AN AGENT-BASED CONTROL SYSTEM FOR OUTAGE MANAGEMENT IN DISTRIBUTION NETWORK IN PRESENCE OF DISTRIBUTED GENERATION

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ABSTRACT

In this paper, a new control scheme based on the multi-agent system concept is introduced which is completely compatible to the today's smart grids with presence of distributed Generations. The aim here is to define an agent-based system, and accordingly a suitable procedure, to improve the fault locating, isolating and restoration process in a distribution network. The proposed system, then, is applied to a network with real characteristics in order to be assessed and evaluated based on its performance compared to some other outage management systems.

INTRODUCTION

In a distribution network, which is the last part of the power system in charge of delivering the produced electricity to the end users, it is crucial to deal with the occurred faults properly, in order to minimize the duration and the extent of the outage. This is the responsibility of an outage management system to realize the occurrence of a fault, in the first place, and take the appropriate measures to handle it.

Generally, an outage management system is expected to sense that a fault is occurred within the network, locate the fault as accurate as possible, isolate it and finally, restore the uninvolved loads by proper switching.

With the growth of complexity of the distribution network, it is important to use more automated and less-human-dependant approaches. Therefore, distribution system automation can lead to more effective outage management systems, reduce the time of the process and consequently, more reliability in supplying the loads. An automated distribution network makes it possible to collect the data from different parts of the network, process them and send the proper operational orders, automatically.

The conventional centralized control system requires the information from different parts of the network in a fault condition for making a proper decision. However, the growth and complexity of today's smart networks is likely to make it impossible –or at least very difficult- for the system to deal with such large amount of data in the future. So, decentralized and distributed control methods, which do not require all network's component's data to be transferred to a central unit, are considered as an effective option for solving the problem. Multi-agent systems, as a novel distributed and intelligent approaches can be applied for developing an outage management system.

Multi-agent systems

Multi-agent systems are intelligent and distributed systems that can be used for solving the problems that have a distributed or complex nature. A multi-agent system is composed of several intelligent agents, each of which tries to achieve its predefined goals.

An agent is usually considered as a computer software entity or other autonomous intelligent components. It is situated in the agent's environment and has the ability to sense changes in its environment and act in it whit some actuators [5].

An agent that has flexible autonomy is considered as an intelligent agent. Reactivity, pro-activity and social ability are three important properties that make an agent, autonomously flexible [3].

Because of their distributed nature, electricity distribution networks are a suitable field for applying an agent-based approach and develop an outage management system which satisfies its needs.

In this paper, a control system for outage management in distribution network is introduced which is able to sense, locate and isolate an occurred fault and restore the maximum numbers of uninvolved loads. Every agent type is defined by taking a specific network component and modifying it.

The proposed system is implemented using JADE middleware –a software framework for multi-agent systems developed in java by Telecom Italia. Then, it is applied to a network feeder, with real characteristics and the results are reported.

THE PROPOSED SYSTEM

The proposed outage management system is composed of several agent types that have different levels of intelligence. Moreover, the interactions between these agents and the message templates they use for communication with each other are defined. Every agent type that is defined and applied in this paper is basically a network component. Thus, the agents are practical. In this section the agent types will be introduced.

Fault Indicator Agent

Fault indicators are the distribution network components installed between the adjacent sections of the feeder and have the ability to sense an excessive current flow and to determine the direction of that current. So, they are used to indicate the fault currents.

In the proposed system, a fault indicator agent type is defined, that is responsible for sensing the fault current and saving its direction. This agent can save the direction of the fault current, “the state”, and is able to report it to another agent, if it is asked. The possible states for a fault indicator agent based on its relation to the fault are shown in Table 1. Fault indicator agents do not have a passive nature and are not conscious of the occurrence of a fault. They just can report their state when being asked.

Simple Sectionalizer Agent

A sectionalizer in a distribution network is a switch that can be opened or closed remotely. It is used for isolating a specific part of a feeder and prevents the current flow to reach that part.

