# Framework for Capitalizing Multi Agent System in Application of Power Engineering

**Rohit Sharma, Atma Prakash Singh**

*Abstract*— **The growing need of intelligent computing focuses on utilization of Multi-Agent system. Various fields like medical diagnosis, production planning, network monitoring, intelligent tutoring, education planning, production management etc. are facilitated by using MAS based approach. As MAS is an emerging technology where complex problems are solved with collaboration, coordination and communication between agents where Agent can be simply viewed as self-described autonomous software component or piece of codes. Here agent's capability and its characteristics like reactivity, pro-activeness, social ability etc. are used to facilitate applications in power engineering. Multi-Agent System will be beneficial for the construction of powerful, flexible, scalable and extensible system. It also reduces the power system failure and fault occurrence rate. MAS provide capability to power systems to reconfigure themselves. It will have less failure rate. This paper mainly focuses on handling issues of power system like conditional monitoring of plant and equipment by gathering data from sensors, diagnosis from faults, distributed control of power system etc. by mean of Multi-Agent system. In this paper the proposed MAS based model shows the approach to solve these issues mentioned above with the help of various agents. Each agent is either partially or fully independent of each other. The distributed problem solving approach is used to solve these issues. Agents communicate and co-ordinate with each other in order to reduce faults. Several agents are used to monitor and diagnosis from faults. Agents will interact with sensors and from there they will get data with will be further converted into meaning full information's. In case of occurrence of faults agents generate a diagnosis conclusion with help of several algorithms.**

***Index Terms— Intelligent Physical Agent, Multi Agent System, Power Engineering***

## I. INTRODUCTION

More than twenty years of research in the area of agents and multi -agent systems have provided remarkable results from the point of view of both theoretical and practical. However, after many years of research, there is no consensus on a few basics such as "what is an agent? ", "What is a multi -agent systems", an agreement on terminology used, etc. The increasing need for intelligent computing focuses on the use of a multi - agent system. Various fields such as medical diagnosis, production planning, network monitoring, intelligent tutoring, educational planning, management, production, etc. are facilitated by the use of the MAS approach.

As MAS is an emerging technology, where complex problems are solved with the cooperation, coordination and communication between agents where the agent can be easily perceived as self-described independent software component or a piece of code. Here, the ability of the agent and its features such as reactivity, proactivity, social ability, etc. are used to facilitate applications in electrical engineering. Multi - agent system will be beneficial for strengthening the powerful, flexible, scalable and extensible. It also reduces the malfunction of the supply system and the failure rates. MAS provide power systems the ability to reconfigure. It has the least failure rate.

This paper focuses mainly on the management of power system problems that facilities and equipment condition monitoring by collecting data from sensors, troubleshooting, and process control distributed energy system, etc. through a multi - agent system. In this work, the model shows the proposed MAS based on the resolution of these above with the approach using several problems agents. Each agent is either partially or totally independent. The distributed to problem solving approach is used to solve these problems. Agents communicate and coordinate with each other to reduce failures. Several agents are used to control and fault diagnosis. Agents will interact with sensors and there will obtain data that will become more in line with all the information. In case of occurrence of failures agents generate a conclusion using different diagnostic algorithms.

### A. Problem Statement

There is not a single definition of an agent that is universally accepted. However, the following definition from the Wooldridge and Jennings [1] is commonly adopted in the field. An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives.

Note that the agent discussed here is actually a software entity. The two basic properties that an agent must have are autonomous, and situated. Autonomous means that a software agent must be able to operate without the direct intervention of people or other agents and has control over its own action and internal state. Situated means that a software agent is situated in some type of environment. These environments may be dynamic, unpredictable and unreliable.

According to Jennings and Wooldridge, to make an agent "intelligent", the software agent should be able to take flexible autonomous actions in order to meet its design

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objectives [2]. Flexible means an agent is reactive, proactive and social. By reactive, it is meant that the agent perceives its environment and responds in a timely fashion to changes that occur in the environment. By proactive, it is meant that the agent does not simply act in response to its environment but is able to achieve a goal by taking the initiative. By social, it is meant that in order to achieve its goals, the agent interact with people or other agents.

