



A Holonic Multi Agent System For Operating Smart Grid Market

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Abstract

Smart Grid is known as the next generation of power systems. This technology is the main solution to challenges such as increasing electric demand, aging utility infrastructure and workforce, and the environmental impact of greenhouse gases produced during electric generation. The agent based functions are highly autonomous and operate independently while managing energy consumption and production by human is autonomous and independently in power systems. The smart grid consists of several operation layers and in each layer there are several operating segments that must be coordinated with each other. These operating segments can map to an organization to reduce the complexity of coordination between them. A holonic multi agent system presents hierarchical organization structure with decentralized control. This paper proposes a model of holonic multi agent system (HMAS) for smart grid market to manage electricity agents in Smart grid operation. This approach controls the smart grid complexity by intelligent agents in a holonic organization mounted on smart grid infrastructure. The presented approach utilizes the advantages of using the HMAS technology for managing smart grid energy market and trading strategies to obtain satisfying energy exchange and energy price between the production units and loads in the smart grid.

*Keyords:*Holonic multi agent system, smart grid, energy market, distributed generation



Introduction

In recent years, the power industry has been on the verge of a great transformation. Increasing demands for production of electricity and resource constraints, on the one hand, and environmental impact, on the other hand, have been forward great challenges for power industry in recent decades. Due to the vast expansion of the electrical grid and the emergence of new economic concepts such as electricity market today the traditional methods of supervisory control and data acquisition, cannot longer use to control electrical networks any more. These problems, leads to the extensive research that smart grid is its crowning achievement. Smart grid will change the technology, development and promotion of all electrical energy network components including power generation, transmission, distribution and consumption [7].

Smart grid has different sub-system operations. Since each of these sub-systems can manage and optimize their internal resources, they can achieve better performance by communicating with the surrounding segments and their level. This task is hard and impossible at centralized procedures, and as a result, nowadays distributed approaches are commonly used. In these researches, multi agent systems well adapted to the challenges of the smart grid because of their unique features on representation and control of distribution issues, therefore in recent years, much attention to MAS has been developed.

Although Multi-agent systems are known as effective approaches and efficient abstraction for modeling complex, distributed systems, there are problems and difficulties to design and engineer these systems. Especially In situations where a large number of autonomous components (like agents) interacting with each other in one system, Predicting the behavior of the system and the assurance of the expected performance will be very hard. On the other hand, none of the existing methods guarantee to reach the global optimum. These factors lead to introduction of enormous multi-agent system usage in smart grid. Holonic-Multi-agent systems are systems that use their organizational structure to reduce the complexity of large systems. This paper introduces a model to use the capabilities of Holonic-Multi-agent systems management of smart grid markets. This hierarchical organizational of agents Reduce the complexity and Facilitates achieving Satisfaction in all parts of smart grid.

The remainder of this paper is organized as follows: in section II, the concepts used in the paper are described. Section III discusses the related works. In Section IV, we present the model of our system. in last section, conclusions are given.

Literature View

Agent

An agent is defined as one that interacts between external environments, cooperates with other agents and processes to solve problems autonomously. Agents those can have beliefs, desires and intentions Known as the BDI model. This definition created the concept called intelligent agent that proposed by Wooldridge. In this definition, autonomy of agent changed to flexible autonomy of intelligent agent. An agent which displays flexible autonomy has three characteristics of Reactivity, Pro-activeness and Social ability [1].



Multi agent System

A multi-agent system is a structure given by an environment together with some artificial agents capable to act on this environment. Multi-agent systems are considered as one of the characteristics of distributed artificial intelligence. A multi-agent system consists of several intelligent agents and a way to coordinate the behavior of the agents. Multi-agent system is an autonomous system that many agent actions depend on each other and gathered together. Recently, MAS gathers researcher's attention because it is capable to handle complexity of problem that can be adopted with a centralized handling. MAS have some advantages such as flexibility, extensibility, and fault tolerance [4]. Many important computing applications such as planning, process control, communication networks and concurrent systems will benefit from using multi-agent system approach [9].

