A Cooperative Multiagent System for Enhancing Smart Grid Performance

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Summary
Sharing power data between electrical power grids is crucial in energy management. The multi-agent approach has been applied in various applications to improve the development of complex systems by making them both independent and collaborative. The smart grid is one of the most intricate systems that requires a higher level of independence, reliability, protection, and adaptability to user requests. In this paper, a multi-agent system is utilized to share knowledge and tackle challenges in smart grids. The shared information is used to make decisions that aid in power distribution management within the grid and with other networks. The proposed multi-agent mechanism improves the reliability of the power system by providing the necessary information at critical times. The results indicate that the multi-agent system operates efficiently and promptly, making it a highly promising candidate for smart grid management.

Keywords:
Multiagent System, Smart Grid, JADE, Energy performance

1. Introduction

Conventional power generation refers to the production of electricity using traditional methods such as fossil fuels (coal, oil, natural gas) and nuclear power. These sources of energy are widely used to generate electricity due to their accessibility and affordability. In conventional power generation, fossil fuels are burned to heat water and produce steam, which then drives a turbine to generate electricity. Nuclear power plants use nuclear reactions to heat water and produce steam for turbine generation. Conventional power generation has been the dominant source of electricity for many decades, but has faced criticism for its negative environmental impact, such as greenhouse gas emissions and nuclear waste. Despite this, conventional power generation remains a critical component of the world's energy mix and is likely to continue to play an important role in electricity production in the coming years.

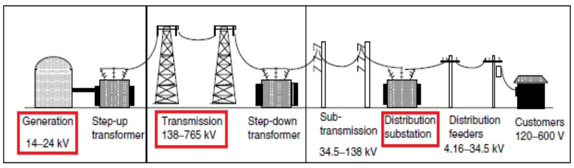

Fig.1. Conventional Power Generation, Transmission, and Distribution

The renewable energy sources may be connected to the system at transmission or in the distribution stage .

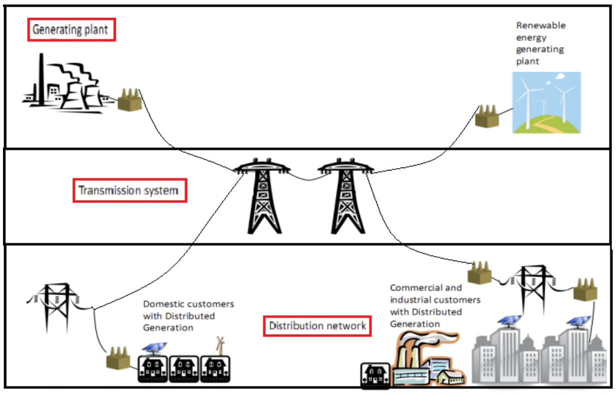

Fig.2. Connections in the Power System

A smart grid power system is a modernized version of the traditional electrical grid that incorporates advanced technology to enhance the efficiency, reliability, and sustainability of power distribution. It uses real-time data, communication networks, and automation to dynamically respond to changes in energy demand and supply. Smart grid technologies include smart meters, advanced distribution management systems, demand response programs, and renewable energy integration. These technologies enable better energy management and help to reduce energy waste, improve energy security, and support the integration of renewable energy sources. The overall goal of a smart grid power system is to create a more resilient, flexible, and efficient power grid that can adapt to the changing energy needs of society.

Global warming and the energy crisis made Energy Management System (EMS) one of the most sought-after study different subjects [1]. The electric grid is rapidly evolving and becoming more a smart grid, which is distinguished by increased energy efficiency and resource manageability, for example home energy usage is controlled through energy management systems (EMS), which are frequently combined with home automation systems. These systems also encourage greater customer involvement [2].

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All smart devices that produce and store electricity are included in the smart grid framework, enabling user participation and meeting energy needs [3]. The smart grids have different applications in power systems. They could exist as active filters [4-5]. Or it could exist as a combination of distributed and centralized generators which control the voltage in the distribution grids [6]. An emerging idea in smart grids called a microgrid (MG) increases the efficiency and resilience of power systems by enabling intelligent control of consumer power usage and integrating dispersed generation resources like solar and wind power [7].

