An Autonomous Optimal Coordination Scheme in a Protection System of a Power Distribution Network by using a Multi-Agent Concept

Seung-Ho Hyun, Byung-Woon Min, Kwang-Ho Jung, Seung-Jae Lee, Myeon-Song Choi and Sang-Hee Kang

Abstract - In this paper, a protection system using a Multi-Agent concept for power distribution networks is proposed. Every digital over current relay(OCR) is developed as an agent by adding its own intelligence, self-tuning and communication ability. The main advantage of the Multi-Agent concept is that a group of agents work together to achieve a global goal which is beyond the ability of each individual agent. In order to cope with frequent changes in the network operation condition and faults, an OCR agent, suggested in this paper, is able to detect a fault or a change in the network and find its optimal parameters for protection in an autonomous manner considering information of the whole network obtained by communication between other agents.
Through this kind of coordination and information exchanges, not only a local but also a global protective scheme is completed. Simulations in a simple distribution network show the effectiveness of the suggested protection system.
Keywords - multi-agent system, OCR(Over Current Relay), communication, protection of distribution network

1. Introduction

A multi-agent system is, basically, a kind of decentralized system. An agent performs its own job with given information and functions. Sometimes a group of agents work together to achieve a global goal, in which case each agent does the given job only.

Recently, the rapid development in digital technology and communication has drawn considerable attention of power system engineers to the digital protection systems. Especially, under the circumstances where the size of power systems grow rapidly, and the requirements of the customers for the quality of electricity is also increased, it is quite natural for the engineers to strengthen the ability of each digital protection device.

A distribution network inevitably meets many kinds of faults and sudden changes in its loads or structure. In each case, if we can provide sufficient information to all the digital protection devices and every device has an adequate level of intelligence, then a very reliable and efficient automatic protection of a large scale distribution network can be realized. Especially, if the concept of a multi-agent system is considered from the design stage of a distribution network, the efficiency of design, construction and operation of a distribution network will be enhanced to a considerable degree. That is the ultimate goal of the application of a multi-agent concept to a distribution protection system.

As a first step of the multi-agent protection system, correction methodology of changing pick-up values in an over current relay(OCR) is suggested in this paper. An OCR trips a circuit breaker(CB) to cut the line when the current is beyond the pick-up value. The pick-up value is selected between the maximum load current through the line and minimum fault current at that point, both of which are dependent upon the structure and operation condition of the distribution network concerned. Furthermore, the structure and operation condition change from time to time. Therefore, the auto parameter setting of an OCR with network information considered is the first area to which the multi-agent concept is applied with efficiency.

In this paper, a multi-agent protection system is suggested for a distribution network. Every OCR is defined as an agent. An agent calculates and corrects its parameter by itself through communication with neighboring agents and its own intelligence. No human effort for calculation and re-setting of parameters are needed at all. The proposed concept is applied to a simple network to show its soundness and effectiveness.

2. Multi-Agent System

Several years ago, the concept of an agent system was introduced to software engineering with communication. There are many kinds of definitions and taxonomies on the agent system[3]. A common characteristic is that an agent has 'autonomy, i.e. self starting ability' and 'intelli-

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gence'. It has its own knowledge base, reasoning and judging ability. With these tools, an agent performs some functions in an autonomous manner[3-5]. Recently, great efforts are being concentrated on the multi-agent system[2,6-7]. Several agents group themselves automatically and they exchange information with each other and, lastly, they work together and achieve a global goal beyond the ability of an individual agent.

Since a power network is spread over a wide range of areas with many OCR's, the decentralized concept seems to be very useful in control and operation. Especially, recent remarkable developments in digital protection devices and in communication technology enable us to adopt the multi agent concept. It would be very efficient if every OCR corrected its parameters by itself every time a change occurs. Furthermore, the optimal operation can be realized without centralized control action if each agent has an adequate level of intelligence and information. That is why the multi agent concept is focused on as a promising research area in the protection of power systems in which sudden changes or faults may occur frequently and in which there are many devices able to work as agents and in which coordination between devices is absolutely required. A multi-agent system is realized most efficiently if it is considered from the start of the design stage. And this concept should be applied not to an individual device but to the whole system.

