An Architecture of a Multi-Agent System for Power System Operation
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Abstract: - There is a permanent demand for new application and simulation software for power systems. The main idea of this work is purpose architecture of a Multi-Agent System to help operators during restoration task of power substations and distribution systems. This tool was developed using an Object-Oriented approach integrated with the intelligent agent technology. The application of object-oriented modeling in power system has been shown appropriated due to its reuse and abstraction. Furthermore, the Multi-Agent Systems (MAS) are being applied in power system problems solving, and some good results were obtained and the interest in this area has increased in the last two years.

Key-Words: - Multi-Agent System, Object-Oriented Approach, and Power System Operation

1 Introduction
There is a permanent demand for new application and simulation software, required for different purposes such as research, planning and power system operation. This software becomes larger and increasingly complex, and as a consequence, to create it is more difficult to complete in time and within the budget’s constraints. It has become very difficult to create these new applications with traditional software development technology. When finally finished, they are difficult to understand, to maintain, to integrate into old application and to modify for new requirements.

Studies in computer science have shown that the reuse may improve software development productivity and quality. Productivity increases as previously developed assets can be used in current applications, which saves development time. Quality may be increased as frequently reused assets have been tested and corrected in different study cases.

The main idea of this work is to purpose architecture of a multi-agent system for power system operation, and also to show the development of a computer tool based on this approach to help operators during restoration task of power substations and distribution systems. The restoration of power system normal configuration after a fault, or even a blackout, is performed by intervention of a human operator. Considering the growing complexity in the arrangement of substations and power distribution systems, and the probability of human failure, the time spent in the execution of the restoration actions is larger and has to be optimized.

This tool was developed using an Object-Oriented approach integrated with the intelligent agent technology. The application of object-oriented modeling in power system has been shown appropriated due to its reuse capability and abstraction [1 - 3]. Furthermore, the Multi-Agent Systems (MAS) are being used in power system problems solving, and some good results were obtained and the interest in this area increased in the last two years [4, 5].

The implementation was done using the Java-based Framework, which provides a generic methodology for developing MAS architecture, and a set of classes to support this implementation.

MAS are a way to artificially reproduce real-life system through a model made of autonomous and interacting objects, called agents. The main advantage of multi-agent simulation is to allow the modeling of individual behavior, and the facility to get more real simulation systems. The behavior of the power system components can be simulated by agents that act in the same way.

2 Multi-Agent Architecture for Power System Restoration
The MAS use in power systems research has been increasing with the development of several studies in power systems operation [4], markets [5], diagnosis and protection. The Intelligent Agents’ theme for the first time have had a session at The International Conference on Intelligent System Application to Power System, in 2001, and this shows the researchers’ interest in this area.

The development methodology follows five stages: (i) identifying the agents, (ii) identifying the agent conversations, (iii) identifying the conversation
rules, (iv) analyzing the conversation model, and (v) MAS implementation. The system developed provides communication, linguistic and coordination support through Java classes. Communication support is provided for both directed communication and subject-based broadcast communication. This feature enables the development of scalable, fault-tolerant, self-configurable and flexible MAS.

The Multi-Agent Model architecture is shown in Fig. 1. Two main packages and support agents compose this model: a Distribution System Package and a Power Substation Package. There are four support agents working on integration of the model with the real world and among the packages.

2.1 Support Agents
There are four support agents in the model responsible for the integration of model with the real world and among the packages. The Interface Agent is responsible for accessing the SCADA database, so this agent is responsible for the temporal continuity of the MAS in providing timely and consistent information to the other agents. In this agent is described what information is given to each agent, filtering all irrelevant data, minimizing communication and pre-processing tasks.

The Communication Agent is responsible for agents’ interconnection; it works like communication center: all messages flow through it. This is very important for network processing and for future development of new agents, because the address of a new agent is recorded into the communication agent only, instead of in all the agents. This scheme of communication is called federated systems.

Planning Agent is responsible for determining the actions to solve operation tasks. This agent contains a planning algorithm that analysis all messages from other agents, providing an assigned plan to the user.

Model Agent contains the object-oriented model and continuously compares the power system model with the information provided by the Interface Agent. If a difference between the model and the real world is detected the agent immediately inform the communication agent that is responsible for transferring this for the appropriate agent [2, 3].

The object-oriented modeling allows the system’s distributed representation, providing flexibility. The distributed representation is interesting for the study of power systems, because of the natural properties of these systems in presenting distributed topology, and also because the model must reproduce the occurred alterations in the real world. Another advantage presented by this type of modeling is the reuse capability.

2.2 Power Substation Package
The Power Substation Package performs operation tasks in substations, and contains five agents: Alarm Processing Agent, Switching Agent, Measurements Agent, and Equipment Agent.

Alarm Processing Agent provides expertise about the possible occurred problem. When a disturbance occurs in the system, there will be many alarms provided by the SCADA system. Usually, most of these alarms are redundant and happen due to secondary problems caused by the primary problem.
The main idea of this agent is to detect the primary problem, and to send two kinds of alarms to the MAS. The first kind is the alarms of the primary problem, while the second kind are the main alarms for secondary problems. The first kind is very useful to know the problem and to provide a solution. The second kind (sometimes, more important than the first one) is useful to decide the degree of the contingency.

