Integration of Supervisory Control and Data Acquisition Systems Connected to Wide Area Networks

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*OVERVIEW: Continued evolution of networking and PC technologies has enabled better integration of control center systems and driven down operating costs. By employing low-cost-high performance PC servers, we can anticipate new load dispatching control systems implemented at substantially lower development cost. Especially in the current fluid and rapidly changing environment faced by the power industry, these new load dispatching control systems can be readily tailored to flexibly accommodate whatever operating structural changes emerge in the years ahead. These were the circumstances motivating the Hitachi Group to develop integrated SCADA (supervisory control and data acquisition) systems interconnected over WANs (wide area networks). This is the first time such a system has been developed in Japan featuring WANs-interconnected substation controller and PC servers running the Linux*1 operating system. The new integrated WANs-interconnected SCADA systems have now been deployed at The Kansai Electric Power Co., Inc.'s Tokai Load Dispatching Center.*

INTRODUCTION

UNTIL now SCADA systems have been largely based on UNIX*2 servers, which exchanged information with substation controller via telephone lines with proprietary protocols. But due to changes now facing the power industry, power companies have been seeking ways to push down the costs of developing and operating power networks.

To address these issues it is necessary to
(1) employ low cost PC servers that run Linux,
(2) minimize system operating costs by adopting an

*1 Linux is a registered trademark or a trademark of Linus Torvalds in the U.S. and other countries.
*2 UNIX is a registerd trademark in the United States and other countries, licensed exclusively through X/Open Company Limited.

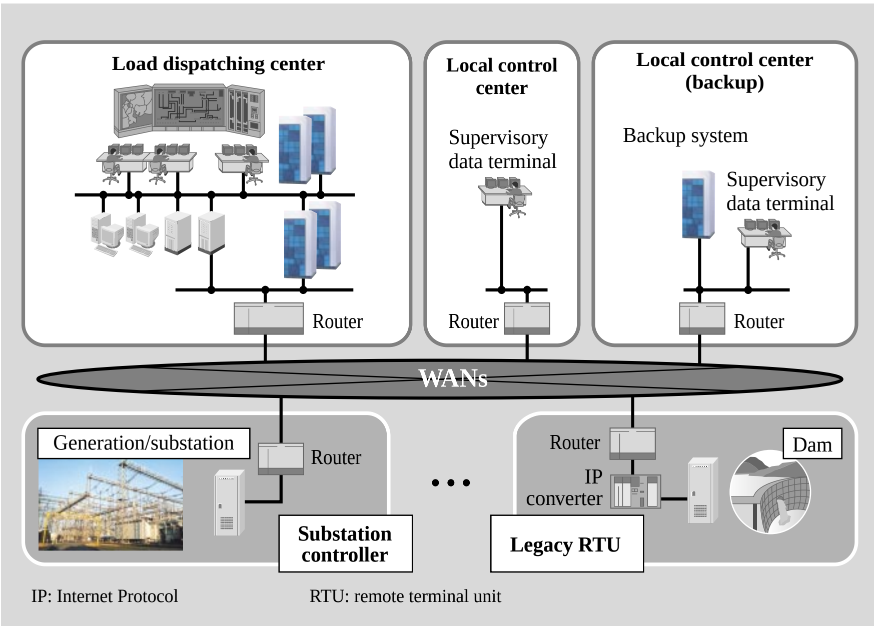

Fig. 1—Configuration of Load Dispatching Control System, The Kansai Electric Power Co., Inc.'s Plant in Tokai Region.
All operating sites are interconnected and integrated over WANs and backup systems are dispersed over a wide area. Also interconnected over WANs, the substation controller provides supervisory control information over a wide area. The main servers configuring SCADA system are PCs running Linux.

integrated type of SCADA systems, and
(3) reexamine the traditional system configuration both in terms of constituent elements as the system as a whole.

The Hitachi Group has developed comprehensive WANs-interconnected SCADA systems that fully integrate all the independent power control systems. While preserving the excellent reliability and processing capabilities of Hitachi's existing supervisory control technologies, the new comprehensive system combines an integrated control center system based on PC servers running Linux and substation controller connected to WANs using IP technology. Now deployed at The Kansai Electric Power Co., Inc.'s plants in Tokai Region, a schematic of the new system is shown in Fig. 1.

This paper details some of the issues faced and the technologies developed in implementing the new system.

SPECIFIC REQUIREMENTS OF WANS-INTERCONNECTED SCADA SYSTEMS

Fig. 2 depicts the configuration of the WANs-interconnected SCADA systems. Deployed over WANs, the systems consist of control center systems and substation systems.