In the next section, the application of a multi-agent system to the protection of a distribution network is suggested.

3. Protection system of a Distribution Network using MultI-Agent System

3.1 Basic concept

In a distribution network, an over current relay(OCR) is frequently used as a protection device. The pick up value of an OCR is selected among the values between maximum load current and minimum fault current. Therefore, every time the operation condition changes, the pick up value should be also changed according to it. In this paper, each OCR is defined as an agent so that the frequent changes in a distribution network may be considered automatically.

Another type of agent is the feeder agent which represents the source of electrical power in the distribution network concerned. It works as a starting point of a branch and also gives the OCR agents information on the source, e.g. the source capacity, source impedance and so on.

The last agent is the data agent, or equivalently display agent. This is not a prerequisite for real field application. It gathers data and displays it for an operator or a developer to watch the current state.

Each agent gives and takes information to and from neighboring agents not only to perform its own job but also for other agents to do so. The schematic diagram is given in Fig. 1.

3.2 Design of agents

3.2.1 OCR Agent

The main function of an OCR is to protect the network from a fault by measuring the current and comparing this with a pick up value which is calculated in advance. The main functions of an OCR agent are summarized in the following. Since a distribution network is, in general, operated in the radial structure, we use the notations 'upper' and 'lower' to represent the direction to source and to load respectively. In other words, the end of the 'upper' agent is the feeder agent and the end of opposite side, the OCR agent connected to the load directly.

♦ Self correction

1. When it receives either the signal of network change or requirement of correction, it sends this signal to neighboring agents and inquires of the upper agent about source impedance.
2. When it receives the source impedance from the upper agent, the line impedance between the receiver and the sender of source impedance is added to the source impedance received. This updated source impedance is sent to the lower agents. In addition, it calculates the minimum fault current.
3. It calculates the maximum load current with the load both in lower agents and in itself considered. It sends this maximum load current to the upper agents and decides the pick up current value.
4. It corrects itself when required
5. It trips the circuit breaker when required.
6. It sends data changed to the data agent.

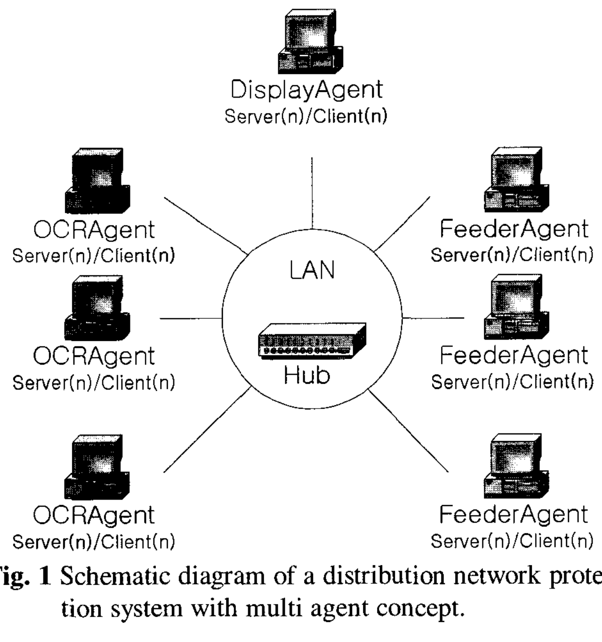

Fig. 1 Schematic diagram of a distribution network protection system with multi agent concept.

♦ Protection

1. It measures the current and trips the circuit breaker concerned when the current exceeds the pick up value.
2. It sends all the protective action data to the data agent.

3.2.2 Feeder Agent

The feeder agent is located at the secondary winding sides of a transformer. It checks if any change in source impedance happens. And when a lower agent requires the source impedance, this agent responds to it.