Holonic multi-agent systems

In some recent decades, since there are some more complicated and greater problems and consequently increasing the number of agents and interaction among them, it is difficult to solve the problems with the simple multi agent systems. Some solutions such as holonic multi agent systems have been proposed. The bases of the holonic structures are holons. The holon could consist of some sub holons and also be a part of a super holon. A tree structure which its members cooperate together to reach a complex goal, is made by these holons. The tree structure or holarchy has unique advantages in terms of stability and resistance to internal and external injuries and disorders. These structures are efficient in using resources and have a high adaptability against the environmental.

In holonic multi agent systems, each holon could be a group of some intelligent agents or only consists of one agent. Since this structure is a regressive one, each holon is also considered as one agent and is shown by a representative agent called "head". The head can be chosen among the agents in the holon or a new agent is made for this purpose as long as holon is alive. It states the intensions of the Holon. The head (and only it) communicates with the outside of the Holon and can negotiate with the agent's in the holon environment. The more concepts about holonic multi agent systems for further reading are [11].

Smart Grid

According to the definition of Energy Organization of America, smart grid is a power system that is completely automatic and controls of all of its nodes and subscribers. In smart grid there is a two-way flow of electricity and information between the power plant and household devices and all parts of the network [10].

Smart grid is known as the next generation of power systems. Due to restructuring of power systems, creating modern telecommunications infrastructure, and the intelligent control of power networks, regarding to the role of consumers in managing their consumption and reducing costs of electric energy consumption, the need of using smart grid has been increased dramatically [7]. On the other hand because of increasing use of



distributed generators in future, local generators and consumers are desired to actively participate in matching power supply and demand.

Due to complexity of the analysis, modeling and control of complex systems with large-scale using the concepts of multi-agent systems increases performance of these systems dramatically [4].

Market Functioning In A Smart Grid

In the future, local consumers and producers would like to play an active role in production and energy demand. In fact, the energy matching is a continuous and widespread problem that must be solved at all times. Nowadays, the power matching process is centralized according to coordination of company manufacturers, producing passive loads. In the future, due to large number of discontinuous renewable energy sources, power matching can't be organized centrally. therefore it is required to support the decentralized actions on price signals and market operations [6].

In smart grid market, each consumer and producer makes a bid corresponding to its loads or produces. Then, market operation, matches power by using auction mechanisms and power matching rules. Each consumer (residential/industrial/commercial) can have a set of low-priority and high-priority loads, and sends separate bids corresponding to each set of loads. Low-priority loads will satisfy when the energy prices are low, and high-priority loads are served always irrespective of energy price. Based on the set of bidding rules, the trader submits a bid or asks toward the target price in a similar way as in the first round. If the target price is higher (lower) than the outstanding ask (bid) at any time during the bidding process, the buyer (seller) accepts the outstanding ask (bid) [8].

Related Works

In reference [5], presents a control approach to impossible energy market and claimed that the micro grid can be an example of the power systems. There are four control levels in this paper: Distribution Network Operator, Market Operator, and Central Control System of micro grid and load control. In this paper there is a central control system that for each local load provides energy and voltage and make sure the loads are consumed. In this paper the smart grid has Infinite energy and can buy Infinite energy from micro grid.

In [3] multi-agent systems are used to monitor micro grid. The proposed method utilizes the advantages of multi-agent systems. The proposed method utilizes by advantages of multi-agent systems to control of micro grid and a distributed algorithm based on the classical symmetrical assignment problem to optimize the energy exchange among the production units of micro grid, local loads and main grid. There are three different control layers in this paper: distribution network operator and market operator for the medium voltage, micro grid central controller and the local controller. The first two entities do not belong to the micro grid, but they are the delegates of the grid.



First The Energy Market Operator announces buying and selling prices. The local loads announce their needs for the next 15 minutes and their base price. The producer accepts or rejects price lists according to the auction price results. Negotiations continue until a specified time. If none of the producer units are unable to respond to the load, the required energy purchases from the power grid. And if there is Extra energy production it can be sold to the grid. Maximum number of iteration in this paper is 100 and number of participants for negotiation considered between 20 and 30. Operation of this market is simple only for low count of agents [3, 5].