A Multi-Agent System (MAS) is an organization of heterogeneous and self-motivated agents that interact with one another. The agents in MAS could have conflicting interests or they could coordinate with one another to accomplish the same mission.

Reactive systems that maintain an ongoing interaction in some environment are inherently more difficult to design and implement [2]. One can classify these systems into three categories: open systems, complex systems, and ubiquitous computing systems. Some of the characteristics that these systems have are dynamic, highly complex, and unpredictable. With a better encapsulation, and modularity, the agent paradigm can develop a number of modular components that are specialized at solving a particular aspect of the complex, unpredictable system. In addition, with reactiveness and proactiveness, an agent can be relied upon to persist in achieving its goals, trying alternatives that are appropriate to the changing environment without continuous supervision and checking [3]. The Agent technology also helps to improve the efficiency of software development, especially when the data, control, expertise, or resources are physically or logically distributed.

## II. MPACT AND BENEFITS OF AGENTS IN POWER APPLICATIONS

Agent technology offers a way of developing new and innovative applications. Some of these will target traditional issues and problems in the industry, but agent technology provides a new suite of techniques and abilities to solve them. Instead of considering systems which have a fixed interaction between individual software modules and hardware elements, we are now able to consider the interactions flexibly altering in real-time. In addition, instead of the decisions on the interactions being centralized in some form, each individual module within the system, implemented as an intelligent agent, can determine its own goals in terms of interactions and co-operation.

In this way, systems are dynamic and flexible. New intelligent agents can be accepted into the overall functionality at any point, and agents can be stopped without affecting the integrity of the other agents in the system. Moreover, an intelligent agent will proactively seek new sources of data or other agents to collaborate with in order to be able to fulfill its own goals.

These capabilities offer advanced benefits for many applications. A limited number of examples are provided in the following sub-sections.

### A. Condition Monitoring

Condition monitoring of equipment and plant items offers a number of challenges:

- Gathering data from a variety of sensors;
- Interpreting the data to extract meaningful information.
- This often requires the use of multiple algorithmic and intelligent system based approaches;
- Combining the evidence and information from different interpretation algorithms to generate an overall diagnostic conclusion;
- Delivering the diagnostic information, in the correct format, to relevant engineers; and
- Automatically altering power system and plant settings based on the condition of the plant.

If we consider plant items such as transformers, there are varying sensors which can be used to monitor them. For example, UHF monitoring of partial discharge, acoustic monitoring of partial discharge, on-line dissolved gas in oil measurement, etc. Furthermore, operational information about the circuit loading and fault conditions from digital fault recorders can also be used to inform the diagnostic process. The use of multi-agent system technology allows individual sensors and information sources to be combined in the condition monitoring/diagnostic process. Importantly, it allows information to be used when it is available or relevant. For example, an intelligent agent responsible for monitoring the output from the UHF sensors can inform the engineer/diagnostic algorithms when significant partial discharge activity has been detected. The agent determines when such information should be communicated, and to whom. This approach allows the flexible integration of as much diagnostic data, information and knowledge as is available. It also permits new sensors and interpretation algorithms to be introduced seamlessly into the overall system, since there is no higher level central systems integration control.

As an example, the authors have developed a transformer condition monitoring multi-agent system.

### B. Post-Fault Diagnosis of Power System Faults

When operational engineers investigate the causes and impact of power system faults, they employ a number of data sources. These include Supervisory, Control and Data Acquisition (SCADA) system data, digital fault recorder data, traveling-wave fault locator data, etc. In a similar fashion to the condition monitoring problem discussed in section III.A, automation of the analysis of such data provides essential decision support to operational engineers. For example, the authors are working with a UK utility which experienced an influx of 15,000 SCADA alarms and 1,695 digital fault records during a single storm. The engineers require effective supporting analysis tools to combat such situations.

Research into the application of intelligent systems for the analysis of power systems data has been ongoing for the best part of two decades and has produced a variety of tools and techniques for analyzing individual data sources. Multi-agent system technology can be used to integrate legacy data analysis tools in order enhance diagnostic support to engineers, giving engineers a holistic view of the performance of power systems based on a variety of data sources.

