System Technology that Supports Next Generation Electricity Delivery

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ABSTRACT

When a large amount of solar power is introduced into a system, reverse flow and voltage fluctuations occur. Moreover, this is feared to affect the demand/supply control, since net demand cannot be ascertained. To solve this problem, Fuji Electric optimized the placement and setting values of voltage control equipment, and is developing a centralized control method. Devices models for analysis, a method of predicting solar power output and a demand/supply control function are also being developed.

To replace aging facilities, a unit replacement-type protective relay using a new IED (Intelligent Electrical Device), and in support of the diversifying operating modes of power companies, IP network devices, middleware for wide-area distributed power, and a disaster prevention and crisis management system are being developed.

1. Introduction

As power consumption increases due to continued economic growth, power companies and manufacturers have been endeavoring for many years to realize a stable supply of power, which is the primary goal of power distribution, and to streamline their operations with the aim of increasing economic efficiency. Systems that support power distribution include centralized monitoring control systems that use computer technology, protection and control systems that prevent the spread of system faults in the event of system trouble, and so on, and these systems have been utilized to realize a high degree of supply reliability.

In the future, with the aim of achieving a low-carbon society, the mass adoption of distributed power generation predominately consisting of solar power generation and wind power generation is anticipated. Additionally, there will be a need for the renewal of aging protective relay equipment that had been delivered more than 20 years prior and for increasing the efficiency of power system operation. These types of challenges and Fuji Electric's efforts in the power distribution field are described below.

2. The Power Distribution Field: Present Status and Challenges

In the power distribution field, Fuji Electric has developed and delivered various types of support systems, including power system control systems, distribution automation systems, remote supervisory control system, protection and control systems, system analysis simulators and power demand prediction systems. Figure 1 shows the main products that Fuji Electric has developed and delivered in the power distribution field.

Challenges related to the mass adoption of distributed power generation, as well as challenges involved in the renewal of aging equipment and efforts to increase the operating efficiency are described below.

2.1 Challenges relating to mass adoption of distributed power generation

(1) Challenges of power distribution systems

In the mass adoption of distributed power sources, such as in the case of solar power generation, the occurrence of voltage rises due to reverse flow and voltage fluctuations on the distribution line due to abrupt output fluctuations are problems associated with power distribution systems. At present, power

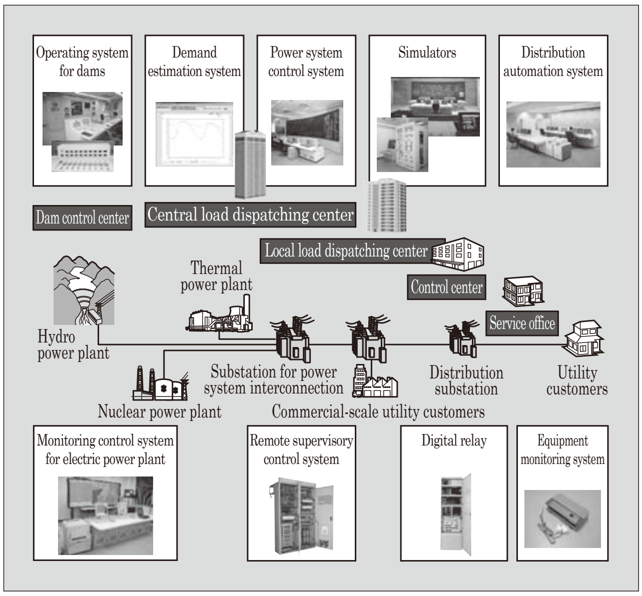

Fig.1 Fuji Electric's power distribution products

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regulating devices such as on-load tap-changing transformers (LRT: load ratio control transformers), automatic voltage regulators (SVR: step voltage regulators) and static reactive power compensators (SVC: static var compensators) are used at distribution substations with the aim of realizing a suitable system voltage in a power distribution system. However, the regulating ability of a voltage control method based on the effect of individual voltage regulating equipment is limited, and solutions for anticipated problems are needed.

(2) Challenges in supply/demand operational management

In the case of the mass adoption of solar power generation in homes, the generated power output will not be measurable in real-time. The power companies will be unable to ascertain the net demand for power, and therefore must, in order to maintain the power system frequency, implement supply/demand operational management based on predictions of solar power generation output. Moreover, to accommodate the absorption of surplus electricity at the load side and increased loads due to sudden fluctuations in the weather, a storage cell optimization control function, a reverse flow detection function and the like are necessary.