A simple sectionalizer agent in the proposed system is the collection of a sectionalizer and a fault indicator. In fact, a simple sectionalizer agent is just a fault indicator agent with the ability to be opened if necessary. So, it has the ability to sense the direction of the fault and report it as its state. Table 1 indicates all the possible states of a simple sectionalizer agent.

Between some specific adjacent sections of the feeder, instead of a fault indicator agent, a simple sectionalizer agent is installed.

Note that, in a distribution network, installing more sectionalizers lets the outage management system have control on more parts of the feeder. But, because of some resource limitations, this is not possible. So, in the proposed system, this assumption has been made that not all of the sections are separated by sectionalizers. However, the system is not dependant on the number of sectionalizers or the order of simple sectionalizer agents and fault indicator agents.

Table 1: possible states of a fault indicator and simple sectionalizer and simple sectionalizer agent

Relation of the fault indicator agent to the fault	State
Sensing a fault current with a direction toward the end of the feeder	1
Sensing a fault current with a direction toward the beginning of the feeder	-1
Sensing no fault current	0

Load Agent

A load agent is simply responsible for responding to queries by its current load. In every single section of the feeder, a load agent is situated that aggregates the electric loads of that section and can report it to other agents through messages.

Distributed Generation Agent

In every distribution network, some distributed generations or DGs may exist. DGs are some local generators that are installed within the network to supply some important or sensitive loads. In order to consider the effect of these DGs in the outage management system, an agent type called “DG agent” is introduced which can be disconnected from the feeder with requests of other agents or be connected to the feeder if being asked.

Relay Agent

An over-current relay is a component that can sense the fault current and make a circuit breaker open. In the distribution network, usually using the relays are limited and it is common that every feeder has just a single over-current relay installed on its root. So, for the proposed system, a relay agent is defined which is very similar to a relay. It has the ability to sense the fault, open the feeder’s circuit breaker and inform the “main sectionalizer agents” about the fault by sending them a message.

After informing the main sectionalizer agents, the relay agent waits until all of the main sectionalizer agents send back a message and say that they are ready for closing the circuit breaker.

Main Sectionalizer Agent

Every feeder in distribution network is usually divided into few zones and each zone can be supplied by a different assistant feeder. In this paper, it is assumed that the feeder is designed according to this pattern. Thus, in the end of every zone, another type of agent, called “main sectionalizer agent” is located. These type of agents are responsible for locating the fault and sending the appropriate orders for other agents such as simple sectionalizer agents and DG agents.

Fault Locating

When a fault occurs on the feeder, every main sectionalizer agent asks the DG agents located in its zone to be disconnected from the feeder. Main sectionalizer agents are not able to realize if any fault is occurred and they can just begin their searching process if they are informed by the relay agent.

To locate the faulted section, a main sectionalizer send queries to the fault indicator agents or simple sectionalizer agents located in the zone and ask their state, respectively. It starts this process from the very last agent of the zone and after receiving the answer from the agent, compares it with the answer of the previous agent. The flowchart of the Figure 1 shows the fault locating process for a main sectionalizer. Note that in this figure the phrase “fault indicator agents” includes both fault indicator agents and simple sectionalizer agents.

Isolating the Fault

Either a main sectionalizer agent finds a fault in its zone or not, it starts to communicate with the adjacent main sectionalizer agents to get ready for sending the “ready message” for the relay agent. This step is shown in details in the flow chart of Figure 2.

Calculating the Available Capacity

If the fault is occurred in the previous zone of a main sectionalizer agent on the feeder, the agent will be asked about its available capacity. To calculate the available capacity, the agent asks the loads of all load agents. It also asks the available capacity of the assistant feeder of the zone. So, by subtracting these to number, the available capacity is obtained and will be reported.