Proposed multi agent system in [9] is based on hierarchical three-layer architecture. There are six kinds of agent, Several Load Agents (LAGs) and Generator Agents (GAGs) are implemented in the bottom layer, a micro grid control agent is in intermediate layer and a grid agent (GRDAG) on top of layers. Each LAG, GAG and GRDAG can create several Seller Agents (SAGs) and Buyer Agents (BAGs) for the negotiation. Proposed multi-agent approach to operation of micro grid power system has many load agents and producer agents and one micro grid agent. The aim of this approach is to maximize profits for micro grid. Negotiation process in this system is between MAG, GAG and LAG and its market operation and auction process similar to the papers Cited. Testing environment in this paper has three producers and three consumers. It's obvious that in large systems the negotiation time of this system becomes very large.

The proposed control structure in [6] is based on a scalable agent-aggregator structure to aggregate a cluster of generators for a virtual power plant (VPP) or a cluster of customers for Demand Side Management and Demand Response (DSM&DR) to handle power matching. There are two layers for coordination market in this paper. The top layer encloses the global coordination market, so demand and energy consumption are equal in this layer, while the sub layers are mapped onto physical grid segments. Allocation takes place on energy using a message exchange between agent and auctioneer. In the sub layers, trade is only on capabilities to increase or decrease small amounts of production or consumption.

Proposed multi-agent systems based approach [8] insists on energy market profitability in smart grid. Auctioneers in the auction, manages distributed generator energies for producers by receive bids from producers and consumers. The authors believe that running the optimization routine before bidding will aid the auction process in an energy market. Therefore in this approach is a hybrid technique between particle swarm intelligence optimization and auctions mechanisms. Use of particle swarm optimization is for minimizing the cost of producing, achieve real price, producing realistic offers and execute load bidding according to consumer preferences. To deal with the problems that arise in Auctions, this approach uses multi-agent systems based architecture.

Reference [2] proposes a computational architecture that allows electricity agents to coordinate in an integrated approach within a smart grid environment. A computational model is given to cope with demand variations and to accommodate selling of power at the customer side. There is a hierarchical structure of agents. The first layer consists of producers, transporters and distributors of power networks. The second layer provides a middleware for network that interacts with all its components. The third layer have the electrical operating agents that perform their activities, interact, and share data on behalf of their underlying



generation, distribution, and transmission companies. The agents interact by using platform of multi-agent system.

Market Operation Of System Restoration Model

By increasing number of agents, achieving equilibrium requires too interaction between them and this process will be time consuming. Therefore by considering that the smart grid is a large network, the number of agents those are interacting as a producer and consumers in the network will be enormous. This makes it very difficult and time consuming to reach equilibrium. On the other hand, in smart grid, there are many agents which are not required interactions between them to achieve a balance in the smart grid.

For example, interaction between small consumers and producers who are spread and far apart to each other doesn't have significant impact on the system equilibrium or their profits. But if the distance between agents is low and energy transfer between them is simple, their interaction may be profitable for them and also affect to system Equilibrium. We proposed a method in which agents should negotiate in a hierarchically organized to reduce the time orders of processing and achieve the energy market Equilibrium. Otherwise the negotiations between the large number agents will be complex, Widespread and time consuming.

Holonification

In this paper, we propose an architecture to control the smart grid market control using holonic multi agent systems. In the proposed approach, holons are formed in two stages. Holonification in first stage is static while the second stage can change dynamically. This feature can cause increasing the flexibility and efficiency of the approach. In this method in first stage, a simple static structure according to power dispatchers and customer those are feeding from them. In another word the smart grid is divided in to some dispatcher holons. Each holon consists of some Producers and Consumers situated in one dispatcher district.

In the second stage, dynamic Holonification happens every some minutes. This Holonification will be only for agents inside one dispatcher district and no agent in different dispatcher district can mount in one Holon, so the Producer and Consumer holons form dynamically for a period of time and after that according to the new situation, some holons may be destroyed or changed and also some new holons may be created. Therefore a new arrangement of Producer and Consumer holons will form. The Holonification of the Producer and Consumer agents in the second stage is as follows: The adjacent agents having the near distance and having same consumption or production, will be in one holon. Thus the head can operate which Producers sell their energy to which consumers inside the holon. If there is additional energy or energy requirements inside the holon, head of holon negotiates with others in his level.