The distribution systems play an important role in electrical grids. It is the stage where the power is directly provided to different consumers [8]. Recently. the reconfiguration of distribution systems based on minimal energy loss and maximum dependability has been the subject of numerous research investigations using a range of modern optimization methodologies [9-14].
The emergence of DG on the electric networks has a number of negative effects, including voltage variation, degraded protection, altered transient stability, bi-directional power flow, and increased fault level, with the voltage variation being addressed as the dominant effect. Distribution networks have not been designed to handle power injections from DG [15-16].

Although switches enable for reconfiguration, electric distribution systems are typically controlled radially. The distribution system's network reconfiguration is accomplished by opening and closing a few switches in order to maintain a linked but radial network. We will solely focus on radially driven systems, even if severely laden urban feeders are occasionally run in a loop [17-18].

When DG penetration rises above a certain threshold, transient occurrences may start to take on greater significance. The rising electrical distances between the remaining large synchronous generators (SG) in operation may make the system less stable, but stiff inverter-based generation technologies may make the system more stable [19]. Numerous dynamic models of electricity systems with substantial DG penetration have been created in order to examine these consequences. Such models are not yet standardized, though. Their wide variation reflects the most recent findings from the writers' or research groups' various fields of study. There are still not widely used, validated models, which is crucial [20].

2. The Developed Multi-Agent System Architecture

Multi-Agent System (MAS) is a type of system in which multiple agents interact with each other to achieve a common goal. These agents are autonomous entities that are capable of perceiving their environment, making decisions, and taking actions. MAS can be used in various domains, such as robotics, computer networks, intelligent transportation systems, and financial systems. One of the main advantages of MAS is that they can handle complex tasks that would be difficult or impossible for a single agent to handle alone. The following are some of the key elements that make up a multi-agent system:

Agents: These are the individual entities that make up the system. Each agent has its own knowledge, goals, and objectives. Environment: The environment is the context in which the agents operate. It can be physical, virtual, or a combination of both. Interactions: The agents interact with each other and with the environment in order to achieve their goals. These interactions can be direct or indirect, and can involve exchanging information, coordinating activities, or negotiating solutions. Coordination: Coordination is an essential aspect of MAS, as it allows the agents to work together effectively. This can involve using shared knowledge, cooperation, and communication. Decision-making: The agents make decisions based on their perception of the environment and their own goals and objectives. This decision-making process can be based on rule-based systems, artificial intelligence algorithms, or a combination of both.

Making an Agent System adaptive involves designing the system in such a way that it can adapt to changes in its environment and objectives over time. This can be achieved through the use of techniques such as machine learning, self-tuning, and dynamic reconfiguration. In an adaptive Agent System, the agents are able to learn from their experiences and adjust their behavior accordingly. This can include adjusting their decision-making rules, adjusting their objectives, or modifying their communication and coordination strategies. Adaptivity can be achieved through a variety of mechanisms, such as reinforcement learning, genetic algorithms, or particle swarm optimization. These techniques allow the agents to continuously improve their performance, by learning from their successes and failures and adapting their behavior accordingly. By making an Agent System adaptive, it becomes possible to achieve better performance and achieve goals more effectively, even in changing and unpredictable environments. This can be particularly useful in applications such as smart grids, robotics, and autonomous systems, where the environment is constantly changing and it is important to respond effectively to new challenges and opportunities.

Multi-Agent Systems are a promising approach for addressing complex problems in various domains. However, there are still many open research questions and challenges associated with the design, implementation, and deployment of MAS, including issues related to coordination, communication, and decision-making. Further research is needed to address these challenges and to improve the effectiveness and efficiency of MAS. Agents in a Multi-Agent System (MAS) communicate with each other to exchange information, coordinate their actions, and negotiate solutions. There are several ways in which agents can communicate, including the following: Direct Communication: Direct communication involves the direct exchange of information between two or more agents. This can be achieved using messaging protocols, direct data transfer, or other communication mechanisms. Indirect Communication: Indirect communication involves the use of shared resources, such as databases, shared memory, or message brokers, to exchange information between agents. This type of communication allows agents to interact with each other without having to directly communicate with one another. Message Passing: Message passing is a common method of communication in MAS. Agents exchange messages with one another, which can contain information about the agents' goals, perceptions, or other relevant information. The messages can be sent using various protocols, such as the Simple Object Access Protocol (SOAP) or the Extensible Messaging and Presence Protocol (XMPP). Publish/Subscribe: The publish/subscribe pattern is a method of indirect communication in which agents subscribe to a topic or channel and receive notifications or updates from other agents that publish information on that topic or channel. Market-Based Communication: Market-based communication is a method of indirect communication in which agents use market mechanisms, such as auction or bargaining, to negotiate solutions and exchange resources.

