41

A WEB-BASED CSCW SYSTEM FOR REMOTE SUBSTATION FAULT DIAGNOSIS

Hongsheng Su, Jianwu Dang, Feng Zhao
School of Information and Electrical Engineering, Lanzhou Jiaotong University, Lanzhou 730070, P.R. China, shsen@163.com

Relying on Computer Supported Collaborative Work (CSCW) technology, expert system (ES) can extend its capabilities from only one working to set up a cooperative labor environment for a group of expert systems working together. In order to more effectively support those remote substations fault diagnosis as well as related departments involvements, Web-based CSCW systems are intensively recommended. The paper for that proposes a framework of CSCW system with Web-based for remote substation fault diagnosis. The system applies Multi-Agent (MA) technology to construct distributed expert systems platform, and presents the collaboration and communication framework of the platform using J2EE. The system is applied in remote substation fault diagnosis, and is proved very effective

1. INTRODUCTION

In recent years, with the fast advancement of Computer Supported Collaborative Work (CSCW) technology and the exponential growth of Internet as well as increasingly broad application of Multi-Agent (MA) technology, an effective support has already been supplied to those far-reaching large-scale distributed expert systems. With respect to those remote or unattended substations fault diagnosis, a general requirement is to yield a cooperative working environment that allows related groups such as fault diagnosis experts in diverse fields, facility manufacturers, management departments, maintenance departments, employment departments, relevant government officers and some persons related to it to work together to cooperate with one another to dispose the accidents while substation faults happen. Supported by Internet and CSCW and MA technologies, expert systems (ES) can extend its abilities from only one working to setup a cooperative working environment, and make diagnosis process possess initiative characteristics. CSCW supplies knowledge share and resource complementation, and also supports cooperative working environment. A Web-based CSCW system can provide user with a friendly human-computer interface and well-regulated cooperative working environment. In addition, it still can integrate each independent small-scale network in Internet such as LAN, WAN, ISP servicing networks to realize joint aims. MA is

Please use the following format when citing this chapter:

Su, H., Dang, J., Zhao, F., 2006, in IFIP International Federation for Information Processing, Volume 220, Information Technology for Balanced Manufacturing Systems, ed. Shen, W., (Boston: Springer), pp. 385–394.

applied to simulate human expert intelligence and behavior to resolve more complicated problem. MAS-based substation fault diagnosis methods have already been reported (Liu *et al.*, 2003; Dong, *et al.*, 2003; Zhao *et al.*,2004; Mao *et al.*,2005; Wang *et al.*,2005), but they expose some problems in process of applications more or less(Su, *et al.*, 2005). Hence, based on Internet, MAS and CSCW technologies, in the paper we propose a Web-based CSCW system for remote substation fault diagnosis. It can effectively apply resources in Internet to improve the serviceability. Meanwhile, the efficiency and speed of substation fault diagnosis are also improved, dramatically.

The paper describes our original work on the design of system architecture, system function, Web-based CSCW and MA technique ensemble as well as some key technique issues to realize it.

2. MAS AND CSCW WITH WEB-BASED

With the rapid development of distributed artificial intelligence(DAI) technology, agent, as an independent calculation entity with cognizing attributes such as faith, aim, intention and behavior properties such as programming, negotiation and interaction, has been broadly considered a very ubiquitous guidance idea for the complicated advanced problem solving(Jennings, *et al.*, 1998). Particularly, the relationships between agent as well as multi-agent and special field knowledge are desired to be able to yield higher intelligent agent (Witting, *et al.*, 1994; Hyacinth, 1996), which is called a super agent. With the farther development of Internet technology, Web-based Multi-Agent Systems (MAS) have been reported in recent years(Wooldridge, 2003), MAS stresses that a large-scale complicated problem may be resolved using cooperative distributed problem solving methods, hence, relevant platform and system architecture as well as communication and cooperation modes have been described(Liu *et al.*, 2003; Wooldridge, 2003).