(3) Challenges in power system analysis

In the future, to demonstrate the effect of the installation of newly-developed distributed power sources and the effect of control systems on the power system, analytical models for distributed power sources must be designed to be easily and rapidly introducible into a systems analysis simulator.

2.2 Next-generation support of aging protective relay equipment

Due to the aging of equipment and an accelerated replacement cycle for major equipment components, renewal work for protection and control systems in Japan will increase in the future. Protective relays utilize electronic components having a short improvement or elimination cycle, and device configurations that allow for easy updating by unit replacement are the mainstream. Moreover, so that protection and control systems can be connected easily to equipment made by different manufacturers, i.e., so as to realize a multivendor system, monitoring control systems and protective relay systems will converge further, aiming for an all digital system.

2.3 Improvement of operating efficiency

In order to reduce the operational management cost of power systems, the trend toward consolidation of multiple operational management organizations such as load dispatching offices and service offices provided with distribution automation systems has been accelerating in recent years. For this purpose, construction technology for monitoring and control systems capable of responding to changes in the operating mode is needed.

Moreover, the workload on the operator increases as monitoring and control is performed over a wider range, and remedial measures are needed.

3. Fuji Electric's Efforts in the Next-Generation Power Distribution Field

3.1 Measurers for the mass adoption of distributed power sources

(1) Measures for distribution systems

(a) Power distribution system voltage fluctuation suppression technology

As voltage fluctuation suppression technology for next-generation power distribution systems that support the mass adoption of distributed power sources, Fuji Electric is using state estimation, power flow calculations and optimization methods to develop planning support for optimally arranging voltage regulating devices, and a voltage control method for controlling the voltage in distribution systems to suitable levels. Fig. 2 shows an overview of the distributed voltage control developed by Fuji Electric.

(i) Optimal arrangement of voltage regulating devices

To streamline the operation to plan for installation or relocation, optimization techniques are used to calculate the SVR installation location at which the deviation rate from upper and lower voltage limits is smallest throughout the year.

(ii) Optimization of voltage regulating device set points

In order to minimize the operating frequency of the SVRs, optimization techniques are used to calculate the combination of set points for multiple SVRs at which the deviation rate from upper and lower voltage limits is smallest throughout the year.

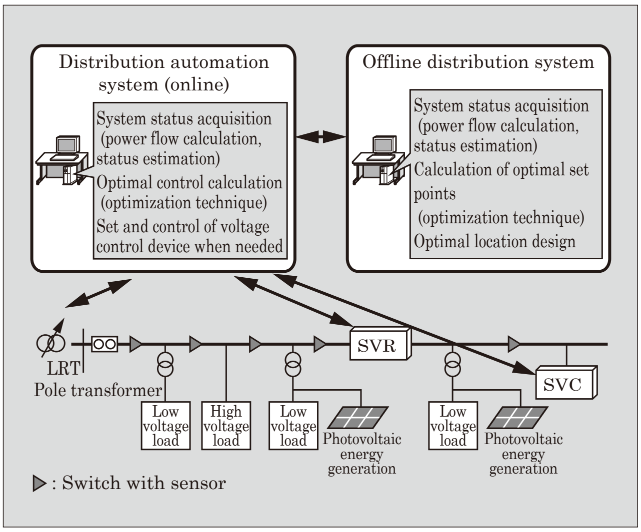

Fig.2 Overview of distribution voltage control

(iii) Centralized control of voltage regulating devices

So that the voltage throughout an entire distribution bank incorporating large quantities of solar power generation remains within an appropriate voltage range, based on measurement information from switches with sensors, tap values for load ratio control transformers (LRTs) and SVRs on a distribution system, and optimal static var compensator (SVC) voltage command values are calculated, and are centrally controlled in real-time.

(b) Next-generation optimizing control technique demonstration project for power transmission and distribution systems

To establish voltage fluctuation suppression technology, Fuji Electric is participating in the "Next-generation optimizing control technique demonstration project" sponsored by the Japanese Ministry of Economy, Trade and Industry. Aiming for the mass adoption of renewable energy such as solar generation by 2020, this project will conduct, with twenty-eight participating entities including Tokyo University, a three-year development and demonstration experiment for an optimized control method for demand-side devices, a system voltage control method for distribution systems, and the like in order to solve the problems shown in Fig. 3. Fuji Electric is participating in the "voltage suppression technology for distribution systems development" sub-working group of the project.