Overall, the communication mechanisms used by agents in MAS can vary depending on the specific requirements of the system and the goals of the agents. However, effective communication is essential for the effective coordination and collaboration of the agents in the system. There are several ways to represent the communication between agents in a Multi-Agent System (MAS). Some common methods include: Message Passing: This is one of the most common methods for representing communication between agents. In this approach, agents send messages to each other to exchange information, request services, or negotiate solutions. Agent Interaction Diagrams: This is a visual representation of the communication between agents. It shows the interactions between agents and the messages exchanged between them. State Transition Diagrams: This is a diagram that shows the changes in state that occur as a result of communication between agents. This can be useful in understanding the behavior of the system and identifying potential problems. Petri Nets: This is a graphical representation of a MAS that models the behavior of the system. Petri nets can be used to represent the communication between agents, as well as the states and transitions of the system. UML (Unified Modeling Language) Diagrams: UML is a widely used modeling language that can be used to represent the communication between agents. UML diagrams can be used to show the interactions between agents and the messages exchanged between them. Event-Driven Simulation: This is a simulation-based approach that models the communication between agents. In this approach, agents react to events, such as messages received from other agents, and update their state accordingly. These are some of the most common ways to represent communication between agents in a Multi-Agent System. The choice of representation will depend on the specific requirements of the system, as well as the goals and objectives of the designer. Petri Nets are a graphical representation tool used to model concurrent and distributed systems, including Multi-Agent Systems (MAS).

The state diagram in Figure 3 depicts a conversation between LOAD AGENT1 and LOAD AGENT2. LOAD AGENT1 initiates the communication by sending a request to LOAD AGENT2, who has the option to either accept or decline the request. At the start of the scene, the agents are in an initial state, W0. The transition to state W1 is triggered solely by LOAD AGENT1 through the expression (1). From W1, the next state can either be W2 or W3, depending on whether LOAD AGENT2 accepts or denies the request.

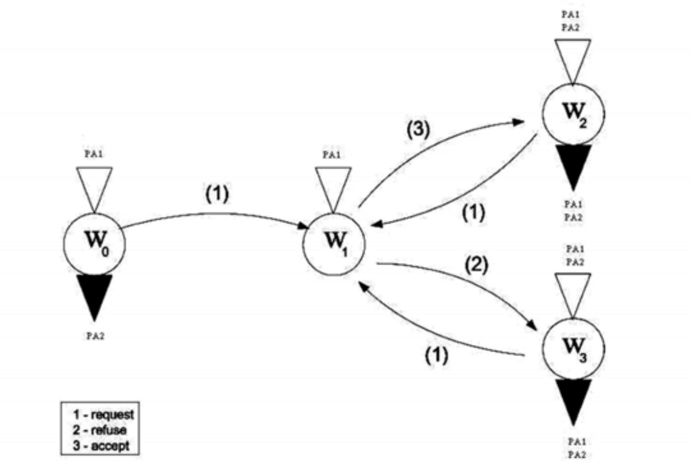

Fig.3. The state diagram of a scene involving two LOAD AGENTs.

In a Petri Net, agents are represented as places and their interactions are represented as transitions. A Petri Net consists of a directed graph with places and transitions, connected by arcs. The places represent the state of the system, and the transitions represent events that change the state of the system.

In a MAS, each agent can be modeled as a place in a Petri Net, and their interactions can be modeled as transitions. The arcs between places and transitions represent the flow of information or control between agents. This allows the designer to model the communication and coordination between agents, as well as the behavior of the system as a whole. Petri Nets are well-suited to modeling MAS because they can handle parallelism and concurrency, and they provide a clear and visual representation of the system. They can be used to model the behavior of the system and analyze its properties, such as reachability, liveness, and deadlocks. Petri Nets are widely used in the design and analysis of MAS, and they provide a powerful tool for understanding the behavior of the system and identifying potential problems. They can also be used to verify that the system meets certain requirements, such as performance and reliability.