### C. Active Distribution Networks

As the penetration of distributed generation and renewable energy increases in the modern electrical distribution systems, there has been a move from passive to more active distribution networks. The management and control of active networks presents a number of challenges, not least in the scalability and flexibility of solutions. A number of researchers are considering agent-based approaches as an alternative to centralized power system management and control. By distributing management and control functionality as intelligent agents, decision-making regarding network restoration, reconfiguration, the dispatch of generation, and the management of loads is no longer centralized but locally managed.

Each local decision is dependent upon the prevailing conditions in that section of the power system. Therefore, intelligent agents which monitor the local conditions, have their own decision making process, can control local switchgear, plant and equipment and are able to co-operate and co-ordinate with other regions of the network are the an appropriate technical solution to this complex control problem.

### D. Agent-based modeling of power systems

The modeling and simulation of complex power systems, energy markets and overall energy networks and energy utilization is a difficult challenge. The area of agent-based modeling has arisen, which supports complex modeling and simulation activities in a number of domains. Within this field, individual actors/entities are modeled as individual agents. For example, in a simple case individual generators (including distributed/renewable technologies) and individual loads could be modeled as separate agents who can interact.

The overall simulation arises from the real-time interaction of the agents. Each agent has in-built intelligence regarding how the actual load or generator would behave in reality. In this way, large networks can be catered for. Enhancing this, suppliers, brokers, generators and customers could all be individually modeled in order to simulate an energy marketplace. This is a powerful use of agent technology.

## III. TECHNOLOGY CHALLENGES FOR POWER ENGINEERING

In order to support the power engineering community in terms of effective implementation of agent technology, a number of key technical challenges must be overcome.

- How should an agent be built for power engineering applications?
- How to should a society of agents be built for power engineering applications?
- Within these questions, there are a number of technical issues to be addressed. These include:
- **Platforms:** a number of multi-agent system platforms exist. However, judicious selection is required to ensure long term compatibility and the required robustness for online applications.
- **Toolkits:** based on the increasing amount of agent research within the power engineering community, there is the opportunity to re-use agent designs and functionality for the benefit of the whole community. Therefore, there is a role for toolkits which allow the re-use of existing agent functions, behaviors and capabilities.
- **Intelligent agent design:** new researchers and industrial implementers need guidance on how exactly an agent should be designed or, at very least, knowledge of the available options. A number of different concrete architectures for intelligent agents can be found in the literature: Belief Desire and Intention (BDI) agents [4], reactive agents [4], agents with layered architectures [4], and agents implemented using model-based programming [10]. Each of these implementation strategies will produce agents with differing degrees of reactivity, pro-activeness and social ability. What is not readily understood is how flexible autonomy varies across these implementation strategies and their suitability for different power engineering applications.
- **Agent communication languages and ontologies**: Underpinning the social ability of agents are agent communication languages. These define how agents exchange information, communicate and negotiate. Within them are protocols and content languages which allow meaningful messages to be composed and interpreted. International standards are set by the Foundation for Intelligent Physical Agents (FIPA). A key aspect of using agent-based technology is that all agents within power engineering applications should be able to co-operate and interoperate, and this should be independent of the individual developer. Therefore, the community must agree on the adoption of appropriate agent communication language standards. This extends to the area of ontologies which define the concepts and data which the agents are able to exchange, interpret and understand.
- **Data Standards:** The power engineering community has expended significant efforts in defining data standards for various application areas. One example is the Common Information Model (CIM) for data exchange between Energy Management Systems and related applications. Another is the IEC 61850 Communication Networks and Systems in Substations standard for data exchange between Intelligent Electronic Devices (IEDs). There is the potential to combine the activities in these areas with those of agent communication languages, to harmonize the standards, and provide seamless data exchange at all levels of functionality. This could accelerate the potential industrial implementations of agent technology.

Beyond technical and implementation issues described above, the lack of experience in the use of multi-agent system technology in industry is an obvious concern of both utilities and manufacturers considering MAS solutions. According to Wooldridge and Jennings [1], the migration of an agent system from prototype to a solution that is robust and reliable enough to be used in practice is a non-trivial step. This naturally leads to a requirement for the demonstration of MAS technology in the industrial environment for a range of applications. Furthermore, there is also a requirement for clear communication of the results of industrial trials of MAS technology, highlighting failures and problems as well as successes, to the wider power engineering community.