(2) Measures for a supply/demand operational management using a demand forecasting system

Fuji Electric has delivered power demand estimate systems that use neural network technology to power companies. Using this technology, meteorological forecast information such as the amount of solar radiation is used to predict and estimate the effect on solar power generation, and research is being carried out to reflect those results in system-wide demand estimates. Fig. 4 shows an overview of a demand estimate system for solar power generation. The amount of solar power generation at certain locations is estimated by calculating the amount of solar radiation from numeric cloud cover data based on Grid Point Value (GPV) forecasts by the Japanese Meteorological Agency, and in consideration of longitude-latitude information and temperature forecasts. Fuji Electric plans to apply this

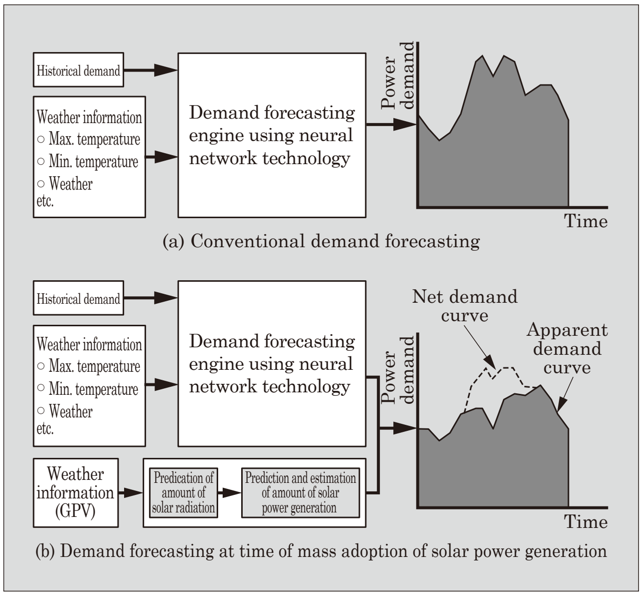

Fig.4 Overview of demand prediction system in consideration of solar power generation

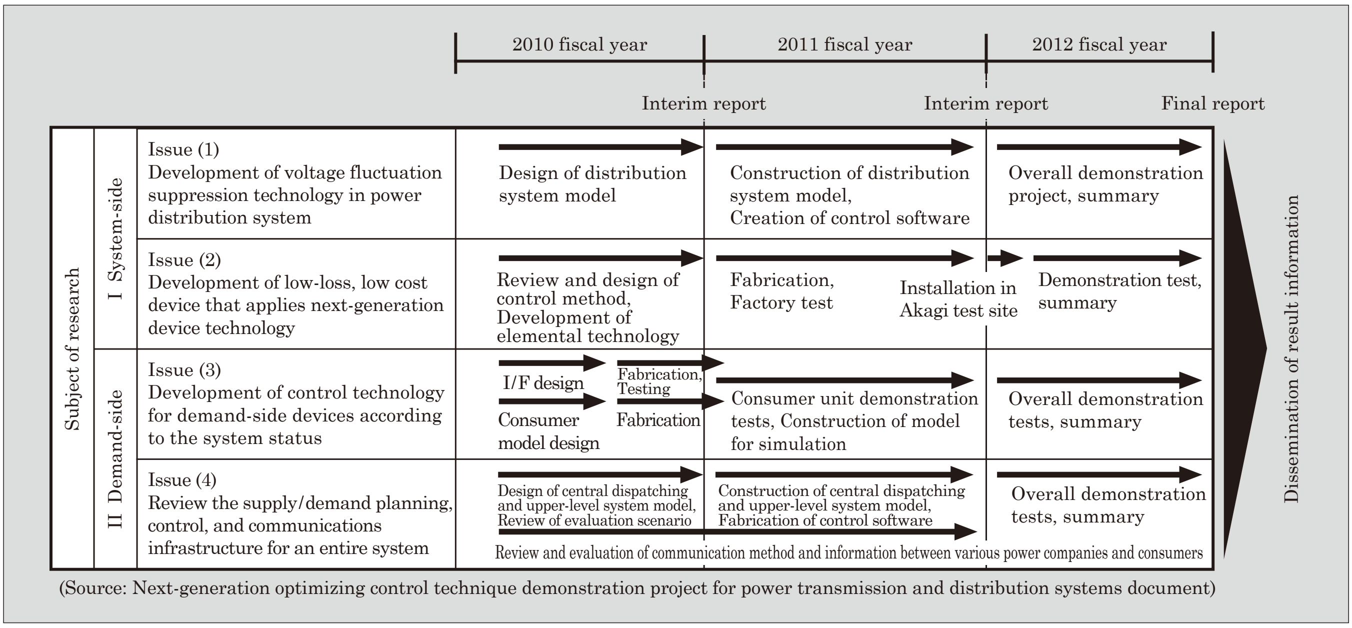

Fig.3 Schedule of next-generation optimizing control technique demonstration project for power transmission and distribution systems

estimation technique to smart community demonstration projects.

