Journal of Southeast University (English Edition) Sept. 2002 Vol.18 No.3 ISSN 1003—7985

Integrated Automation of Power Plant Electrical System ※

Guo Wei[1 ※※] Wang Li[2]

([1] Department of Electrical Engineering, Southeast University, Nanjing 210096, China)
([2] Nanjing 55th Research Institute, Nanjing 210016, China)

Abstract: Aiming at the comparatively laggard level of power plant electrical system automation, this paper analyzes the feasibility, necessity and some key points of the application of integrated automation technology to power plant electrical system. New idea using fieldbus control system technology is presented. This paper also gives the outline and detailed schemes.

Key words: power plant electrical system, fieldbus control system, DCS, integrated automation

Integrated automation technology has been applied in power system substations, and decentralized and distributed technology[1] is widely used in integrated automation system. Compared to the centralized technology, this technology has many advantages such as simple and flexible structure, high reliability, convenient installation and low cost of maintenance.

However, integrated automation technology has not been widely used in power plant electrical system. Protective relay and security devices of electrical system run in a self-governed state, which haven't formed an integrated electrical automation system. Therefore, the managing and maintaining level hang behind. Latterly, more and more power plants, especially those newly constructed are interested in the automation of power plant electrical system and its relationship with traditional distributed control system (DCS).

This paper analyzes the actuality of power plant electrical system, brings out a new ideal of application of microcomputer-based integrated automation technology to power plant electrical system, and gives the material project.

1 Actuality of Power Plant Electrical System

The electrical system discussed in this paper is mainly referred to the protection, measurement, control and automatic devices of secondary system. Main protection devices include generator protection, main transformer protection and start-up/stand-by transformer protection. Automatic devices include antomatic regulator voltage (AVR), automatic transfer switch (ATS), fault kymograph and antomatic synchronization system (ASS). 6 kV auxiliary power protection includes high-voltage motor integrative protection device, auxiliary transformer integrative protection device, feeder protection device, etc. 400 V low-voltage system includes auto-changeover device, low-voltage intelligent motor protector, intelligent breaker, DC system, etc[2]. All these belong to the electrical system. The common systems such as coal handling system, ash handling system and chemical water system are not included.

The characteristics of electrical system[3] are that electrical equipments have less control objects, lower operation frequency than thermal system devices. Electrical devices have high reliability and swift action time. The technology level of individual electrical device is high. Presently, 16 or 32 bit single-chip microcomputer and large-scale programmable logic chip are used to build embedded system. Technologies of AC sampling and digital signal process are also widely adopted.

DCS is widely used in power plants, and it fulfills basic operation and control functions. DCS concerns mainly on steam-boiler system meanwhile little on electrical system. Traditionally, control and signal exchange between DCS and electrical system is through "hard cable". This connection mode needs many cables, and the cost is high. Besides, the information exchange is limited on account of the cost. It is impossible to accomplish more complex electric operation management or achieve deep application of electrical data.

Since DCS is the most important system in power

Received 2001-07-26.
※ The project supported by SEU Technological Foundation(XJ001633).
※※ Born in 1970, male, associate professor.

plants, the connection of electrical system to DCS system is out of question. Many schemes concerned about the connection to the DCS have been presented, but most of them are based on "hard cable". It is worth considering that new technology can be used to this field.

2 Feasibility Analysis of Electrical System Integrated Automation

The improvement of electrical system automation is based on integrated automation and fieldbus or industrial Ethernet technology.

Microcomputer-based protection and automation devices are widely used in power plant electrical system. The measure, logic judge, action, record and man-machine interface function can be done by software. Moreover, all these devices have communication interface, they can exchange information with master system or with each other through fieldbus.

Fieldbus technology has been widely used in industry and electric power field, and it has been paid more and more attention. The technology in communication rate, communication distance and anti-jamming capability has been improved. Many sorts of standards have been formed, such as Profibus advocated by Siemens, FF by ABB, CAN originated from automobile industry and Lonworks brought forward by Echelon company. They are all influential fieldbus technology and applied in industry automation area[4]. Recently, industrial Ethernet network becomes new hotspot.

The application of microcomputer-based devices of electrical system, fieldbus or industrial Ethernet technology and communication capability provided by DCS system bring powerful support for the integrated automation of power plant electrical system.

3 Realization of Integrated Automation in Electrical System

Electrical system integrated automation is to connect foregoing many protective relay and automation devices by fieldbus and then connect them to DCS system and (possible) electrical workstation through communication devices. The electrical workstation implements all the electrical application such as monitoring and maintenance function, and the basic control function is accomplished by DCS system using "hard cable". With the development of technology, the control function can also be fulfilled by communication.

There are two main problems in building integrated electrical automation system. One is how to build the electrical system network; the other is how to connect electrical system with DCS.