A fundamental charactistic of multi-agent systems is that individual agents communicate and interact. This is accomplished through the exchange of messages and, to understand each other, it is crucial that agents agree on the format and semantics of these messages. Jade follows FIPA standards so that ideally Jade agents could interact with agents written in other languages and running on other platforms.

There are many auxiliary parts to a message in addition to the *content*, for example: the intended recipients, the sender and the message type. It is essential for the message as a whole to respect a common format. In JADE, messages adhere strictly to the ACL (Agent Communication Language) standard which allows several possibilities for the encoding of the actual *content*. In particular, Jade supports FIPA's SL (Semantic Language), a LISP-like encoding of *concepts*, *actions* and *predicates*. It also allows the content to be serialized Java objects. For simple application (like our tutorial examples), it is often easiest to treat the content as simply a String whose meaning is application dependent.

## IV. PROPOSED SYSTEM

In exceedingly dominated DER, particularly CHP type, the generators have little inertia, so they with no trouble out of step when the squat circuit occurs in the systems. The defense should response rapidly to look forward to this problem. To solve this predicament, this paper proposes discrete adaptive rule-based defense supported with distributed database agent. The proposed process is based on Oudalov et al.'s federal adaptive protection algorithm [5] and P. C. Maiola [6]. The algorithm will be implemented in the protection agent inside the equipment layer supported by local database agent instead of concentrating it on single management agent.

### *A. Proposed Architecture*

The future architecture of (MASBP) Multi-Agent system based guard can be seen in the Figure 5. In the tackle layer, IED agents are second-hand as combined function of CT representative, PT negotiator, CB agent make longer with local database agent and local knowledgebase agent that formed by local coordination agent and local configuration agent that acted as circulated database and circulated knowledgebase. Because this agent is worn as Intelligent Electronic Device (IED) so it named as IED agent and the structure can be seen in Figure 6. The agents inside IED Agent are named as unit for clarity. Substation layer are consist of coordination agent and configuration agent. Harmonization agent is responsible for identify fault type and fault location according the information received from IED Agents. Configuration agent is expert systems that come to a decision which solution or relay setting should choose to defeat the dilemma and also provide the backside-up system protection scenario. The understanding agent will support by file agent to hoard the data i.e. list of rules of the solution, crisscross topologies, etc. management layer is consist of valuation agent, that will weigh up every condition occurs in the system. The agent will calculate the system's stipulation offline and weigh up if the safeguard system previously running properly and efficiently. Record Agent is agent that food all the information calculated by the other agent such as relay setting, arrangement / topology changing and also faults history. DF (Directory Facilitator) Agent is agent that has a special function to register the services. AMS (Agent Management Server) is agent that has a special purpose to record all the agent used in the MAS. Each agent will converse each other by means of TCP/IP protocol. In the real scheme IED Agent (A01-A12) are install at the location of the CB (see Figure 7). Every IED manager will connect to other agents via TCP/IP communication protocol.