3.2.3 Display Agent

The display agent is designed to show the current operation state of the power network to the operator. Furthermore, it displays the behavior of every agent and data exchanged between agents to confirm the soundness of the suggested algorithm. This agent has no function of control so that it may have no influence on the activities of other agents at all. In real field application, the display agent can be omitted.

Fig. 2 is an example of a display agent showing the current status of each agent.

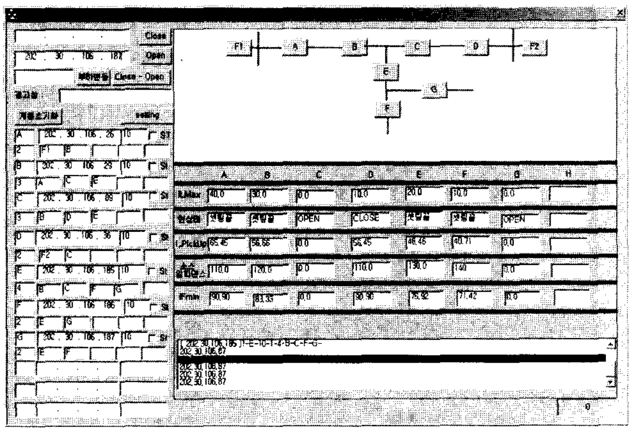

Fig. 2 An example of a display agent

3.3 Communication between Agents

One of the main advantages in the agent-system application is that a global goal can be achieved by grouping several agents and their co-working. An OCR agent protects its responsible area such as generally used OCRs. The optimal or sub-optimal protection of the whole network, which may be regarded as the global goal, is realized by the coordination of agents. For example, if a change in the structure of the network concerned occurs, the nearest agent from the changed point recognizes it and sends other agents this fact. Some OCR agents must correct their pick up values in this case. The information needed for this correction is obtained through communication with other agents: source impedance from upper agents, load current from lower agents, etc. Fig. 3 shows a data flow when a change in structure of the studied network occurs.

The key words used in the communication between OCR agents are tabulated in table 1. If any functions of OCR agents are to be added, the numbers or kinds of keywords can be extended easily.

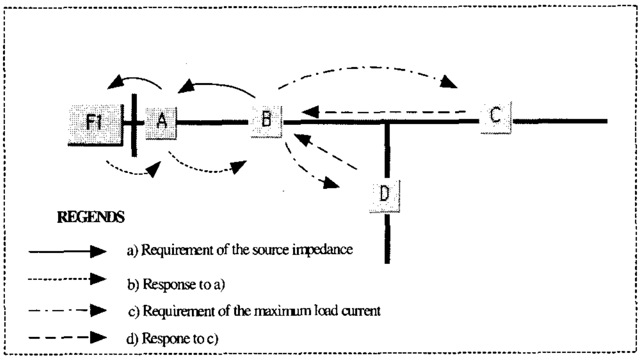

Fig. 3 Data flow in deciding the pick up value

Table 1 Key words for communication

KEYWORD	CONTENT
OPEN	To open CB
CLOSE	To close CB
RESET	To Reset the data of an agent and to require the source impedance of upper agents
SOURCE_IMP RECEIVE	To receive source impedance from upper agents
IL_MAX RECEIVE	To receive maximum load current from lower agents
IL_SELF CHANGE	To change self load value
CH_OPEN	To open the changes in network
CH_ CLOSE	To close the changes in network

4. Simulation Results

4.1 Test network

A simple distribution network is selected with 2 transformer buses and 7 OCR's as shown in Fig. 4. There are a total of 10 agents, 7 for OCR agents, 2 for feeder agents and one for a display agent. Every agent is realized in an individual PC and 10 PC's are connected through Local Area Network(LAN) for communication.

In Fig. 4, F1 and F2 are feeder agents linked to a transformer and from A to G represent the OCR agents with a circuit breaker. A regular black square means that the circuit breaker concerned is closed, and a white one vice versa. For example, the circuit breaker in agent C is open: consequently, feeder F2 supplies electric power only to the load at agent D. For a simple illustration, the operation condition is chosen as simple values. It is supposed that the load at each agent is 10kVA, line impedance is 1p.u./km and the distance between agents is equally 10km. The set value of each agent is given in Table 2.

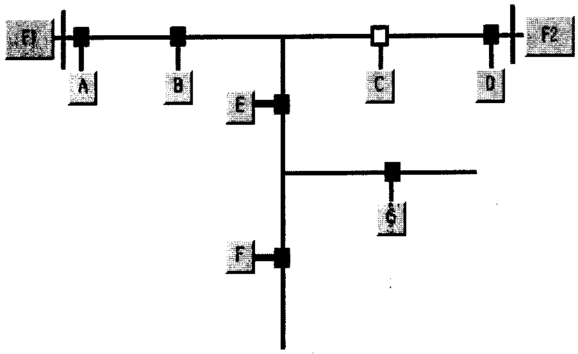

Fig. 4 Simple diagram of the studied network

Table 2 Initial setting status of 2 OCR Agents

[A]

	A OCR	B OCR	C OCR	D OCR	E OCR	F OCR	G OCR
PU	70.45	61.66	Open	56.45	53.46	40.71	40.71
Max. I_load	50.0	40.0		10.0	30.0	10.0	10.0
Min. I_fault	90.90	83.33		90.90	76.92	71.42	71.42
I_self	10.0	10.0		10.0	10.0	10.0	10.0
Source feeder	F1	F1		F2	F1	F1	F1

Max. I_load : Maximum Load Current
Min. I_fault : Minimum Fault current
I_self : Self Load Current

4.2 Fault case

It is assumed that a line to ground fault occurred at area ① which is the protection area of OCR G as shown in Fig. 5. Agent G tripped the circuit breaker successfully. Then, in the whole network, the load decreased as much as the amount that had been supplied through agent G. In this situation, the actions of each agent can be described as follows;

- Agent G sends a reset message to neighboring agents: in this example to agents E and F.
- Agents E and F send this signal to upper agents, which also do the same job until this signal reaches feeder agents F1 or F2. In this example agent F2 does no action because it is separated from the faulted part by the circuit breaker at C.
- Agent F1 calculates the source impedance and sends it to lower agents.
- Agent A, as soon as it receives the source impedance from an upper agent, calculates its own source impedance and sends this to lower agents and finds its minimum fault current. Each agent involved in the faulted part does the same thing.
- The lowest agent(F) sends its maximum load current to upper agents. Other agents calculate their maximum load currents using their own load currents and data received from lower agents.
- Every agent decides its pick up value from its maximum load current and minimum fault current.

Fig. 5 shows the signal flow in the above procedure and the resultant correction values are given in Table 3.

Table 3 Correction results after the fault

[A]

	A OCR	B OCR	C OCR	D OCR	E OCR	F OCR	G OCR
P.U.	65.45	56.66	Open	56.45	48.46	40.71	Open
Max. I_load	40.0	30.0		10.0	20.0	10.0	
Min. I_fault	90.90	83.33		90.90	76.92	71.42	
I_self	10.0	10.0		10.0	10.0	10.0	
Source feeder	F1	F1		F2	F1	F1	

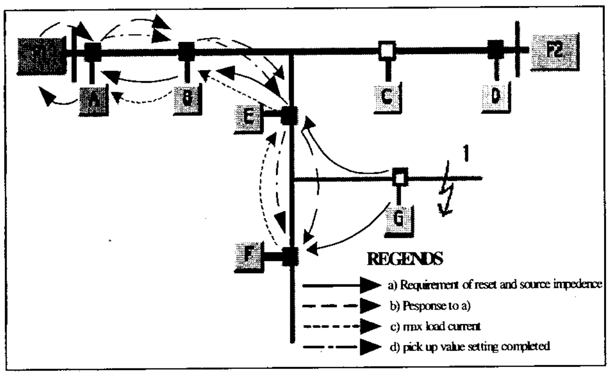

Fig. 5 Signal flow after the fault

4.3 Re-closing case

Let us suppose the fault given in the previous subsection, was fixed and the circuit breaker at G closes the line again. First, agent G sends all other agents a signal that it will re-close the circuit breaker. This is necessary to avoid the malfunctioning of any OCR because of the sudden increase in current. After every agent recognizes the re-closing and corrects its parameter, Agent G re-closes the circuit breaker and sends notices of it to all other agents again.