Additionally, in a remote island micro-grid demonstration project, Fuji Electric has developed and applied a supply/demand operational management planning function, an economic load allocating function and a load frequency control function. As the mass adoption of distributed-type power sources and the adoption of electric vehicles (EV) progresses, power companies are expected to implement supply/demand operational management in smaller regional units than at present. For this purpose, Fuji Electric intends to apply its technical expertise acquired through demonstration projects to the power distribution field.

(3) Measures for power system analysis

A power system analysis simulator is configured from an equivalent reduced model of system component devices, and is used to analyze the power flow, steady-state/dynamic-state stability, and power system resonance phenomena, simultaneous faults, and the like.

Fuji Electric has delivered analog-type power system analysis simulators, capable of the real-time analysis from surge phenomena of several micro seconds to economic load allocating that lasts several hours or more, primarily to power companies and universities. An analog-type power system analysis simulator performs calculations with continuous quantities, and therefore has an advantage in that the divergence occurring in digital calculations due to the operation time interval and numeric solutions is less likely to occur. In recent years, to analyze the effect on a power system of the adoption of large-scale renewable energy generation from massive solar power stations, wind stations and so on that is associated with output fluctuations, Fuji Electric has developed models of solar power generation and wind power generation, and has supplied these as device models.

Among such efforts, there is increased utilization of analog-type power system analysis simulators in the analysis of high-level application technology of future power systems, such as next-generation power distribution systems, smart communities and the like.

Analog-type power system analysis simulators support the research and development of future methods for power system device location and control, such as studies of the operating method and point of optimum location of electric power storage systems installed on a power distribution system, including assessment of the effect on power quality due to the mass adoption of solar power generation and wind power generation.

Fuji Electric has begun development of a next-generation hybrid-type power system analysis simulator that combines conventional analog technology with the latest digital processing technology.

3.2 Next-generation substation protection and control systems

At present, Fuji Electric is moving forward with the development of a new intelligent electrical device (IED) that conforms to the IEC 61850 international communication standards. While retaining the environmental performance, reliability, lifespan and the like required of protective power-use relays in Japan, the new IED is positioned as a successor to Fuji Electric's existing protective relays and measurement units, and is a highly reliable controller suitable for use in protection, control, measurement and communication terminal applications. Fig. 5 shows an example configuration of the new IED. The combination of a basic unit and an expansion unit allows the optimal configuration to be provided for individual equipment application. Fuji Electric is also considering application to all-digital substations in the future, including application to protection and control systems.

Moreover, based on the assumption of modular replaceable units, Fuji Electric is also advancing the development of a main unit for digital relays. Fig. 6 shows an example of unit replacement-type protective relay. By integrating the main processing part, the input/output part and the power supply part of a