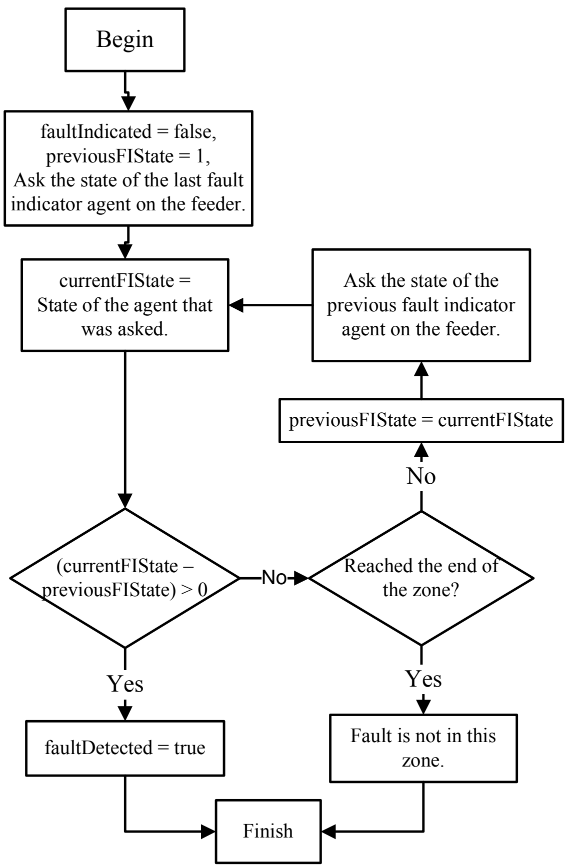

Figure 1: Flowchart of the fault locating process for a main sectionalizer agent.

Finding the Best Sectionalizer to open

The main sectionalizer agent which has detected the fault is responsible for finding the best simple sectionalizer agent to open, in order to restore the maximum number of the uninvolved loads. To do this the agent inquires the available capacity of the next main sectionalizer and the assistant feeder of the zone. Then it starts from the end of the section, asking the load agents about their load. After asking each load agent, it subtracts the load from the total available capacity. Since, only the simple sectionalizer agents can be used for isolating the fault, it is important to save the last passed simple sectionalizer agent. This way after reaching the point that available capacity cannot satisfy the loads' needs, the agent will ask the last simple sectionalizer agent to open. After finishing the process, the main sectionalizer agent sends the "ready message' to the Relay agent.

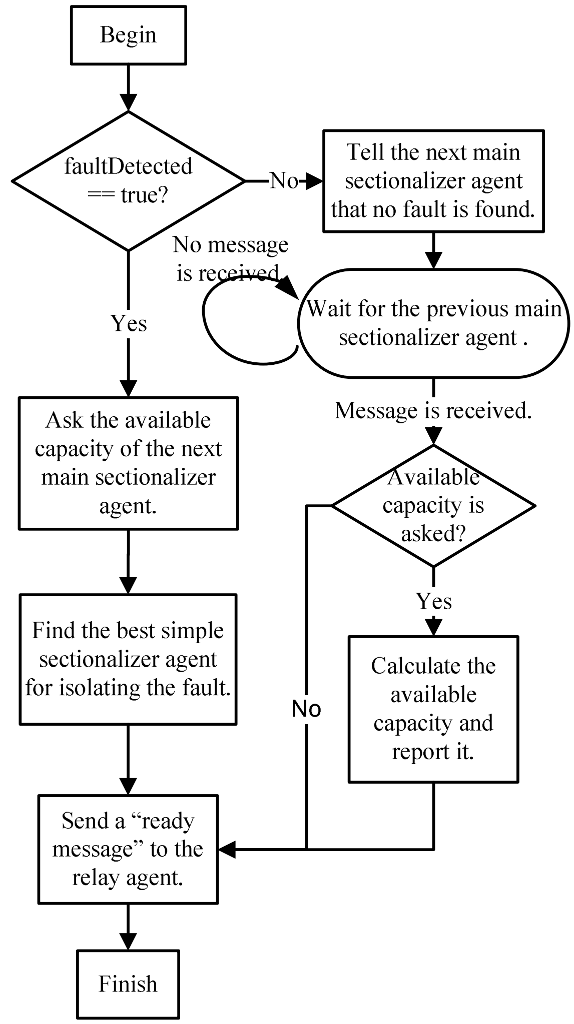

Figure 2: Flowchart of the fault isolation process and preparing for circuit breaker closing.