The Equipment Agent acts as a function of the affected equipment, according to a defined procedure. This program checks up the transformers, buses and capacitors conditions, and in the absence of equipment’s inside defects, it signals to liberate the restoration action.

The Measurements Agent monitors the analogical signals of interest, as the voltage values, current, frequency and the angle between voltage and current, in permanent state, with their linked inputs through transducers to CT and PT. This monitoring detects the defect possibilities or oscillations that affect the restoration and, in agreement with the found values, the process can be validated, interrupted or modified, impeding voltage outages and badly energization caused by strategy mistakes and damaged equipment.

The Switching Agent checks up the operated switches, performing continuous monitoring of the switches’ state, circuit breakers, grounding switches and by-pass switches. Accordingly with its knowledge base it defines the action to be taken into system switches.

2.3 Distribution System Package
The Distribution System Package performs the operation tasks in distribution systems, and contains five agents: Restoration Agent, Switching Agent, Load Flow Agent, and Load Shedding Agent.

Restoration Agent contains some advice about the best strategy for switching on. Two main ideas provide the ways for problem solving. The first one is to try a restoration by a previously energized feeder. The second idea is to find parallel circuits to provide this restoration.

The first idea is possible to apply in radial systems or in temporary unavailable circuits (e.g. temporary faults). In the case where a partial blackout occurs, the system contains a strategy to feed in first place the boundary buses of the blackout system. The idea is to reduce the affected area step-by-step.

Load Flow Agent is a numerical application inside an agent and provides the voltage drop on each feeder branch, the voltage on each bus, and the projected power flow through the distribution system. This information is used by the Planning Agent in finding between the possible solutions, which one has better chances to be executed.

Load Shedding Agent is designed to avoid a frequency or voltage power system collapse. This agent contains a knowledge base about the load shedding strategies of the system under analysis, and comprises a standard numerical program.

2.4 Interaction Diagram
The Interaction Diagram of the MAS model of the power substation application is shown in Fig. 2. In this diagram is presented all communication between agents. It starts with Interface Agent accessing SCADA database, and then sends this information to the Model Agent through Communication Agent.

The Model Agent compares the power system model with the information provided by the Interface Agent, and then sends all changes to Protection, Measurement, Equipment and Switch Agents, which are responsible by analyze it and provide operation actions.

Furthermore, the Protection Agent performs an analyze of protection status trying to identify primary and secondary problems.

All actions suggested by agents were send to Planning agent via Communication Agent by concurrent computation. With all this suggestions Planning Agent determines what actions are needed to solve operation tasks providing an assigned plan to the user.

In Fig. 3 is presented the interaction diagram of the MAS model of the distribution system application.

As the first diagram all computation starts with Interface Agent accessing SCADA database, and then send this information to the Model Agent through Communication Agent.

The Model Agent compares the power system model with the information provided by the Interface Agent, and then send all changes to Restoration Agent, who is responsible by determining the best strategy for switching on the system and managing the solution search.

The Restoration Agent asks Switch Agent to provide all possible solution of switching. For each solution finded the Restoration Agent will ask the Load Flow Agent to perform its analysis providing the voltage drop on each feeder branch, the voltage on each bus, and the projected power flow through distribution system.

If it is necessary the Load Shedding Agent is called to help finding a switching plan. Since Load Shedding Agent indicates the low priority buses the Restoration Agent restart the process.
Fig. 2 – Interaction diagram of the MAS Model of the power substation application

Fig. 3 – Interaction diagram of the MAS Model of the distribution system application
When a good switching plan is obtained the Restoration Agent determines what actions are needed to solve operation tasks providing an assigned plan to the user.

3 The Computer Packages
The computer packages are under development, the first one performs the distribution system package tasks, and the second one the power substation package tasks. It was used a Java platform for the power substation problem, as presented in Fig. 4. It has a diagram of the substation, a dialog box, a floating window where plans for operation are presented, and finally a status bar where is presented all system’s measures.

The user has an option to visualize all protections by activating a menu command, and also, it is possible to visualize all the messages exchanged by the agents.

For the program of distribution system it was used a Visual Basic platform presented in Fig. 5, and this program is under development yet.

4 Conclusions
The MAS shows to be adequate for working with the object-oriented model, given to the characteristics of distribution of both the technologies.

The MAS architecture is divided into packages of agents that interact to solve the same problem. This packaging is organized as to facilitate the development process, which can be done by different developer groups. In addition, it gives the possibility of including hierarchical analysis of power systems, and flexibility to extend the system through addition of new agents.

The main benefits obtained with the multi-agent model were: Cooperative behavior, characterizing dynamic exchange of information between entities and making possible segmentation of tasks, besides allowing the reduction of the hierarchic characteristics of the decision process; Competitive processing, making possible better use of the hardware resources and reduction of the computational load, improving the execution speed; Distributed topology, making possible in the abstraction process, the division of the system in lesser number of parts, limited by functional characteristics; Open architecture, allowing the addition of components and the expansion of the system, as part of a bigger system, with creation of new environment levels.

Beyond restoration tasks, these programs can be used to perform operation tasks like maintenance planning, reconfiguration, etc. This is provided by the general knowledge base developed in each agent.

References: