MULTI AGENT-BASED ON-LINE DIAGNOSTIC SCHEME OF SUBSTATION IED

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Abstract: This paper presents a novel multi agent-based diagnostic scheme of substation IED. The proposed method is the on-line diagnostic scheme for the IEDs in IEC61850-based SA system using multi-agents. Multi-agents detect the fault of IED installed in substation and apply to improvement of reliability in protection and control system of substation. These agents in the SA system embedded in the station unit, the engineering unit, the trouble manager, backup IED and protection and control IED as the thread form. Through the implementation and the case studies of the proposed scheme, the availability is proven.

1 INTRODUCTION

IED (intelligent electronic device) mis-operations, such as failing to isolate a faulted line or incorrectly tripping a healthy line, are involved in major disturbances within power systems and can lead to catastrophic cascading events or even blackouts (Bertsch, J. *et al.* 2003). Giving IEDs the ability to diagnose would be a significant addition at critical locations in the power system by helping to reduce the number of mis-operations.

The existing diagnostic method of IED mainly uses off-line TBM (time-based maintenance) or CBM (condition-based maintenance) (Yu X.Z. et al, 2000). Especially IED doesn't operate in normal condition and operate it when the disturbance occurs in power system. It is hard to determine the fault condition before IED is tested.

On the other hand, the conventional scheme to improve the IED's reliability, have the redundant structure as the backup device (Ding M. et al., 2004). Redundant structure employs the dual device with the same function so that improves the reliability of the system. However, this system has the drawback which not only increases the probability of mis-operation but cost. Thus, the improvement scheme of the reliability is required to overcome these problems.

In this paper, a novel multi agent-based diagnostic scheme of substation IED is proposed. This method is the ODS (on-line diagnostic scheme) for the IEDs in IEC61850-based SA system using multi-agents (IEC 61850, 2002-2005). Multi-agents detect the fault of IED installed in substation and apply to improvement of reliability in protection and control system of substation. These agents in the SA system embedded in the station unit, the engineering unit, the trouble manager, backup IED and protection and control IED as the thread form. Through the implementation and the case studies of the proposed scheme, the availability is proven.

2 IEC61850-BASED SUBSTATION AUTOMATION

The scheme presented in this paper used many features of IEC61850 to diagnose the substation IED. The typical features of IEC61850, which make our scheme possible, consists of the network based data transfer (process bus), the standardized interface and SCL (Substation Configuration Language)-based engineering.

2.1 Process Bus

In the existing substation protection and control system, analogue data such as voltage and current are fed into protection relays from CT and VT which are installed on the primary protection equipments such as transformers and circuit-breakers. In the

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IEC61850 based SA system, analogue signal will be converted into digital data by the process IED installed on the primary protection equipment and be sent to the bay IED through the process bus (Fig.1). The largest difference between the two schemes above is whether the data transfer path can be changed during operation. In the existing system, analogue data are transferred through hardware, so data transfer path cannot be changed unless the physical connection is changed. In this scheme, data are transferred on process bus, so the data transfer path can be changed by changing the destination of data packet.

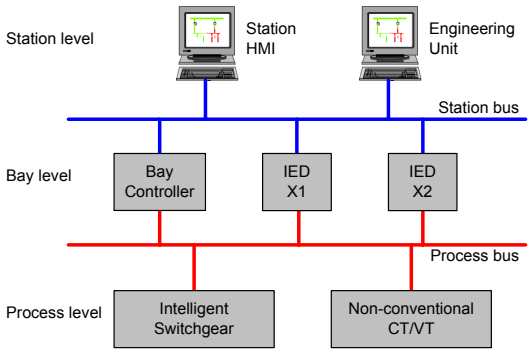

Figure 1: Structure of IEC61850-based SA System.

2.2 SCL-Based Engineering

For integration of various IEDs, IEC61850 suggests a standard engineering technique. The key is in two softwares called system configurator and IED configurator. Figure 2 shows the course of IEC61850 engineering. First, system configurator gets all the information about the substation from the SSD (System Specification Description) file that contains system related information and the ICD (IED Capability Description) file that contains IED related information, and creates the SCD (Substation Configuration Description) file that configures the function and data flow for each IED. All the files mentioned above are made by XML-based SCL. An IED configurator receives the SCD file and creates CID (Configured IED Description) file that contains the format suitable for IED. Finally to download CID file, each IED is able to communicate with among them.