In view of expansion of system scale, many diverse computers and working stations as well as servers as well as broadly heterogeneous systems in Internet need to be connected for collaboration work, the overall system therefore becomes extremely complicated and considered heterogeneous. To meet the requirement of integrating numerous computers with diverse operating systems in networks for work, CSCW technology is needed to construct enterprise level systems, whose core content is J2EE(Liu, *et al.*, 2003). Certainly, in order to connect more wide-area heterogeneous systems and computers, Autonomous Decentralized Systems (ADS) has already been reported(Mori, 1984), it has no centre but its architecture is more flexible, whether existence of each autonomous agent or not has no important influence on the overall systems, more robust characteristic makes it very adapt to dynamic indeterminate environment. Hence, ADS can be applied to link the heterogeneities.

CSCW provides a means for people to collaborate, which makes many people in different places share the environment and information, engage common task, e.g., decision support, etc. With the fast development of Internet, networks and multimedia technologies, that public takes part in group decision over networks is made possible. With the advancement of MA technology, due to its prominent characteristics such as initiative, autonomy, sociality, intelligence, coordination, cooperation and negotiation etc, which makes the efficiency and speed of MAS-based diagnosis systems are greatly improved. Hence, Web-based CSCW systems supported by MAS benefit form Web and CSCW and MA for public participating in collaborative work for task solution.

3. CSCW FRAMEWORK WITH WEB-BASED

The aim of the Web-based CSCW systems for remote substation fault diagnosis is to establish a visual cooperative work environment for diverse departments, experts, public to collaborate in the activities about remote substation fault diagnosis, whose architecture, function and security are investigated in the section

3.1 Design of System Architecture

The Web-based CSCW system enable more departments, experts, groups and public related to it involved, for example, management, employing and servicing departments, diverse field experts or expert systems, and all concerned persons. The Web-based CSCW system can supply the assistance for communication, interactive operation and data disposal etc. In addition, it also support those distributed heterogeneous systems in communication, collaboration and data disposal. The architecture of the overall systems is shown in Figure 1.

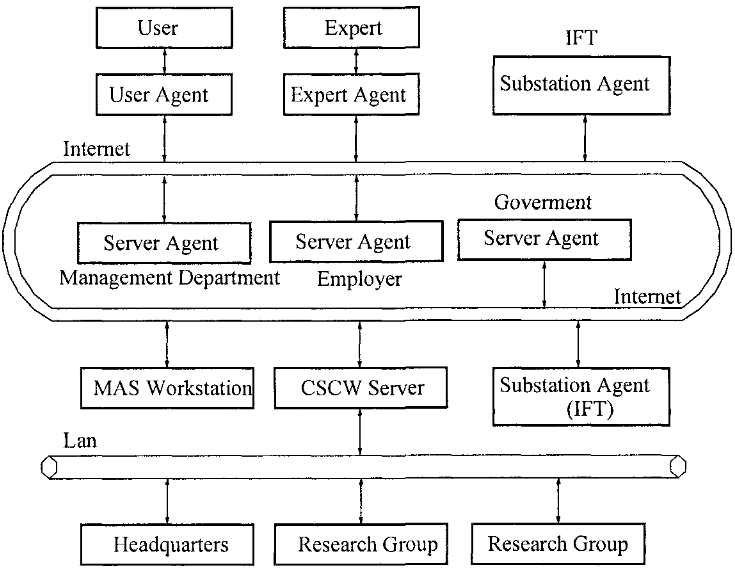

Figure 1 – Architecture of CSCW systems with web-based

In Figure 1, IFT means an Infinite Field Terminal, which usually is used to monitor and diagnosis home substation faults, called a super agent. MAS workstation is a core unit of the overall agent system. It is the centre of agent management and the centre of collaboration information exchange. It supports naming, log-on, log-out service for the agent in the platform, and also supplies service management and message transmission services for the agent in platform. CSCW server is a node, through it a visual collaborating work environment may be set up for different departments, public, research groups, headquarters and government departments involved to collaborate in the activities about substation fault diagnosis.