A Multi-Agent System (MAS) in power systems is a system in which multiple agents (e.g. power plants, power grid controllers, consumers) work together to control and manage the power grid. In a MAS-based power system, each agent is responsible for a specific task, such as monitoring power generation or controlling the flow of electricity. The agents communicate with each other to exchange information, coordinate their actions, and negotiate solutions. The use of a MAS in power systems can bring several benefits, including: Improved Reliability: By using multiple agents, a MAS-based power system can be designed to be more robust and reliable. If one agent fails, other agents can take over its tasks and keep the system running. Increased Flexibility: A MAS-based power system can be more flexible than a traditional centralized system. Agents can adapt to changing conditions and respond to new requirements, making the system more responsive to changing needs. Improved Energy Efficiency: By allowing agents to communicate and coordinate their actions, a MAS-based power system can optimize energy use, reducing waste and increasing efficiency. Enhanced Security: By distributing control and decision-making across multiple agents, a MAS-based power system can be more secure than a traditional centralized system. If one agent is compromised, the system can still function, reducing the risk of a major failure. Better Scalability: A MAS-based power system can be designed to be scalable, allowing new agents to be added or existing agents to be removed as needed. This makes the system more adaptable and easier to maintain.

Data management in an Agent System refers to the processes and techniques used to store, retrieve, and manipulate data within the system. This can include tasks such as: Data storage: Storing information in a way that is easily accessible and retrievable by the agents. Data retrieval: Retrieving information from storage in response to requests from the agents. Data processing: Transforming data into a useful form for decision-making or other purposes. Data sharing: Sharing information among agents to support collaboration and coordination. Data management is an important aspect of an Agent System, as the quality and availability of data can greatly impact the performance of the system. Effective data management can help ensure that the agents have access to the information they need when they need it, enabling them to make informed decisions and respond effectively to changes in the environment. To support data management in an Agent System, it is common to use databases, data warehousing techniques, and distributed data management systems that can store and retrieve data efficiently, even in large and complex systems. The use of data management standards and protocols can also help to ensure consistent and effective data sharing among the agents.

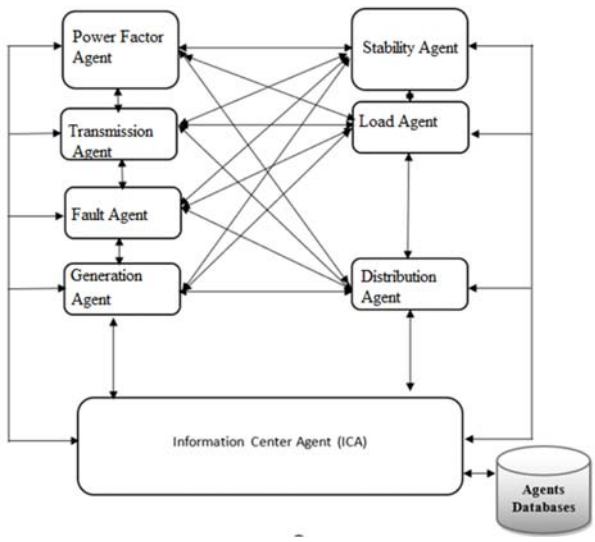

Fig.4. The developed multiagent smart grid block diagram system

The Distribution Electrical Power System is responsible for delivering electricity from the transmission system to the end-users. It includes the following components: substations, distribution transformers, feeders, distribution lines, service drops, load centers, power distribution panels, circuit breakers protective relays, and metering devices.

Transmission lines are high-voltage electrical power lines used to transmit electrical energy over long distances from generating stations to substations, from where it is then distributed to end-users. They include the following components: towers, conductors, insulators, ground Wires, circuit breakers
, protective relays, surge arresters, and fuses.

Load Agent

Load in a power system refers to the electrical demand placed on the system by consumers. Load can vary over time and can range from small residential loads to large industrial loads. Load is one of the most important factors affecting the design, operation, and control of power systems. Load management is critical for ensuring the safe and reliable operation of power systems, as the load can have a significant impact on system stability, power quality, and energy efficiency. To meet the varying load demand, power systems must have sufficient generation and transmission capacity, and must be able to balance supply and demand in real-time. Load management strategies can include load forecasting, demand response programs, and energy storage systems, among others. Understanding and managing load is an essential aspect of ensuring the safe, reliable, and efficient operation of power systems. In electrical power systems, a load refers to the electrical devices or equipment that consume electric power. This can include residential and commercial appliances, industrial machines, and lighting systems. Loads can be classified as:

- Resistive Loads: These loads consume power in the form of heat, such as incandescent light bulbs, electric heaters, etc.
- Inductive Loads: These loads consume power in the form of a magnetic field, such as electric motors, transformers, etc.
- Capacitive Loads: These loads consume power in the form of an electric field, such as capacitors, electronic circuits, etc.