Fieldbus standard is the main problem in building the network. Due to the protection and automation devices produced by different manufacturers, the physical layer and communication protocol may be different, so the devices cannot be connected simply.

Since it is difficult to unify the fieldbus standard, one way to solve this problem is to divide electrical system into several subsystems. According to the electrical system feature, the subsystem can be divided into 6 kV subsystem, 400 V subsystem, generator-transformer protection subsystem and AVR subsystem etc. Each subsystem supports the same fieldbus standard. For example, feeder protection, motor protection, transformer protection on 6 kV bus must support one kind of standard. Protections of 400 V system or intelligent circuit breaker use the same standard. Generator transformer protection and AVR can have the same or different standards. Those subsystems can be connected to DCS system separately, or they can connect to special communication controller before being connected to DCS.

As for the connection between electrical system and DCS, there are several aspects.

- Connect mode. The electrical system network can connect DCS in two ways. One is by DPU (data process unit) — the base layer of DCS. The other is by Ethernet network. In DPU mode, DCS must provide one or several communication ports, mostly this port using RS485 and MODBUS protocol. In Ethernet mode, the electrical system can connect to DCS factory layer using TCP/IP.
- Control problem. The ideal control mode is that all the monitoring and control function are fulfilled in DCS using monitor. But currently, considering the electrical interlock and reliability, the DCS control function still uses "hard cable".
- Common system. Both two generator units DCS can monitor the common system data. Common system control function should be realized in both two generator units DCS. But only one DCS can control the common system at time, and the control can be switched between two DCS.
- Information exchanges between DCS and electrical system. The information includes measurement information, switch state, meter information, action information, set point, fault diagnosis, time checkout,

control command and so on. In fact, the DCS concerns only a part of these data, other data can be used for further electrical application.

Unlike substation integrated automation, electrical system integrated automation have two masters. One is DCS, the other is electrical workstation. The electrical workstation system can achieve the following functions.

- Data acquisition and monitoring. With the assistance of electrical connection map and other pictures, it can monitor all electrical parameters of auxlliary power.
- Automatic meter-reading. In most plants, the meter-reading of auxiliary system is completed manually. Some power plants use specific meter-reading system, set up special network to record the power consumption. With electrical automation system, electrical workstation can implement all the functions of meter-reading system.
- Equipments management. It includes accounts, files, maintainence records of protection and automatic equipment, and this function is online(such as the running time record).
- Set point management. This function carries out remote setting, modifying and online automatic checking of setting value.
- Fault information management. This function fulfills action alert, SOE, fault recall, fault replay, wave recording and analyzing.
- Fault diagnosis. This function diagnoses motor state such as sqirrelcage break and motor stop.

In addition, other applications, such as generator monitoring and analytical system of steady state operation[5,6] can be included in electrical workstation.

4 Project of Electrical System Integrated Automation

The model of system frame is shown in Fig.1 and Fig.2. Each figure shows only one generator unit and corresponding electrical automation system.

In Fig.1, the electrical system is divided into four parts: #1, 6 kV subsystem #1, 400 V subsystem; 6 kV common subsystem and 400 V common subsystem. All the subsystems connect to DCS by DPU. The communication controller must be designed to handle different communication protocols. If all the devices un-