The system software architecture is composed of three levels as shown in Figure 2. The 1st layer is database layer, including related diagnosis knowledge base, CSCW data, etc. The 2nd layer is transaction layer, including diverse systems function module such as user management, transmission information collecting, collaborative system functions, etc. The 3rd layer is user interface, including CSCW workstations, user interface agents, etc. Web-based user agents can get and display related diagnosis information in Web-site.

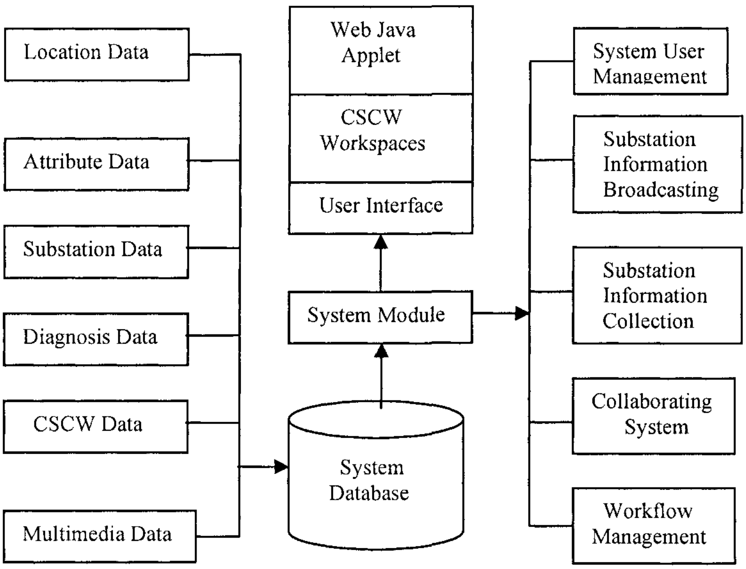

Figure 2 – Software architecture of CSCW systems with web-based

3.2 Design of System Function

In a Web-based CSCW system, the basic principles of system are described below.

(1) Information Sharing: The data base of expert systems, substation information, and CSCW knowledge base are the centre of the systems. All the cooperation and information sharing rely on the database agents.

(2) Collaboration: All departments related to fault diagnosis must be integrated through the centre databases. Substation fault diagnosis information, CSCW information can be shared and exchanged through Web. All collaborations are realized by Multi-agent-system (MAS).

(3) Transactions Broadcasting: In this system, every one can participate in the activities to cooperate, broadcast the data of substation fault diagnosis through Web-agent system.

(4) User Agent: In this system, everyone participates in cooperation and broads the data of diagnosis through user agent. It supplies a basic function in a flexible way in cooperative environment, e.g., friendly human-computer interface, etc.

3.3 J2EE Framework

In a Web-based CSCW system, for there are many heterogeneous computers, systems, workstations and servers that operate in diverse system platforms, the decentralized distributed platforms independent of any system architectures need to be considered to support them for collaborative working and future application and rectification. To satisfy and adapt the situation of integrating heterogeneous systems in Web to work, the J2EE and EJB and Java Servlets technologies have been reported (Xie, *et al.*, 2005). In addition, ADS has already been reported for many years for integrating heterogeneous systems in networks while every system's characteristic is preserved. Because Internet is a complicated large-scale heterogeneous system, the Web-based CSCW systems should ensure the collaboration among all independent systems without knowing the whole system architecture to realize the synergistic effect.