The sum of the power consumed by all the loads connected to a power system is called the total load demand.

Power Factor

Power factor is a measure of the efficiency of an electrical power system, defined as the ratio of real power to apparent power. Real power is the power that is actually delivered to the load and used to perform work, while apparent power is the total power supplied to the system, including both real power and reactive power. Reactive power is the power that is used to establish and maintain the magnetic fields in electrical equipment, such as motors and transformers. A low power factor indicates that a significant amount of the apparent power is consumed by reactive power, reducing the efficiency of the system. Improving the power factor can reduce the losses in the system, improve energy efficiency, and reduce the size of the electrical equipment required. Power factor correction can be achieved through the use of capacitors, which store and release reactive power as needed. Ensuring a high power factor is an important aspect of ensuring the safe, reliable, and efficient operation of power systems. A power factor of less than 1 means that the system is consuming more apparent power than real power. This results in wasted energy and higher utility bills. Improving the power factor can help reduce energy losses and improve the efficiency of the system.

A substation is an electrical facility that forms part of an electrical power system and serves as a hub for power distribution. It includes the following components: high-voltage switchgear, transformers, circuit breakers, protective relays, isolators, metering devices, grounding equipment, cables and busbars. The primary function of a substation is to step down the high voltage electricity received from the transmission system to a lower voltage level suitable for distribution to end-users. Additionally, it helps improve power quality, increase system reliability and ensure safety.

Fault Agent

Faults are temporary or permanent interruptions in the normal flow of electrical current in a power system. They can occur due to various reasons, such as equipment failure, human error, natural disasters, and others. Faults can cause significant damage to electrical equipment and pose a safety risk to both people and property. To mitigate the impacts of faults, it is important to have protection systems in place to detect and clear faults in a timely manner. These protection systems typically include various types of relays, circuit breakers, and other devices that monitor the power system and respond to faults. Faults can also be analyzed and used to improve the design, operation, and control of power systems, leading to increased reliability and safety. Understanding and managing faults is a critical aspect of ensuring the safe, reliable, and efficient operation of power systems.

There are several types of faults, including: 1) short circuit fault is a fault where the current flow is interrupted by a direct connection between two or more conductors. 2) Open circuit fault: a fault where the current flow is interrupted due to a break in the electrical circuit. 3) ground fault: a fault where current flows to ground instead of following its intended path through the circuit. 4) overload fault: a fault where the current flow exceeds the design capacity of the equipment. Faults can cause significant damage to electrical equipment and pose a safety risk; hence it is important to have protection systems in place to detect and clear faults in a timely manner.

Advantages of multiagent in power system

Multi-Agent Systems (MAS) is a distributed system architecture that consists of multiple autonomous agents that work together to achieve a common goal in a power system. These agents can interact with each other and with the physical system to make decentralized decisions, providing improved flexibility, scalability, and reliability compared to traditional centralized approaches. The use of MAS in power systems can lead to better coordination and information sharing, enabling improved performance, and reducing the impact of faults. For example, agents can be used to manage the operation and control of renewable energy sources, improve the efficiency of energy storage systems, and optimize the use of power generation and transmission resources. Multi-Agent Systems offer an innovative solution for managing complex and dynamic power systems, and are expected to play a significant role in the future of power systems.

Stability Agent

Stability in power systems refers to the ability of the system to return to its normal operating state after a disturbance. Power systems are vulnerable to various types of disturbances, including changes in load, faults, and loss of generation. Maintaining stability is crucial for ensuring the safe and reliable operation of power systems. There are two main types of stability: transient stability and dynamic stability. Transient stability refers to the ability of the system to return to its steady-state operation after a disturbance, while dynamic stability refers to the ability of the system to maintain stability over an extended period of time. Ensuring stability requires a combination of equipment design, control strategies, and operating procedures, including load management, generator control, and protection systems. Power system stability is a complex and challenging issue, requiring ongoing research and development to ensure the safe, reliable, and efficient operation of power systems.