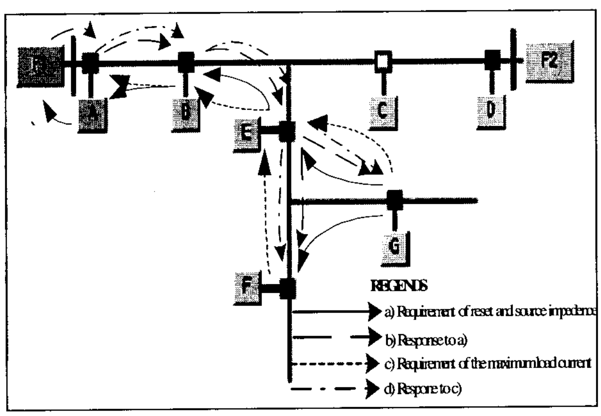

Fig. 6 Signal flow when the CB G is re-closed.

Table 4 Correction results when the CB G is re-closed

[A]

	A OCR	B OCR	C OCR	D OCR	E OCR	F OCR	G OCR
P.U.	70.45	61.66	Open	56.45	53.46	40.71	40.71
Max. I_load	50.0	40.0		10.0	30.0	10.0	10.0
Min. I_fault	90.90	83.33		90.90	76.92	71.42	71.42
I_self	10.0	10.0		10.0	10.0	10.0	10.0
Source feeder	F1	F1		F2	F1	F1	F1

Fig. 6 is the signal flow of this procedure and the results can be found in Table 4. As it is respected, the resultant corrected values are the same as in the pre-fault stage, since no change occurred during the term from fault to reclosing.

4.4 Structure change case

In this case, it is assumed that the source of load at E, F and G is transferred from feeder 1 to feeder 2. The circuit breaker at C should be closed and the circuit breaker at B should be open. The procedure is very similar to those of previous subsections except that the open operation of circuit breaker B is performed after it is confirmed that CB C is closed. It is necessary to avoid a black out of area E, F, and G in case CB B opens the circuit ahead of the closing of CB C.

The results are tabulated in Table 5.

Table 5 Correction results after a change in structure

[A]

	A OCR	B OCR	C OCR	D OCR	E OCR	F OCR	G OCR
P.U.	50.45	Open	61.66	70.45	53.46	40.71	40.71
Max. I_load	10.0		40.0	50.0	30.0	10.0	10.0
Min. I_fault	90.90		83.33	90.90	76.92	71.42	71.42
I_self	10.0		10.0	10.0	10.0	10.0	10.0
Source feeder	F1		F2	F2	F2	F2	F2

5. Conclusions

In this paper, the 'Multi-Agent' scheme is applied to a protection system of a distribution network.

A digital over current relay(OCR) is developed as an agent by adding abilities of self-tuning, intelligence and communication.

The detection of changes in the network, and tuning of pick up value in an OCR according to the changes are performed autonomously by the decision ability in every agent and exchange of information between agents. This type of protection system is mostly adequate for a distribution network protection system where the structure is complicated and sudden changes take place frequently.

It can be concluded that the agent concept should be extended to other protection devices such as distance relay, and that the coordination schemes in the operation of every protective device should be developed in order for the total protection system to be realized.

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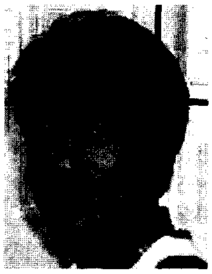

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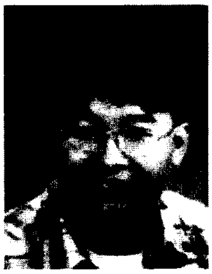

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