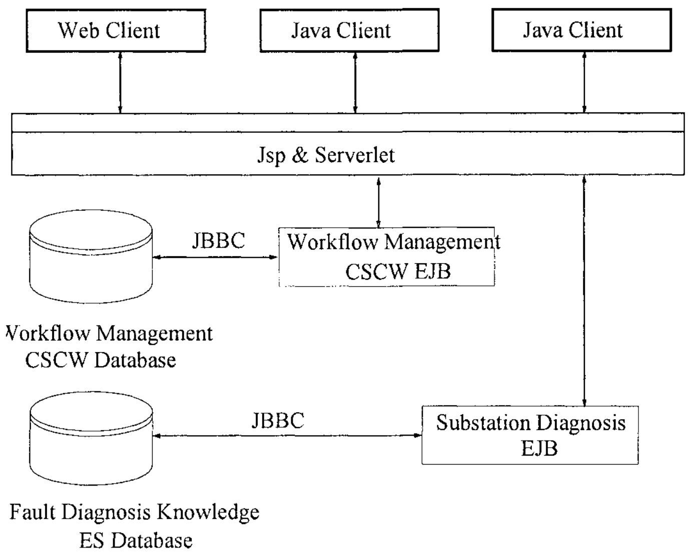

Figure 3 – System framework with J2EE-based

Figure 3 shows the infrastructure of the systems. The middleware of each subsystem such as CSCW, expert systems and other some subsystems, offers a distributed transaction processing. Many host computers can be added to supply many services. Compared with other distributed system, EJB has hidden lower details, for instance, the target management, multi-thread management and some events management etc. Moreover, J2EE offers many sorts of diverse middleware to be applied to enterprise logic. The data are managed and stored with EJB. Distributed computing enables users to operate in remote virtual servers to achieve business logic and data disposal anytime, anywhere. Distributed systems enable the databases and services in same and different computers. The database employs JBBC to communicate with EJB (back-end server). The system front-end adopts JSP and Servlet that employ back-end job to supply service. In the front-end java clients apply to communicate with JSP/Servlet and back-end EJB in Browser.
The system infrastructure has the following advantages:

(1) Platform Independence and good human computer interaction: Codes written in Java could run on any Java Virtual Machine (JVM) and any platform supported by JVM, This happens to be a boon for all, for it allows virtually any available computer systems to be home for the agent in distributed system. Once the parts of the system have been specified using by Java classes and compiled into Java codes, they can migrate to any of the hosts without recompilation. This makes it easy that data and loads balance across the networks. To improve interaction between human and computer, the front-end embedded techniques such as Active X and Java Applet are employed. Active X is constructed on COM, and not only applied in application program, but also could embed inside webpage to realize very complicated functions. Java Applet is a small application program in Java, it could run in any browsers supported by Java, this is equal to a self-inclusion web client program. Active X and Java Applet own the good connected and mobile characteristics. They run in client end and accomplish interaction and simulation.

(2) Network Support and Security: Java programming language API includes multi-level support for network communications. Lower-level sockets can be established between agents and data communication protocol can be layered on top of the socket connection. The Java.io package contains several stream classes intended for filtering and disposing various input and output data streams. APIs built on top of the basic networking support in Java provide higher-level networking capabilities, such as distributed objects, remote connections to database servers, directory services, etc.

(3) Runtime Environment and Remote Transactions: In addition to that Java facilitates the distribution of system elements across the networks. It makes it easy for the recipient of these systems to verify that they can't compromise the security of the local environment. If Java code runs in the context of an applet, then the Java VM places rather strict restrictions on its operation and capabilities. Also, any class denotations loaded on the network, whether from a Java Applet or application, have to go through a stringent byte code verification process.

With the advantages, J2EE can help us to design enterprise-level, reusable and distributed applications compare to other language.

System architecture is platform independence and multi-layer distributed structure. It can combine expert database, CSCW database and lots of one of the host computers together and share the system resources and data.

3.4 System Security Consideration

The security problem is very important because the system operates on the Internet. To ensure the system, we applied following three measures. First, user's identification authentication and authorizing process were served to control the safety and users identity authentication. Second, the firewall is used to set up the high-efficient and practical safe protection for the attack from the outside network and isolate system from the external environment, prevent the external threat and realize the strict system safe border. Finally, the critical information was encrypted. The encryption enabled the sensitive information stored and transmitted safely in communication in Internet safely. In this way, the system's security has been increased, greatly.