Market operation

Smart grid operator announces two prices to start negotiation. the price for selling kW and the price for buying kW. Each unit adjusts their selling energy or buying energy after negotiation with other units based on the grid price, their operational costs, and the load demand. The overall procedure for each Holon is the following:

- Holon head Agent (HAG) announces the market initiation message to all its market participants.
- Consumer Agents (CAG) announce their demand for the following some minutes and an initial price for the kW.
- Producer Agent (PAG) announces their available generation for the following specified minutes and an initial price for the kW.
- After a specific HAG announces the market end message to all its market participants and makes a priority list for the PAG and CAG according to their price and the amount of power.
- HAG sets pairs of PAG and CAG, and then announces the result to all market participants. If there is no CAG that satisfies the load demand, the power is bought from the grid. Furthermore, if the amount of generation is larger than load demand, the HAG begins selling energy to the grid.
- If HAG needs to sell (buy) energy to (from) grid, negotiates with agents whose are in his Holon.

Model Advantags

It is obvious that, if the scalar and the benefits for the first and the second best object be the same, then this leads the algorithm to infinite iterations. But by forcing a minimum increment scalar for sellers bids and minimum decrement scalar for buyers, we will have finite number of iterations.

The approach proposed in decentralized and this allows each manufacturer of DER units or loads to embed a programmable agent in the controller of his equipment, according to his rules. By adding new consumer or producer in the smart grid, most of systems require extra programming. But our system finds its Holon dynamically in Holonification part. So the new participant of market can negotiate with the Holon that he belongs to it. The new participant can sell or buy his electricity to (from) grid by negotiate with participants in his Holon.

Conclution

This paper proposed a Holonic Multi agent system for operating Smart Grid market. In this paper, emphasis is placed on the internal operation of the smart grid and its participation in the Energy Market. The main idea of the presented algorithm is that every DER or controllable load decides what is best for it, taking the overall benefit through the auction

algorithm into account by using participants and benefits of multi-agent systems and organizational concepts. It reduces operating costs of the network to its participants in such a distributed approach. In the Proposed multi-agent approach, each participant has a representative agent in the Smart Grid market. The agents participate in a real-time market according to the market policy and help their participant to manage the energy consumed or produced effectively according to the smart grid status. According to greatness the smart grid and being many active participants in the network, a hierarchical architecture used. Dynamic Holonification method which is used in the system reduces the complexity of the interactions and negotiations. Our proposed method in which agents should negotiate in a hierarchically organized to reduce the time order of processing, can achieve the energy market equilibrium in big environments like smart grid.

Shapes

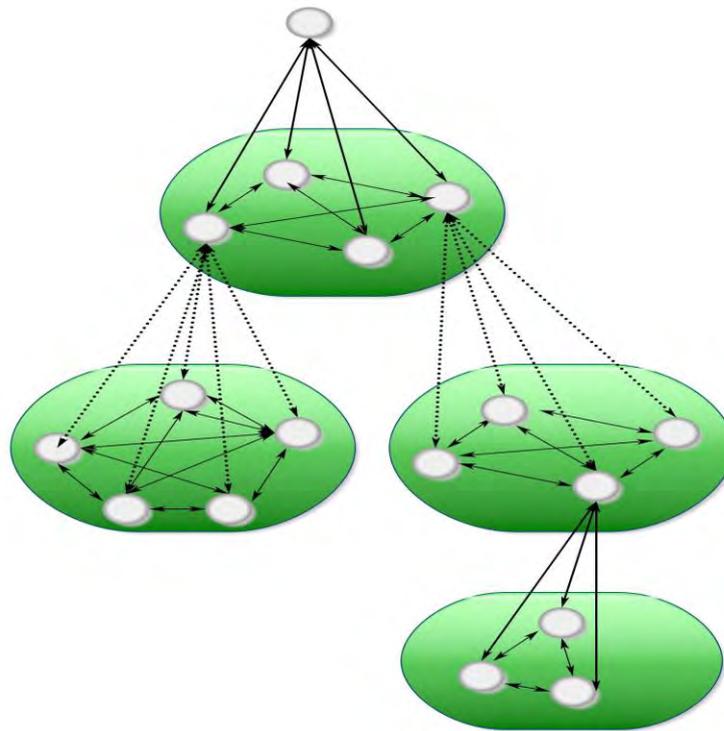


Image 1. structure of a holonic system

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