(1) Control center systems

The control center systems consist of an integrated load dispatching computer system with servers and support for client terminals in the ACC (area control center) and LCCs (local control centers) for operators. The integrated load dispatching computer system effectively integrates the various computer systems deployed at the ACC and LCCs. Processing performance and reliability are significantly improved by the integration and consolidation of system operations. The terminals in LCCs are connected to the integrated load dispatching computer system via WANs, and operators in LCCs can access real-time information using the terminals. Backup equipment is installed in one of the LCCs in the event the main load dispatching equipment fails.

(2) Substation systems

Substation controllers are installed in substations and generating stations. The substation controllers support RTU and communication functions. They interconnect the integrated load dispatching computer system and backup equipment over the

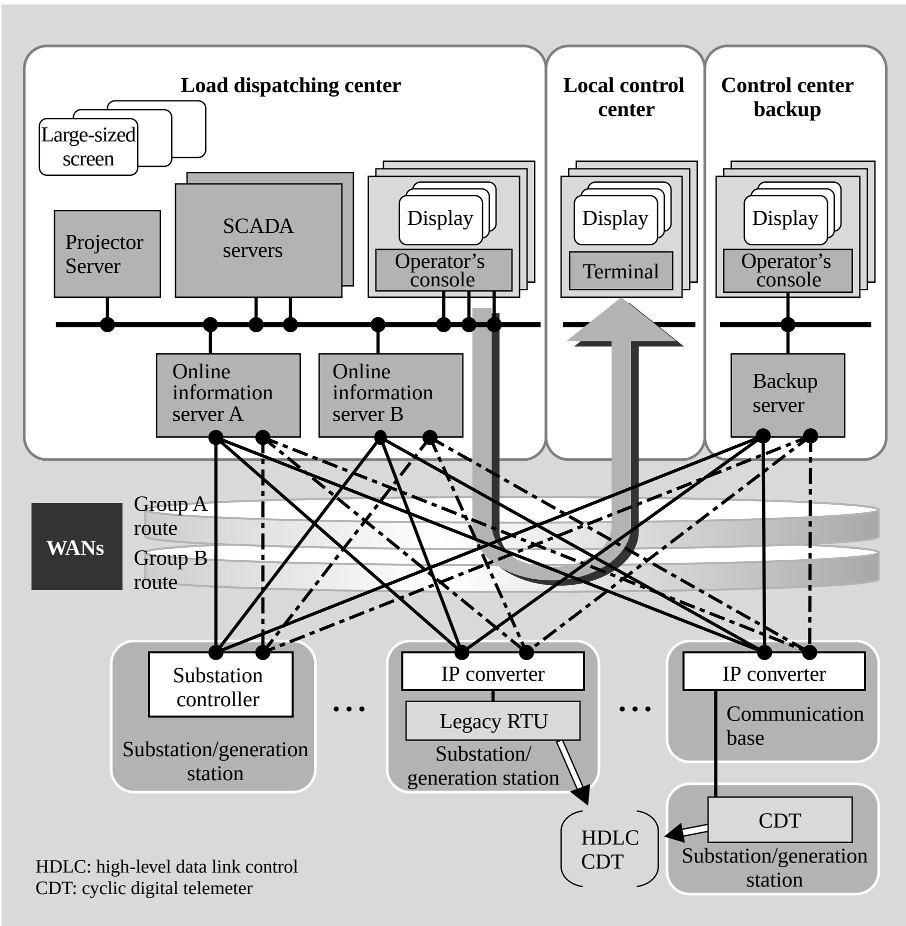

Fig. 2—Configuration of WANs-interconnected SCADA systems. Substation controllers are linked to higher stations by a broadband network.

WANs. The substation controllers must provide the control center systems with real-time data at all times to ensure rapid switching to backup equipment and continuity of data delivery. Substation controllers will be installed in generating stations and substations in a phased deployment, so IP conversion equipment will be installed in the generating stations and substations until they are upgraded to translate conventional data transmission protocols to IP network protocols.

(3) WANs

WANs must ensure adequate bandwidth to transmit real-time data within a certain length of time even under heavy network traffic conditions. The WANs must also provide redundant network paths and path switching so no data is lost when a network path fails.

LINUX SERVER RELIABILITY ENHANCEMENT TECHNOLOGIES

It is essential that the server supporting the core functions of the supervisory control system must provide extremely high reliability and long-term stable operational support. It was to provide such a platform that low-cost Linux servers were commercialized that employ a PC server and open source Linux that has attracted so much attention as the operating system. In the rest of this section we will consider the main advantages of this approach.

Enhanced Hardware Reliability

Adopting a PC server with Pentium4* processor for the hardware provides a highly reliable and long operating life solution.

(1) Parts for the power supply designed for long life were rated as highly reliable according to the same criteria used to evaluate computers for conventional control purposes.