In this scheme, when an IED error is detected, it reconfigures its data path so that the data that were transferred to bay IED is now transferred to the backup IED. The reconfiguration is feasible because of the SCL based engineering.

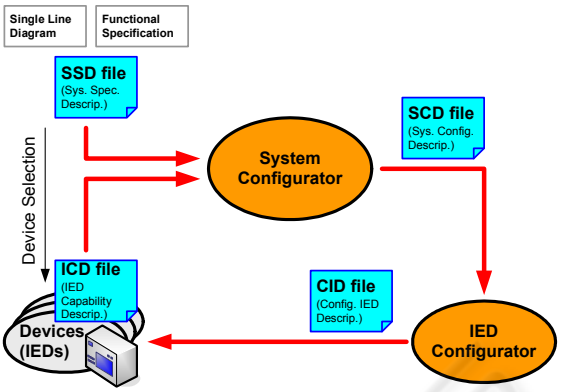

Figure 2: SCL based engineering.

2.3 Standardized Interface

In IEC61850, all the information about a substation is modelled into a standard interface called LN (Logical Node). Data exchange between these IEDs is possible as long as all these IEDs follow the standard LN interface regardless of IED hardware structure or algorithm. For example, if there are two distance relays made by different companies, whose signal filtering, calculation of RMS, error detection algorithm, and hardware are different, the two relays can be exchanged when they use the same services and the same LN interface.

3 MULTI AGENT-BASED ON-LINE DIAGNOSTIC SCHEME

3.1 On-Line Diagnostic Scheme

The structure of the ODS (on-line diagnostic scheme) is shown in Fig. 3. Note that the station unit, bay IED, process IED, and engineering unit constitute the substation automation system, which follows IEC61850 standard. Backup IED and trouble manager are added to the system to implement the ODS. Trouble manager is in charge of detecting the IED error by sending a test pattern to bay IED and comparing the results with expected ones. Backup IED is a redundant IED that downloads software from engineering unit and then starts to operate when error is detected on bay IED.

The TM (trouble manager) periodically checks the functions of each bay IED to determine whether the IED has an error. The fault detection procedure in trouble manager is as follows:

1) EU (engineering unit) assigns the DUT (device under test) and inform to TM.
2) TM transfers the information such as LN, preco nfigured control block and settings for the DUT to backup IED.
3) TM starts the sample value path from process IE D #1 to backup IED.
4) TM stops the sample value path from process IE D to DUT.
5) TM sends the test input pattern to DUT via proc ess bus.
6) DUT sends the response for the test input patter n to TM.
7) TM notifies the fault status of the DUT to statio n HMI if TM detects the abnormal status of DU T.

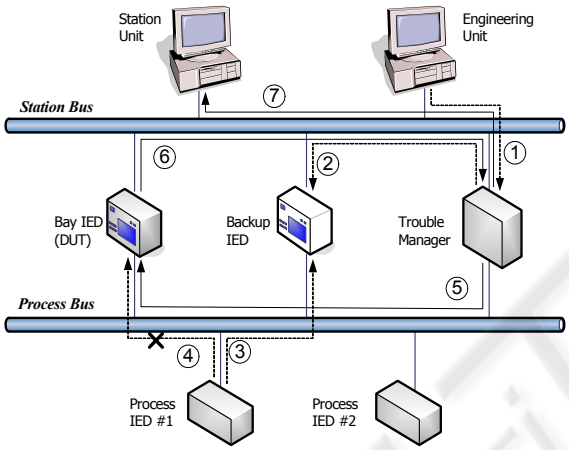

Figure 3: Structure of ODS.

If no fault is detected on DUT, TM requires EU to reconfigure the system to recover the original operation of DUT and then continue to check next IED. Also if fault is detected, system waits for repairing. Backup IED will replace the failed DUT until it is repaired.

3.2 Structure of Multi Agent-Based ODS

The proposed method uses several agents which distributed in a protection/control IED. This method detects the IED fault and replaces IED to be tested. In order to operate efficiently, these distributed systems, agents have the functionality which autonomously interacts between them. Figure 4 shows the proposed multi agent-based ODS structure.

As shown in figure 4, the multi agent-based ODS structure consists of data source, data storage, communication mechanism and data consumer. When agents detect the fault of IED in protection system, it replaces faulted IED and operates with backup IED properly.

