Basic Technology Subjects

System Engineering Research Laboratory

Brief Overview

The System Engineering Research Laboratory (SERL) conducts research on the planning, operation, control of, as well as analysis methods for, electric power transmission, distribution systems, and information/communication systems, in order to facilitate the secure supply of electricity generated by large-scale and distributed power sources. The laboratory also pursues research on the development, testing, and assessment of customer service technologies to achieve more efficient use of electricity.

Achievements by Research Theme

Electric Power Systems

We develop the fundamental techniques of transmission system analysis and evaluations, control and protection for economic and stable operation of the system. Also, using these fundamental techniques, solutions for recent technical issues surrounding the increase in renewable energy introduction, wide-area interconnection and so on are developed.

- High penetration of renewable energy sources could cause an increase in the frequency fluctuations and the shortage of control reserves. Therefore, a requirement arose for new models of thermal power plants (conventional steam power plants and combined cycle power plants) suited for balancing and frequency control analysis. In order to achieve this, the developed models[*1] are arranged to be manageable and generic reducing the size of the models and integrating various types of thermal power plants into two models. The developed models were validated through a comparison between the model response and the measured response of representative thermal power plants (R14018).
- Construction of frequency converters and HVDC transmission systems for wide-area interconnection has been planned to be carried out in Japan. The two novel control schemes for the HVDC system using the full bridge modular multilevel converter (MMC)[*2], which is suitable for improving the performance of the HVDC transmission system, have been developed. A full bridge MMC with the developed schemes enables continued operation during high voltage in AC grid and prompt starting which cannot be achieved using the conventional scheme (R14016).

Customer Systems

We develop a management technology targeting air conditioning for living environments and proposed a ventilation design criteria for commercial electric kitchens as energy conservation and load leveling assistive technology. In addition, we also developed a reasonable harmonic suppression method for maintaining power quality, an autonomous distributed control system of distributed energy systems.

- A heat source characteristic model to estimate the power consumption of air conditioners to achieve both energy saving and comfort was developed. This model can make estimations depending on the air temperature and airflow distribution of various room air conditioners (R09). With this model a tool was developed to facilitate the selection of a suitable type of air condition based on the user's various residential characteristics, lifestyle and selection rates of preference (R14010). The heat source characteristic model was incorporated into the CFD tool 'CADIEE-Airflow' and an examination was conducted into the accuracy calculation of the power consumption and temperature and airflow distribution of the air conditioner (R14005).
- The harmonics current generated from loading apparatuses connected to distribution lines causes voltage distortions and generally, since the fifth harmonic current is most influential, there is a need to develop a countermeasure technology. Therefore, by analyzing temporal transition of the fifth harmonic current, the phenomenon was found to be due to difference in load type composition (R14002). Furthermore, fifth harmonic currents were estimated for the load type composition for each area and the influences to the harmonic voltage by power factor correction capacitor etc. were shown (R14011).
- A community model for economic efficiency evaluation of an energy system in a demand area (community) was developed (Fig. 1). Using the community model, the benefit to the community operator under the present electric rate structures was calculated by annual simulation. One simulation result suggests that the operator can obtain a profit by installing cogeneration in the commercial area and also by utilizing exhaust heat (R14017).

Communication Systems

In order to secure high reliability of communication networks for power utilities required for operations and control of power systems, we develop disaster tolerance improvement technologies for communication systems, construction technologies for communications systems to assist restoration of damaged power systems and security technologies for SCADA systems.

■Incoming surge current from lightning through a waveguide is a problem in microwave radio equipment. We have been developing a system using optical fibers instead of waveguide to improve lightning protection performance. We have made a prototype of an outdoor type radio signal transmission unit. We have confirmed the transmitting and receiving of signals and power supply is possible by using optical fibers alone. Furthermore, we have evaluated communication characteristics using real radio equipment, and discovered that the signal quality was equivalent to the conventional system (R14006).

■A range (communication distance) to ensure a required transmission rate for voice and video applications by long-range multi-hop wireless LAN used for a temporary communication line between a manned site and a devastated area during a large-scale disaster was evaluated based on field measurement.

Furthermore, operations to be performed by field workers, such as adjustment of antenna direction and confirmation of received signal strength, were listed and a basic construction procedure for quick and reliable construction of temporary communication lines using long-range multi-hop wireless LAN was developed.

Mathematical Informatics

To realize accurate diagnosis in the maintenance and inspection of electric power equipment, we develop diagnosis methods for electric power equipment based on high performance machine learning and image processing techniques. We also develop optimization methods for complex large-scale systems.

■Water wheels of hydroelectric power plants are renewed based on damage levels. Cavitation is one of the major causes of water wheel damage. Depths of cavitation damages on water wheels are measured with caliper gauges in current periodic inspections. To support the inspections, a depth measurement method of cavitation damages was proposed (Fig. 2). The method uses a small camera and a small laser module. It calculates depth of the cavitation damage by triangular surveying. Measurement errors of cavitation damages' depth were within 0.5 mm in water wheel inspections. The method is able to measure the depths of cavitation damages by simple operations more than caliper gauges.

*1 A dynamic model which is able to adequately represent the active power response to demand changes and frequency fluctuations (within about ±0.2Hz).
*2 MMC is a new type of converter which consists of semiconductor cells with cascaded connections. MMC is one of the promising converters and is expected to increase in capacity for application with higher voltage.

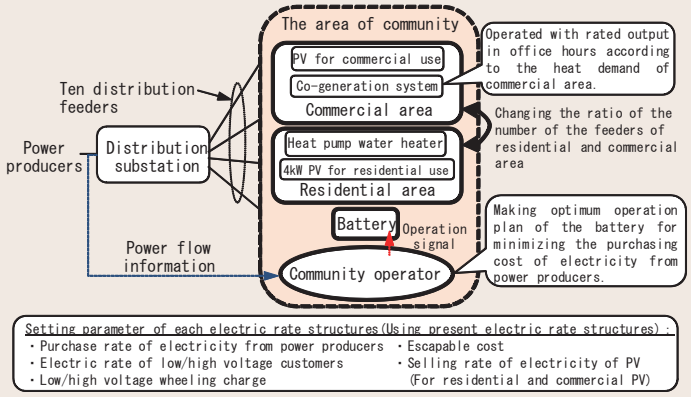

Fig. 1: Community evaluation model

By the supply and demand simulation of electric power and thermal energy considering economic operation of customer equipment (heat pump water heater, battery storage system) and community equipment (battery storage system, cogeneration), relationship between the configuration of community (PV installation ratio, ratio of residential and commercial area, capacity of battery storage system and cogeneration) and the benefit of the community operator can be analyzed.

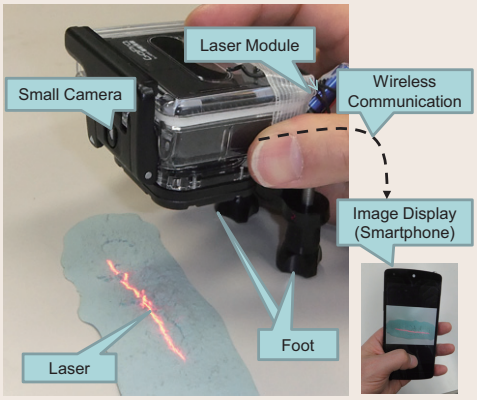

Fig. 2: Prototype of measurement system

Position of the laser projection line is moved in according with depth of the cavitation damage. A captured image by the small camera is displayed on the smartphone using wireless communication. A user can measure the depth of cavitation damage by the line position on the display which is drawn scale.