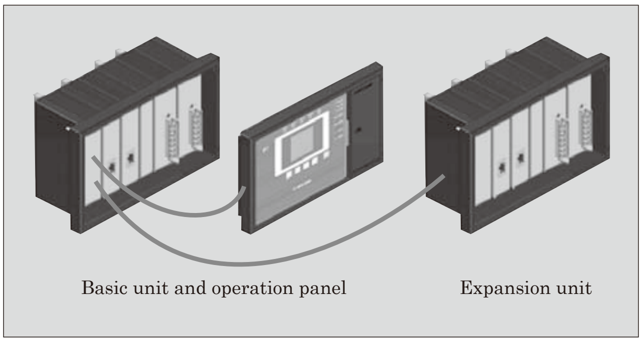

Fig.5 Example configuration of new IED

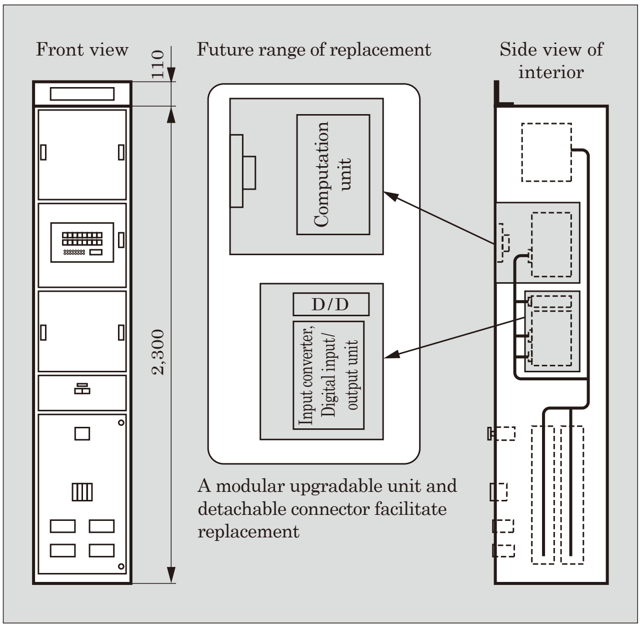

Fig.6 Example of unit-replacement type protective relay

protective relay into a single unit, the structure can be upgraded simply by replacing each single unit.

3.3 Technology for realizing improved operational management

Fuji Electric has been providing technologies that support the realization of operational management systems configured in various forms, such as for ensuring the reliability of information transmission. These technologies are outlined below.

(1) IP network support

In the case where multiple operational management organizations are to be consolidated, ensuring a route for the transmission of information to a substation and guaranteeing the reliability of that transmission of information are challenges. Fuji Electric applies the JEMA industrial protocol known as protocol for mission critical industrial network use (PMCN) to ensure data ordering and real-time performance, and to provide an IP network terminal that supports 2-route transmission and 1:N transmission. While maintaining a conventional level of reliability, these terminals support the different operating systems of various power companies.

(2) Middleware for wide-area distributed power systems

The different power companies have various system configurations. Fig. 7 shows an example configuration of a wide-area distributed system. In this system,

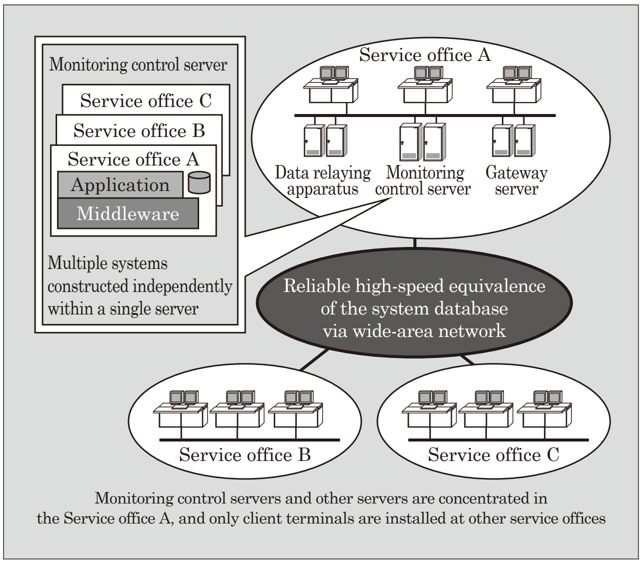

Fig.7 Example configuration of wide-area distributed system

a single server is centrally positioned at one location and clients only are installed at the other various locations. Other systems include a backup system for a server positioned among multiple locations, and a system capable of monitoring the respective systems at adjacent locations.

To realize these configurations, the distributed servers must be constantly monitored for application startup/response, database high-speed equivalence, and server status, and for this purpose, Fuji Electric uses middleware for wide-area distributed power systems.

This middleware has been realized by extending the conventional middleware for power systems to wide-area distributed power systems. Thus, the extension of an existing in-use system to a wide-area system involves little risk of the need for significant software modifications and the installation of new applications.

(3) Support for disaster crisis management

When operational management organizations are merged, the operator burden increases not only for usual business operations, but also in the response to natural disasters such as earthquakes, typhoons and so on. Consequently, Fuji Electric has developed a "Disaster crisis management support system." This system provides an integrated display, which shows load dispatching information, map information, weather forecast information and disaster prevention information for each layer, and makes a preliminary estimate of risk based on the weather forecast and disaster prevention information, and supports operations to avoid that risk. If a real disaster were to occur, the system will provide subsequent recovery support.

4. Postscript

In addition to systems for the power distribution field, Fuji Electric has also delivered many dam control systems, including pumped-storage power generation stations, water control systems, gas control systems, and so on.

As the range of operation expands from microgrids to smart communities, which aim to increase efficiency and optimally operate all forms of energy, including electricity, heat and water, Fuji Electric, based upon its prior experience with social infrastructure, intends to contribute to stabilizing the supply of electric power and to improving the efficiency of its usage.

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