(2) We developed a high-performance heat pipe and upgraded the cooling system to efficiently cool the Pentium4 processor known to give off substantial heat.

(3) We also developed a proprietary fault detection monitoring LSI endowed with functions to monitor the cooling fan, temperature, and power supply problems. In addition, we also added a server operation monitoring capability that greatly enhanced the RAS (reliability, availability, and serviceability) of the system.

* Pentium is a registered trademark of Intel Corporation in the USA and other countries.

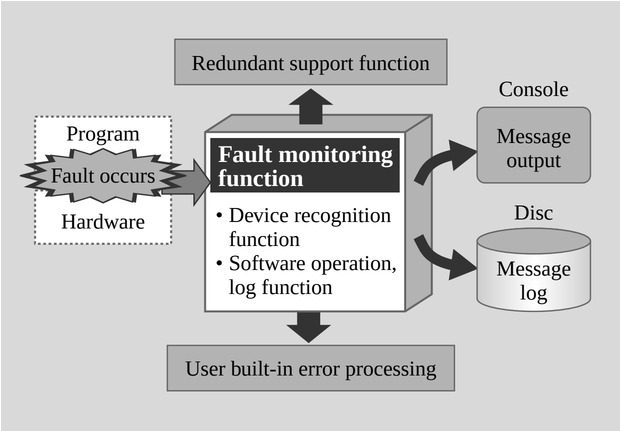

Fig. 3—Fault Monitoring System.
The fault monitoring system detects software and hardware faults, collects detailed information about faults, and initiates user built-in error processing and recovery based on classification of faults.

Fault Monitoring System

The commercial Linux package that is available does not always provide notification when there is a problem. This led us to develop several accurate fault diagnosis and advance notification tools including a hardware device recognition function that accurately pinpoints the hardware part that fails and a software operating log that logs program operating states just before the software fails, making it easy to troubleshoot the problem. Fig. 3 shows an overview of the fault detection and monitoring system.

Hardware and software failures are detected by the fault monitoring system, which identifies the specific part that fails and logs all data pertaining to software failures. In the event of a serious breakdown, the redundant support function automatically switches over to a backup server. A number of user built-in error processing procedures can also be run when faults are detected including restoration processing depending on the type of failure and function degeneration processing. Information detailing the specific part or location of hardware faults and program operation status is recorded to hard disk and displayed as a failure message on the console.

Redundant Server Support Capabilities

To further bolster the reliability of the supervisory control system, we developed a redundant support system interconnecting two Linux servers with a dedicated redundant supervisory control network (see Fig. 4). The safety monitoring system is implemented so that the suspension or interruption of communication

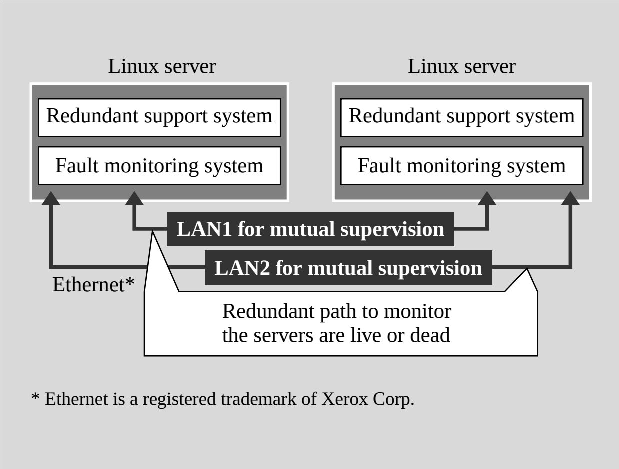

Fig. 4—Server Redundant Support System.
Two Linux servers monitor each other using redundant mutual supervision LANs. If a problem occurs on one of the systems, it is forcibly stopped and all activity is immediately switched to the standby system.

with other systems is detected by the network for redundant mutual supervision. Notification of server abnormality is sent to the fault monitoring system, the faulty system is forcibly stopped by the backup server redundant support system, and operations are switched to the standby server.