Principal of work of power system multiagent system

Power system agents in a multi-agent power system are autonomous, artificial intelligence-based control algorithms that are designed to monitor and control various aspects of a power system, such as load management, power generation, and power distribution. The agents are distributed throughout the system and communicate with each other to coordinate and optimize the performance of the power system. The use of power system agents enables the system to be more adaptive and responsive to changes in the environment, such as variations in demand, renewable energy sources, and disturbances in the grid. The agents can also detect and respond to anomalies and failures in the system, ensuring that the power system remains reliable and efficient. The use of power system agents in a multi-agent power system can lead to improved energy efficiency, reduced greenhouse gas emissions, and reduced costs for electricity generation and distribution.

Principal of work of power factor agent

In a multi-agent power system, a Power Factor Agent can be used to manage the power factor of the system in real-time. The agent can monitor the power factor of the system and adjust it as needed, by controlling the amount of reactive power supplied by capacitors. The use of a Power Factor Agent provides improved efficiency, reliability, and scalability compared to traditional centralized approaches. The agent can communicate with other agents in the system, including generation agents, transmission agents, and load agents, to coordinate the management of power factor and ensure that the system operates optimally. The Power Factor Agent can also respond to changes in load and generation, and can dynamically adjust the power factor to ensure stability and efficiency. The use of Power Factor Agents in a multi-agent power system provides an innovative solution for improving the power factor and ensuring the safe, reliable, and efficient operation of power systems.

Principal of work of stability agent

A stability agent in a multi-agent power system is an artificial intelligence-based control algorithm that is responsible for monitoring and maintaining the stability of the power system. The stability of a power system refers to its ability to return to a normal operating state after a disturbance or perturbation. The stability agent uses real-time data from sensors and communication with other agents in the multi-agent system to detect and respond to stability issues. This can include adjusting the generation or load of the power system, or adjusting the parameters of power electronics components. The stability agent is critical to ensuring the reliability and stability of the power system, as disturbances and fluctuations can lead to blackouts or damage to the power grid. The use of stability agents in a multi-agent power system can result in improved system resilience and reduced downtime, leading to a more efficient and reliable power system.

3. System Implementation Using JADE

These are some of the benefits of using a Multi-Agent System in power systems. However, it is important to note that designing and implementing a MAS-based power system can be complex and challenging. It requires careful planning, coordination, and monitoring to ensure that the

system is functioning properly and delivering the desired benefits.
JADE (Java Agent Development Framework) is a toolkit that provides a framework for developing multi-agent systems (MAS) in Java. The following are the steps to develop a multi-agent system in JADE: Create an Agent Class: To create an agent in JADE, you need to extend the jade. Core agent class and override the setup method. In the setup method, you can specify the behavior of the agent, such as what it should do when it receives a message or when a specific event occurs. Define Agent Behaviors: JADE provides a Behavior class that you can use to define the behavior of your agent. You can create multiple behaviors for an agent and add them to the agent using the add Behavior method. In an Agent System, behavior refers to the actions and interactions of an individual agent in response to its environment and goals. The behavior of an agent can be thought of as its "strategy" for achieving its objectives, based on its perception of the world and the information it has available.

An agent's behavior is typically defined by a set of rules or algorithms that dictate how the agent should respond to different stimuli and events. This can include decision-making logic, communication protocols, and reactive actions in response to changes in the environment.