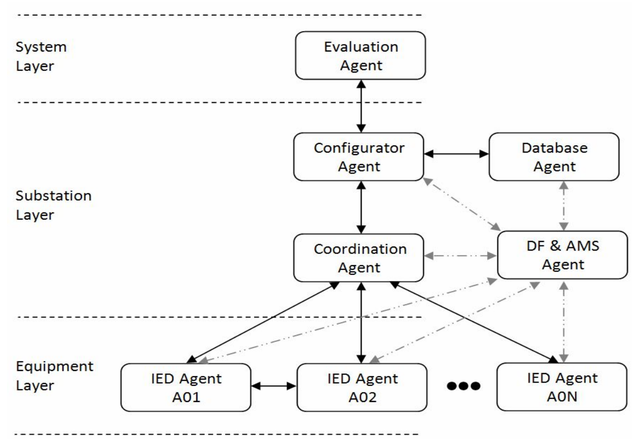


Figure 1: Block diagram of proposed MAS protection architecture

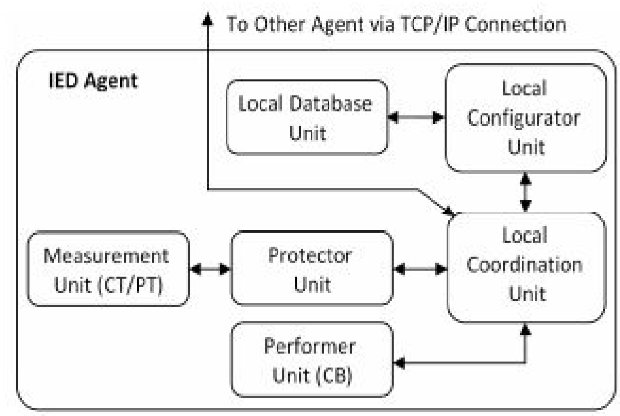


Figure 2: Block diagram of IED agent architecture

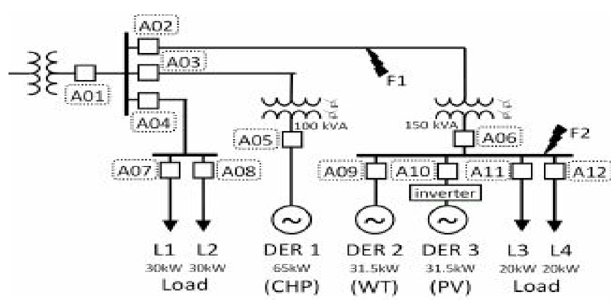


Figure 3: Distribution feeder with DER and MAS protection

### *B. Proposed Algorithm*

In the commencement, all agents require to register their name and function to AMS agent and DF agent respectively. Every

IED Agent should make sure and list the neighbor IED Agents which are associated to them. This will carry out clause topology. After agent initialization completed, IED Agents will found to measure and keep an eye on the system current and voltage every certain time via measurement unit (CT/PT) and send to Protector Unit (see Figure 7). The Protector Unit will calculate and determine the fault current and maximum load current when changing circumstances like fault happen in the network. If fault occur Protector Unit will hurl the in turn to the Local Harmonization Unit. After in receipt of information from Protector Unit, Local Harmonization Unit will first check the set of connections grid condition is in islanding situation or grid attached by inspection of the status of the representative at main breaker. Next step, Local Coordination Unit will request information from neighboring IED Agent. From all data gather Local Coordination Unit will determine and calculating the fault type. All information will drive to Local Configuration Unit to get the “Relay surroundings Configuration”. After strong-minded the relay setting, the Local Configuration Unit will send the information to Local Coordination Unit what condition should be achieved. The Local Harmonization Unit will send Trip Signal to CB through Performer Agent. The Local Harmonization Unit will send the report information to Harmonization Agent of Substation Layer. In the Substation Layer, Harmonization Agent will gather data from every IED Agent in the whole system. Harmonization agent will check whether the fault is cleared by IED Agent or not. If it is cleared, the Harmonization Agent will capture the new topology and send all information to Evaluation Agent in the System Layer for evaluation.

If the fault condition still occurs, the Harmonization Agent will calculate the fault location and send the information to Configuration Agent to get the “Relay Configuration” list, that is the list of which relay will operate and which relay will block according the situation. After received the list, the Harmonization Relay will send the information to all IED Agents what condition should be achieved and wait the confirmation from IED Agent if it is done. If one or several Relay Agents failed to respond, the Harmonization Agent will send the request for back-up planning list to the Configuration Agent and the new list of “Relay Configuration” will be issued to Harmonization Agent. The “Relay Configuration” list is saved in the Database Agent. The whole information will be send to Evaluation Agent in the System Layer to evaluate. In the Evaluation Agent all information will be evaluated and reported to the operator. The proposed algorithm can be seen in the flowchart in Figure 8