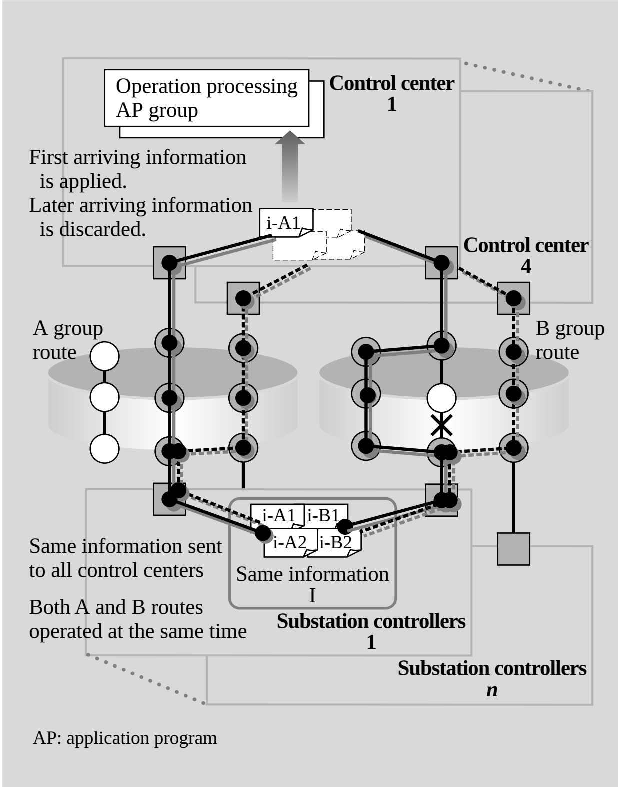

Fig. 5—Schematic of Transmission Protocol.
Employing substation controller using two routes (A group and B group) and transmission protocols, transmission reliability is enhanced by sending the same information over two routes at the same time.

DATA TRANSMISSION PROTOCOL

Basic Data Transmission Protocol

There are two types of IPs:

(1) TCPs (transmission control protocols) that deal with setting up interconnections and the reliability of data transmission, and

(2) UDPs (user datagram protocols) that focus primarily on connectionless transmission efficiency.

For remote supervisory control of power systems that can handle telemeter measurement, binary state data, and control request information, realtime delivery with the highest standard of reliability is critically important. Moreover, in contrast to conventional HDLC (high-level data link control) communication schemes assuming connectivity between one RTU and one control center, in the wide-area distributed topology that we are proposing, supervisory control information is provided to multiple control centers at the same time. This calls for a very sophisticated protocol supporting excellent data transmission efficiency, responsiveness, and the ability to ascertain states very rapidly. Based on a comprehensive assessment of these special requirements, we adopted UDP as the protocol for basic data transmission, and a scheme guaranteeing failsafe delivery of data for the application level protocol.

Transmission Protocol

In this section we will highlight the key features of the transmission protocol (see Fig. 5).

(1) One feature that markedly improves data transmission reliability is to send the same data twice (initial transmission and follow-on transmission) simultaneously to all control centers via two separate routes (a two-route simultaneous transmission scheme). In addition, we adopted a protocol that coordinates traffic over the two routes so that when one route develops a problem or data is corrupted by a transient surge and the line is switched, no data is lost and there is no appreciable delay.

(2) To make sure the continuity of incoming data is correct and that no data has been lost in transmission, a protocol is adopted that attaches a sequential number to each packet of data that is delivered. The same packet data numbers are attached to the same two streams of data that are simultaneously delivered over

the two routes, and the redundant data is efficiently handled by processing the first data stream to arrive and discarding the second data stream to arrive.
(3) In order to immediately detect if data has been lost, the transmission route has developed problems, or the far-side station is having trouble, devices have been implemented in all control centers that determine whether the received packets arrive within the prescribed time and in the right sequential order. When no regular data is being sent over the system, network monitoring packets are transmitted at three-second intervals from the substation controller to control centers to ensure the network is working and problem-free.
(4) If a control center detects that data is missing, it sends a retransmit request message to the substation controller from which the data was sent, and the missing data is recovered and resent. In cases where missing data cannot be recovered in response to a resend request, all displayed data sent from substation controller is periodically restored so recovery is not endlessly repeated.
(5) In order to efficiently transmit telemetry measurement data and the binary state data from a lower station to several control centers at the same time, the following protocols were implemented.

(a) For the telemeter measurement information, transmission by exceptional scheme is adopted in which the current value is compared with the previous value at each periodic transmission and only that which has changed to exceed the prescribed bandwidth is sent. This way, the amount of transmitted data representing normal states can be reduced.

(b) The timing at which the periodic information is transmitted is slightly shifted for each substation controller to avoid congestion of network.

CONCLUSIONS

This paper described the implementation of WANs-interconnected SCADA system using Linux servers and substation controllers.

Up to now, most SCADA systems have been implemented using proprietary equipment, but here we have described a way of implementing such systems over an IP network and taking full advantage of generic, general-purpose equipment and systems while maintaining the same high standard of reliability. This system has been installed and began operating in July 2004 at The Kansai Electric Power's Tokai Load Dispatching Center.

System adjustment tests were performed and it was found that the system exhibits better performance responsiveness than the conventional system while maintaining the same high level of reliability.

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