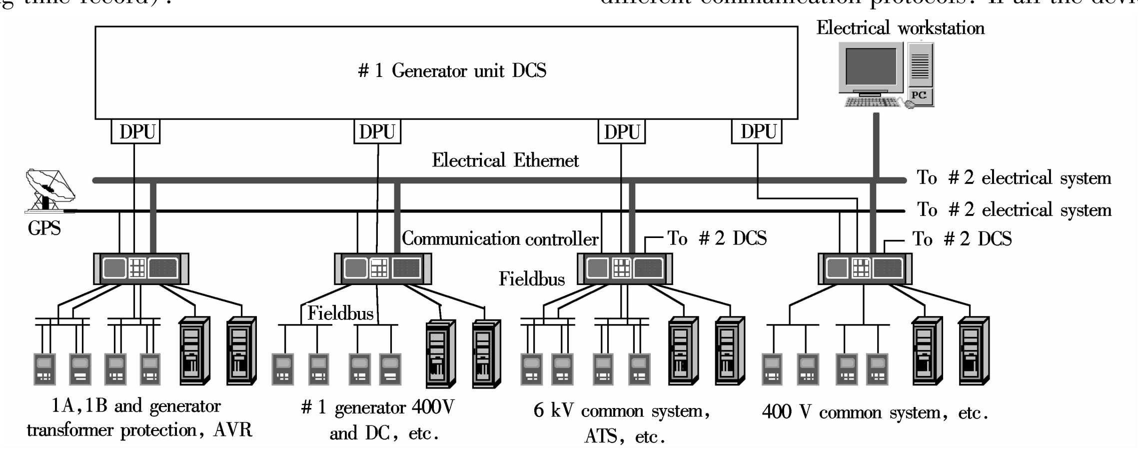

Fig.1 Sketch map of system structure 1 — DPU mode

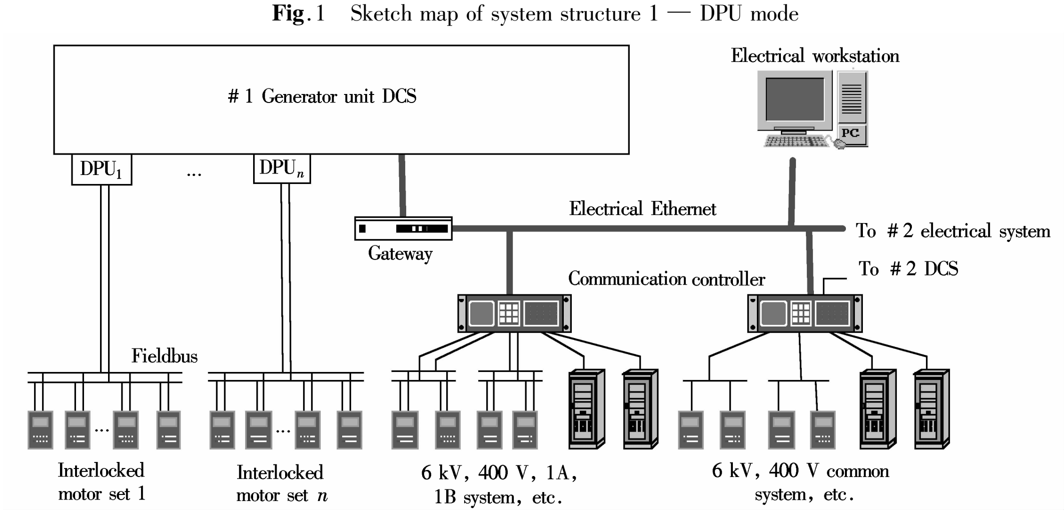

Fig.2 Sketch map of system structure 2 — DPU-Ethernet hybrid mode der the communication controller use the same communication protocol, the controller can be cancelled. For typical power plant design, two generator units with one common system, only two subsystems (#2, 6 kV subsystem and #2, 400 V subsystem) must be added to the #2 generator unit.

In Fig.1, fieldbus layer uses different network topology. We recommend that 6 kV subsystem uses dual-net whereas the 400 V subsystem uses single network.

If we disconnect the DPU interface, and connect the DCS by electrical Ethernet, the communication mode is changed to Ethernet communication mode.

Fig.2 shows the DPU-Ethernet hybrid communication mode. In this mode, interlocked motor belonging to the same set is directly controlled by one DCS DPU. Other devices connect to DCS by Ethernet.

5 Conclusion

Adopting integrated automation of power plant electrical system is the tendency of improving the automation level of power plant, especially improving electric operation management level. It will save the investment and improve the reliability. Microcomputer protection, automatic device, mature communication and fieldbus technology are the technical guarantees for integrated automation of electrical system. This paper puts forward two schemes of integrated automation of electrical system. But the modes of connecting with DCS, standard of filedbus and structure of communication network, are still under research and need more practice.

References

[1] Jin Tao, Tang Tao, Que Lianyuan. Analysis and discussion on decentralized substation automation system[J]. *Automation of Electric Power System*, 1997, **21**(10): 69-72. (in Chinese)

[2] Liu Guolin, Wu Shihong. On field buses of intelligent low voltage controlgear and switchgear systems[J]. *Low voltage apparatus*, 1999, **1**: 3-9. (in Chinese)

[3] Qiu Hua. Discussion on application of integrating the electric monitoring system to DCS[J]. *Hubei Electric Power*. 1999, **23**(4): 19-22. (in Chinese)

[4] Yan Xianhui. *Fieldbus technology and application*[M]. Beijing: Tsinghua University Press, 1999. (in Chinese)

[5] Dai Xiaohui, Wei Wei, Wang Yu. Implementation of monitoring system of thermal generator based on Profibus in power plant[J]. *Automation of Electric Power System*, 2000, **24**(16): 51-53. (in Chinese)

[6] Yang Ping, Wu Jie. Real-time state supervisory system and fault diagnosis for thermal power plant[J]. *Automation of Electric Power System*, 2000, **24**(17): 37-40. (in Chinese)

发电厂电气系统综合自动化

郭 伟　　王 莉

(东南大学电气工程系,南京 210096)　(南京第五十五所,南京 210016)

摘 要 针对电厂电气系统自动化水平相对落后的状态,本文分析了在电厂电气系统中采用综合自动化技术的可行性、必要性及几个关键问题,提出了利用现场总线技术的新思路,并给出了具体的实施方案.

关键词 发电厂电气系统,现场总线控制系统,DCS,综合自动化

中图分类号 TM76