/S Communication Model

2 Peer-to-Peer (P2P) model

P2P technology, also called as peer to peer network technology, the central server does not exist in the P2P network structure. In the structure of P2P. Each node most simultaneously has three aspects functional such as information consumption, information provide and information communication rights and obligations owned by each node are peers. The structure of P2P communication model changed from central to distributed, communication between nodes without going through the server forwarding, but direct communication increased communication efficiency, load are more balanced, better reliability.

Its model structure shown below:

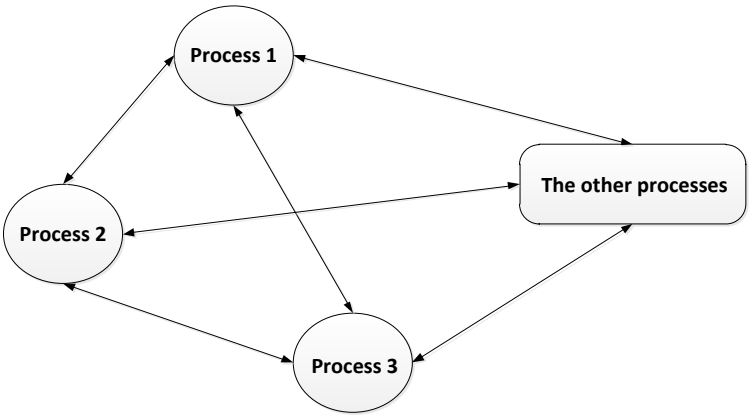

Figure 4. Block Diagram of Peer Communication Model

The structure of C/S model is simple, easy to realize, easy to troubleshoot and system maintenance, because of its centralized control, in favor of the management of process and to achieve a reasonable allocation and scheduling of communication resources. However, because it's such a centralized control mode, lead to its shortcomings are obvious, since all data of system must transit through the central server, thus the lower efficiency of communication between the client process, and would result in a server's workload is too large, server performance and network bandwidth may become a bottleneck affect the performance of system, in addition, the error of central server will cause the entire system to crash, therefore less reliable of C/S communication systems, P2P model solved this problem, but P2P model is not suitable for applications including controlling, scheduling, and managing tasks, therefore desirable to have a mechanism for unified and predictable distributing the resources of system. If P2P model is adopted to realize this mechanism, due to the equal characteristics of agent, then each agent should save the state information of all of agent, increasing the burden on local storage. Any change of internal state of the agent must notify the other agents, increasing the burden on network traffic. Each agent must deal with the calculation relate to control or dispatch, increasing the burden on system. According to the above advantages and disadvantages of the two models, this paper firstly propose a hybrid model base on C/S model and the P2P model, Level-Reticulate Management Control Communication Model, its structure is shown below:

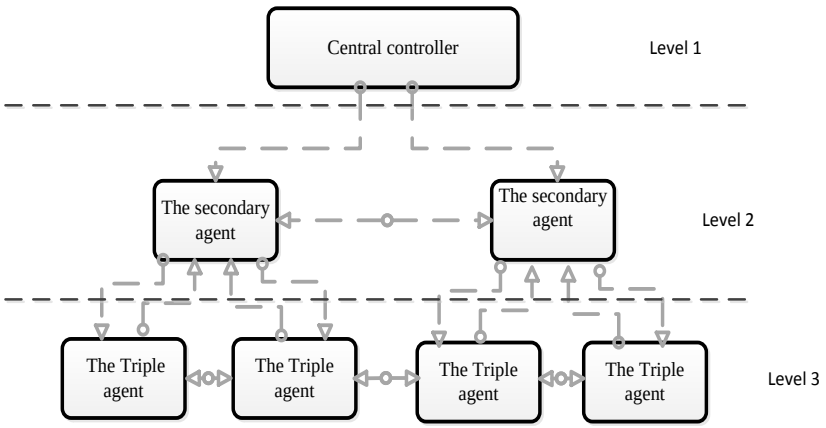

Figure 5. Block Diagram of Peer Communication Model

Multi-agent is divided into three levels according to the frequencies of collaboration and communication. The controller which is set up exchange information with the agent

in level 2. A direct path between the secondary can be exchanged. The agent in level 2 only need to preserve the address of communication center and other agent in level 2, at the same time, central controller only need to preserve address of the agent in level 2, every agent in level 2 is also a local controller, responsible for the control, coordination, and exchange of information to the agent in level 3 in the range of its local control area, similarly every agent in level 3 could exchange data with each other directly. With such a level and a level of control, solve the controller overload problem of C/S model, and because the agent in level 2 could exchange information with each other, and the agent in level 3 also could achieve this, the central controller can obtain status information of each agent in the current system, and to control also manages, solved the problem on controlling, scheduling, managing of P2P system.

4. Conclusion

This paper researched the methods of dynamic intelligent information processing based on multi-agent of distributed renewable energy generation systems, the agents are divided into two types, they are Bus Agents and Coordination Agents, the system is divided into three layers, they are the data layer, the filter layer, and the policy making layer. This paper has conducted a detailed analysis of working process of every layer. By means of information processing to make knowledge and information of power generating system gradually change to full, reliable, accurate, consistent and certain and use it. It provides information foundation for the policy that the balance of mixed optimal power supply and demand of macro distributed renewable energy.

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