CASE STUDY AND THE RESULTS

In order to analyze the performance of the proposed system, it is applied to the typical feeder with real characteristics of the Figure 3, and its final results for a fault in section number 9 are shown in As it can be noticed, because the total amount of available capacity for the agent MainSec02 is 30 amperes, it cannot supply all the loads located after the faulted section despite that they are uninvolved. So, it just isolates the fault by opening the simple sectionalizer number 12.
Table 2.
In this table, the states of important switches in the feeder, such as simple sectionalizer agents, assistant feeders and DG agents, are shown. 1 means that the switch is close and 0 indicates that the switch is open.
The agent MainSec02, which is a main sectionalizer situated at the end of the zone 2, locates the fault and then tries to find the best simple sectionalizer to open, based on

the algorithm described before. The important figures for this simulation are provided in Table 3.

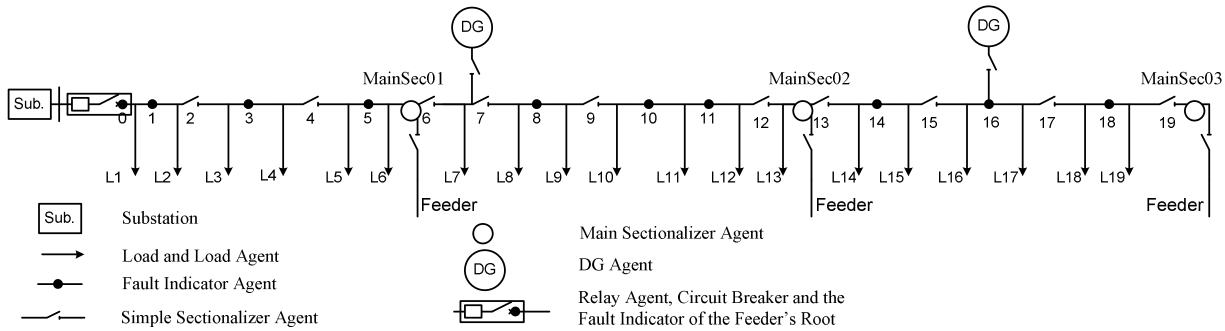

Figure 3: Feeder of the case study

As it can be noticed, because the total amount of available capacity for the agent MainSec02 is 30 amperes, it cannot supply all the loads located after the faulted section despite that they are uninvolved. So, it just isolates the fault by opening the simple sectionalizer number 12.

Table 2: state of the switches after the outage management process for a fault in section 9

Name of switch	Circuit breaker	simple sectionalizer no.						
		2	4	6	7	9	12	13
State	1	1	1	1	0	1	0	1
Name of switch	simple sec. no.			Assist. feeder			DG	
	15	17	19	1	2	3	0	1
State	1	1	1	1	1	1	1	1

Figure 4 shows the communication messages between the main sectionalizer agents and the relay agent, after finishing the fault locating process.

CONCLUSION

In this paper an agent-based system for outage management in distribution network is introduced. The proposed system is implemented using JADE. The system defined is flexible and compatible to the requirements a today's distribution network's needs. Finally, the system is applied to a feeder with real characteristics and the results shows that the system is able to fulfil its expected goals.

Table 3: important data for the simulation

Load of section 10	15 A	Load of section 13	15 A
Load of section 11	15 A	Available capacity of agent MainSec03	0 A
Load of section 12	10 A	Available capacity of assistant feeder	30 A

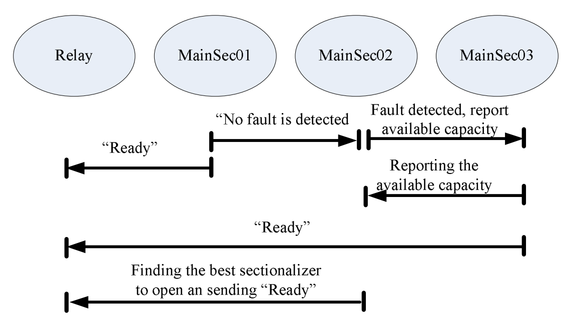

Figure 4: communication messages between important agents

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