4. SYSTEM IMPLEMENTATION

Based on the infrastructure for Web-based remote substation fault diagnosis mentioned in the text, we are studying and developing a prototype design for remote substation fault monitoring and diagnosis. The system adopts the three layers structure of J2EE, that is, relevant diagnosis knowledge and CSCW data are placed in the related databases, User interface is shown with Java applet webpage, Active X embedding into the webpage adopts Delphi and Visual C++ program language. Microsoft Windows 2000 Advance Server acts as operation system of the web server, and SQL server 2000 for back-end databases. Initial experiment proves the availability of the method. Later, diverse system platforms are located at the heterogeneous servers, the experiment results display excellent.

In process of experiment, we still design IFT shown in Figure 1 for each substation, which mostly presides over on-line monitoring substation fault in advance and diagnosis fault, more detail description on which can be seen in our early time work (Su, *et al.*, 2005).

An example below is presented to understand the point.

The tested object in the paper is local main connection diagram of a substation is shown in Figure 3(Su, *et al.*, 2005), five components in Figure 4 respectively expresses bus M and N, transformer T as well as circuits L1 and L2. CB1 to CB4 are breakers. Another 10 protection relays are Mb, Nb, TAm, TBm, TAp, TBp, L1m, L2m, L1p,ml2p, where Mb, Nb are bus protections, TAm, TBm are transformer main protections and TAp, TBp is spare protections, L1m, L2m are circuit main protections and L1p,ml2p are spare protections.

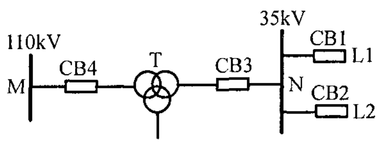

Figure 4 – Local wiring diagram of substation

According to substation fault information collected by home IFT, by data mining, we gain decision rules below (Su, *et al.*, 2005).

Table 1 – Diagnosis decision table

Condition Attribute			Decision Attribute
CB1	*CB2*	*CB3*	Fault Component
0	0	0	*M*
-	0	1	*T*
-	1	1	*N*
1	0	0	*L1*
-	1	0	*L2*

Assume that at one time following fault information is sensed, diagnosis process then is described as follows.

(1) Fault change-site information: *CB3*=1, *TA2*=1, *TB1*=1, *CB4*=1, the rest is no conversion information. According to Table 3, after pattern match, home IFT can judge transformer *T* is fault component. Fielded inspection proves the diagnosis result is right.

(2)Set change-site information is invariable, but information of *CB4* and *TB1* can't be sent over, but at the moment home IFT still can judge that fault component is *T*. This shows noisy tolerance of IFT

(3)Set change-site information is still invariable, but information of *CB1* and *TB1* can't be sent over, thus home IFT has no way to identify, home IFT may seek the solution for that from foreign agents through Web-based CSCW systems. Then foreign agents send back identification information by cooperative working, thus problems are resolved and native knowledge base is also updated.

Compared with the previous method (Dong, *et al.*, 2003), the proposed method in this paper can identify the fault class (3) by CSCW systems, while the previous method only can diagnose fault classes (1) and (2). Hence, with the aid of CSCW systems, ES expands its application range. Meanwhile, the efficiency and correctness of diagnosis are also improved, dramatically.

The system proposed in this text provides an efficient means for remote substation fault diagnosis. First, the proposed system provide a virtual CSCW environment to meet the practical demands in process of substation fault diagnosis, Java-based technique enables system to run in different platforms ubiquitously. Second, Due to operating in Internet, the system can be accessible from anywhere in the world. Third, since substation fault diagnosis activities involve many different departments and diverse public, the collaborative work environment makes it easy to speed up fault diagnosis process. All the jobs in process of diagnosis could be done in real time. Experts and public could take part in activities and report information in different geographical position at the same time. Data collection, analysis, and issue of the fault diagnosis and relevant information will be coordinated operation in diverse departments, and the repeated labor therefore may be greatly reduced. It can ensure and facilitate the advancement of substation fault diagnosis job.