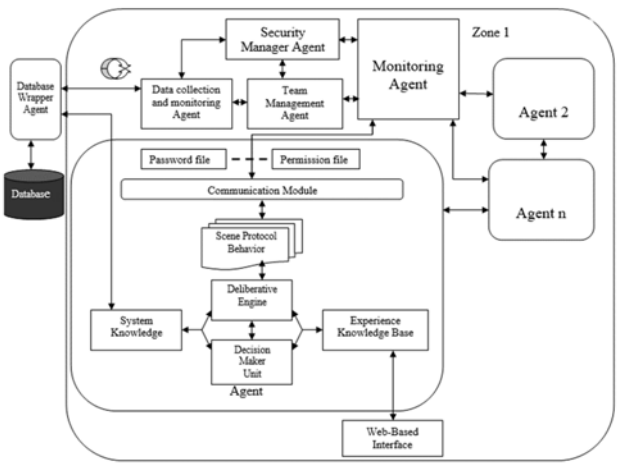

Fig.5. The architecture of the developed agent

The behavior of an individual agent can have a significant impact on the overall performance of the system, so it is important to design the behavior of each agent in a way that supports the goals of the system as a whole. In a Multi-Agent System, the interactions and coordination among the agents' behaviors can be particularly important in determining the overall performance of the system. Create a Container: To run your agents, you need to create a container. The container is responsible for creating and managing the agents. You can create a container using the jade .Boot class, specifying the agent classes and other parameters as command-line arguments. Start the Container: Once you have created the container, you can start it by calling the start() method. Once the container is started, the agents can start communicating and interacting with each other. Debug and Test: Debugging and testing is an important part of the development process. JADE provides a number of tools, such as the JADE GUI and the JADE debugger, to help you debug and test your agents. These are the general steps for developing a multi-agent system in JADE. Depending on the complexity of your system, you may need to perform additional tasks, such as setting up a database or specifying communication protocols. However, by following these steps, you can get started with developing a multi-agent system in JADE

4. System Testing

An Agent System Architecture refers to the design and structure of an intelligent agent system. It defines the components, their interactions, and relationships within the system. The components of an agent system may include: Agents: software entities that act on behalf of the user or owner, Environment: the external world in which the agents operate, Communication: the means by which agents exchange information and coordinate their actions. Reasoning: the mechanism by which an agent processes information and reaches decisions. Knowledge: the information an agent has available to make decisions. Learning: the mechanism by which an agent improves its performance over time. The architecture of an agent system should support the implementation of intelligent agents that can achieve their goals effectively, efficiently, and in a way that is consistent with their objectives and constraints.
In an Agent System, "sense" refers to the process by which an agent gathers information from its environment. The ability to sense the environment is a crucial component of an agent's functionality, as it provides the input that drives the agent's behavior and decision-making processes. Sensing can be performed through various means, such as observation, measurement, or communication with other agents. The type of information that an agent can sense can vary widely, depending on the specific requirements of the system. For example, an agent might sense the temperature in a room, the presence of an object, or the status of a network connection. The quality and accuracy of the information that an agent senses can have a significant impact on its performance, so it is important to design the sensing capabilities of each agent in a way that meets the requirements of the system. In some cases, multiple agents may need to collaborate to sense the environment effectively, sharing information and working together to generate a more complete picture of the world.

Testing multi-agent systems in smart grids is crucial for ensuring their reliability and performance. The testing process involves evaluating the agents' abilities to work together to achieve a common goal in a simulated or real-world environment. This includes checking the agents' communication, decision-making, and control abilities, as well as their response to different scenarios and disturbances. Moreover, it is also important to evaluate the security and robustness of the system against potential attacks or failures. This can be done through simulation or experimentation, and the results are used to refine and improve the system design. An effective testing process is essential to ensuring the success of a multi-agent system in a smart grid.

To effectively test a multi-agent system in a smart grid, a combination of simulation and real-world experiments should be conducted. Simulation experiments can provide controlled testing of the system in a variety of scenarios, while real-world experiments allow for a more accurate representation of the system's performance in actual conditions. Additionally, fault injection experiments can be used to test the system's ability to handle failures and maintain stability, while security experiments can help evaluate the system's resilience against cyber threats. Performance experiments can also be conducted to measure the system's efficiency and effectiveness in meeting specific objectives. By conducting a comprehensive set of experiments, the reliability and performance of the multi-agent system can be thoroughly evaluated and any necessary improvements can be made.

To firmly examine the proposed system and prove its effective ability to communicate, we conducted some evaluation experiments. In an experiment, the agents are initially registered With a central monitoring agent. Then the agents start communicating with each other And the exchange of decisions such as load demand, system efficiency, the amount of energy generated, existing faults, and maintenance work. The system worked successfully as it was designed, and the completion of cooperation between different customers was followed up.

5. Conclusion

The conclusion of a multi-agent power system is that it can provide a more flexible and efficient solution for power management in a complex power system environment. The use of multiple autonomous agents allows for decentralized decision-making and distributed control, which can lead to improved system performance and reduced risk of failure. However, it is important to carefully design the agents and their interactions to ensure coordination and avoid conflicts.

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