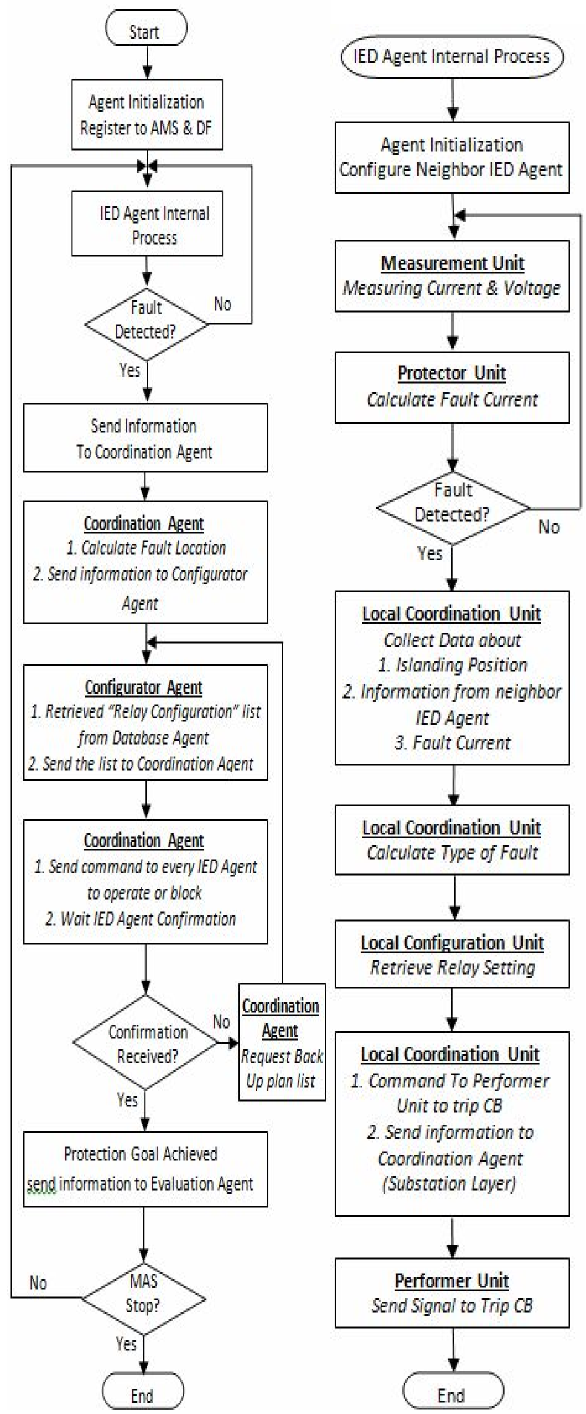

Figure 4: Flowchart of the proposed algorithm

The future algorithm is replicated on the test system using Matlab-Simulink based on Figure 4.3. with three phase to ground responsibility occurred on F1 and F2. After initialization every manager will register the neighbor-agents to create protection zones (Table 4).

| Agent | A02 | A06 | A09 | A10 | A11 | A12 |
|---|---|---|---|---|---|---|
| Neighbor-Agents | A03 | A05 | A10 | A09 | A09 | A09 |
| | A04 | -- | A11 | A11 | A10 | A10 |
| | A06 | -- | A12 | A12 | A12 | A11 |

Table 1: Neighbor-agents for some agents.

If the liability current occurs, quite a few agents will sense the encumber current, first the agent will ensure the islanding status, and then the agent will measure up to the fault current to neighbor-agents and conclude which convey setting should be preferred from the local database and trip the CB.

## CONCLUSION

This paper discusses the design and implementation of the multi-agent system for use in an IDAPS microgrid. The proposed multi-agent system consists of a control agent, a DER agent, a user agent and a database agent. Agents exchange their messages via a TCP/IP protocol based on the IEEE FIPA standard to ensure the system interoperability. The application implementation process is illustrated through a real-time simulated case study, which indicates that the proposed multi-agent system can disconnect and stabilize the microgrid from the local utility when upstream outages are detected. This illustrates the capability of a multi-agent system as a technology for managing the microgrid operation. Multi- agent system's timely response facilitates the seamless transition from grid connected to island mode on detection of upstream outages in a microgrid. This demonstrates that the agent's capability can be considered as a software alternative to a traditional hardware-based zonal protection system for isolating a microgrid. Therefore, the multi-agent system provides a more flexible and updatable IDAPS layout, which will allow the redefinition of the microgrid zonal boundary on the fly. In addition to serving as a flexible protection alternative, the IDAPS multi-agent system also sheds non-critical loads according to a pre-defined prioritized list while stabilizing the microgrid after its isolation from the main grid. In sum, this work aims at demonstrating a practical implementation of multi-agent systems in a smart grid located at a distribution level.

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