To more effective support and supply serviceability for the remote substation fault monitoring and diagnosis in heterogeneous environment, ADS is expected to be adopted. In ADS environment, the system may be modified and changed on-line dynamically without interrupting the overall systems. The integration of the heterogeneous systems can yield the synergetic effect, each subsystem characteristics may be preserved and subsystem can make its decision autonomously. Therefore, the systems realized by ADS own more flexible and robust as well as fault-tolerance ability, without question, it may supply more effective supports to group decision. ADS still can supply effective help to those heterogeneous databases, data-structure and different application models, and it therefore is intensively recommended for future application.

Although the proposed system would be beneficial to remote substation fault diagnosis, this paper only presents its system infrastructure and prototype of Web-based CSCW. Further works should be done and investigated in several key technologies such as the Java applet, cooperative diagnosis model and data type and so forth.

5. CONCLUSION

A Web-based CSCW system for remote substation fault diagnosis provides an easy route for equipment fault diagnosis. It implements a distributed far-reaching multi-expert collaborative diagnosis method, and realizes resource share and information complementation, the efficiency and speed of facility fault diagnosis are greatly improved. In this system, MAS are also applied to realize the initiative and independence of fault diagnosis. CSCW system with Web-based provides user with friendly interfaces and well-regulated cooperative working environment with many advantages such as open communication platform, substation information query, diagnosis task management, resource management and general project management, etc. In addition, it still realizes the departure between exploitation and application environment. Hence, it is very convenient for servicing, expansion and management of the equipments. Combining with exploitation and application, eventually, the paper validates that the method is available and feasible.

6. ACKNOWLEDGMENTS

The authors wish to acknowledge the 'Qing Lan' Talent Engineering Funds supported by Lanzhou Jiaotong University.

7. REFERENCES

1. H Dong, JS Bai, JY XUE. An Approach for substation fault diagnosis based on multi-agent. Advanced Technology of Electrical Engineering and Energy 2003; 22:21-24
2. LP Zhao, SF Xie QZ Li, XC. Chen. Study on multi-agent based power quality monitoring and control system for electrified railway. Power System Technology 2004; 24:69-73.
3. H Mao, Q Xu, W Liang. Research on remote fault diagnosis technique based on web model. Computer Engineering and Design 2005; 26: 686-687.

4. H Wang, Y Wang. "MAS-based Distributed Expert System Platform Research". In Proceedings of the 8th International Conference for Yong Computer Scientists, JS He, ed. , Beijing: IAP/WPC, 2005.
5. L Liu, K Liu, Y Hu. Architecture of multi-agent based distributed monitoring and control system for substations. Power System Technology 2003 ; 6: 26-28.
6. NR Jennings, K Sycar , M Wooldridge. A roadmap of agent research and development. Auto Agents & Multi-agent Syst 1998; 1:7-38.
7. T Wittig, NR Jennings, EH Mamdani. Framework for intelligent cooperation. Intelligent Systems Engineering 1994; 3:168-179.
8. SH Hyacinth. Software Agents: An Overview. The Knowledge Engineering Review 1996; 3: 205-244.
9. M Wooldridge, Writing; CY Shi, W. Zhang, J Xu Translation. An Introduction to Multi-Agent-System. Beijing: Publishing House of Electronics Industry, 2003.
10. X Liu. Infrastructure of United Network Management System Driven by Web Technology. In Proceedings of the Fourth International Conference on Parallel and Distributed Computing, Chengdu: IEEE, 2003
11. L Xie, H Qiu, L Qin and L Li. "The Development of XMSF Based on J2EE". In System Simulation Technology & Application, ZH Chen, Hefei: USTC, 2005.
12. K. Mori. A Pproposal of the Autonomous Decentralized System Concept. IEICE-C 1984, 12: 303-310.
13. Hongsheng Su, Qunzhann Li. "Study on Substation Fault Method based on Multi-Immune-Agent." In Proceedings of the XIVth International Symposium on High Voltage Engineering, ZC Guan, ed., Beijing: Tsinghua University Press, 2005.