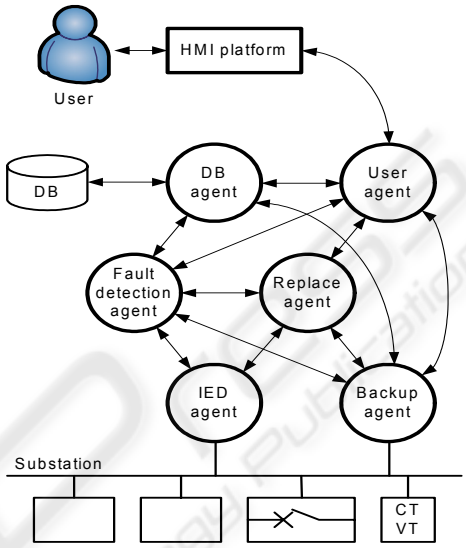

Figure 4: The proposed multi agent-based ODS structure.

Table 1 list a types and functionality of multi-agents required for performing the multi agent-based ODS.

Table 1: Types and functionality of agents.

Types	Duty	Ability
Fault detection	Detect the fault of DUT	Send the test pattern, Create the expected result, Compare with actual result
Replace	Replace DUT with backup IED	Control the communication service
DB	Response the required information	Add the information to DB, Response for query
User	Assign the IED to be tested and display the fault	Display the information, Transfer the query
Backup	Perform function of the DUT	Perform the function of DUT
IED	Perform function of protection/control IED and communicate with other agents	Response for the request

The agents listed in above table communicate each other with MMS (Manufacturer Message Specification) instead of ACL (Agent Communication Language), since the agents embedded in IEC61850-based SA system.

4 CASE STUDY

4.1 Test System

Figure 5 shows the test system to verify the performance the multi agent-based ODS. The part inside dotted line in this figure means the additional equipments to conventional SA system.

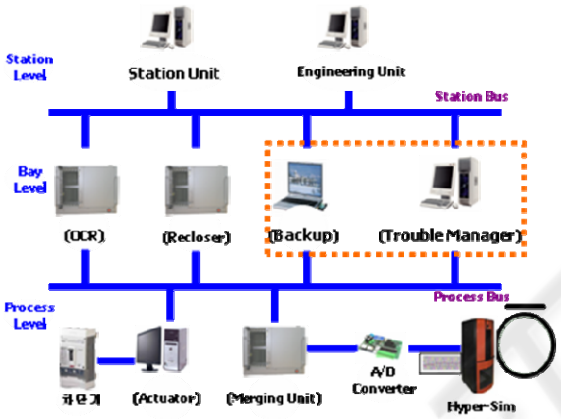

Figure 5: Test system.

In the test system, HyperSim (real-time simulator) uses to generate the fault in power system (HyperSim). MU (merging unit) transfers the digital signal to protection IED (OCR/Recloser) via network after it had A/D conversion. Actuator has the function such as on/off of circuit breaker as process IED. Backup IED performs the same function of DUT.

4.2 Simulation: DUT Diagnosis

In this simulation, we consider two types of fault such as communication and IED hardware part. We assume that the fault in communication part is LAN cable broken and the fault in IED hardware part is power off.

We perform the test that TM can detect the fault. After the DUT's function replaces with backup IED, TM sent the test input pattern and received the response from DUT. Figure 6 shows the GOOSE message from DUT as response.

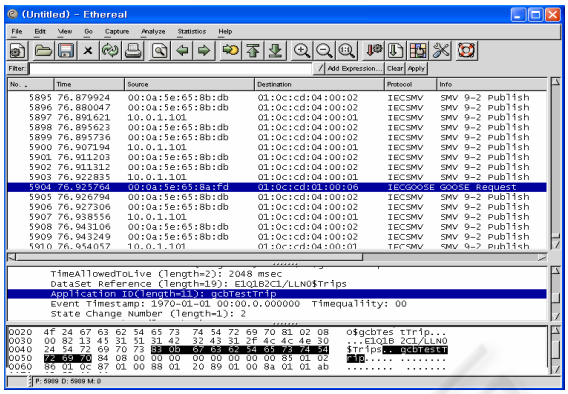

Figure 6: Response message from DUT.

5 CONCLUSION

A novel multi agent-based ODS can be applied in the IEC61850-based SA system is proposed in this paper. The technique presented in this paper detects the fault of IED automatically and it replaces the failed IED by backup IED to tolerate the fault in system level. Through the implementation and the case studies of the multi agent-based ODS, the availability is proven.

ACKNOWLEDGEMENTS

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