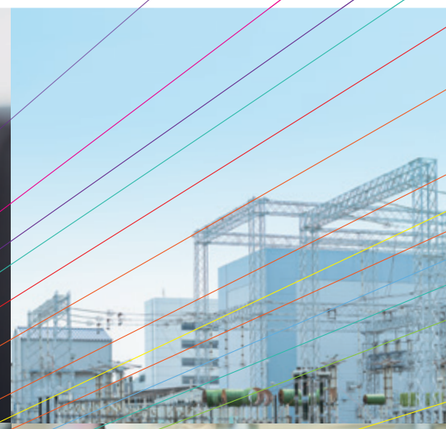
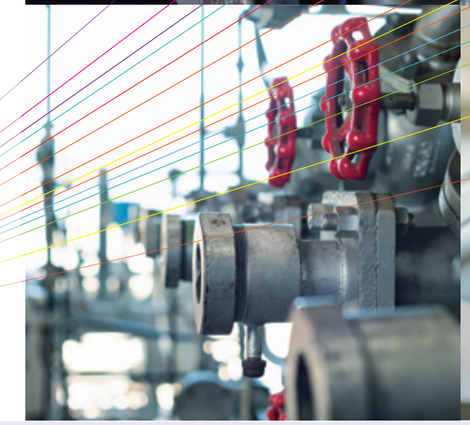
FY2018 Annual Report





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FY2018 Annual Report

CRIEPI

CRIEPI
Central Research Institute of Electric Power Industry

Contents

Message from the President

The electric power industry is confronting major changes in the business environment in Japan. Social trends toward decarbonization are having a significant impact on the supply and demand system of electricity. Providing customers with new value is required for electric utilities in accordance with business circumstances being increasingly competitive. Large-scale and wide-area natural disasters occurred many times in fiscal 2018, reminding us once again of the importance of the resilience of electric power systems.

Central Research Institute of Electric Power Industry has been engaged in research and development to address these issues. For decarbonization, we have developed technologies to further improve the safety of nuclear power generation and the flexible operation of the supply and demand system under massive introduction of solar power. We have also obtained results that lead to the rational formation of facilities for distribution networks, where dispersed power sources and power storage facilities are being highly introduced, and the creation of new services using personal data, such as power consumption. Furthermore, we have developed technologies that strengthen the resilience of electric power systems and the operation and maintenance of electric power facilities, thereby contributing to the stable supply of electricity, which is the first priority mission of the electric power industry.

Central Research Institute of Electric Power Industry will promote research and development by joining the forces of researchers with diverse expertise. We will provide the electric power industry with our research results in a timely manner. We will also actively serve society by publishing academic journal papers and contributing to the development of codes and standards.

Masanori MATSUURA
President

CRIEPI, as the “central research institute of the electric power industry” and “academic research institute contributing to society through scientific technology research”, will support reform of technologies and systems relating to the supply and usage of energy, including electric power, and continue to guide the energy industry forward.

In fiscal 2018, we set 110 research themes and conducted research, creating various results that will contribute to solving problems in the electric power industry and in society. We also actively promoted research activities and spread the results and, at the same time, continued to streamline and upgrade our operations and control costs.

■ Contribution of various research results to the electric power industry and society

・Our resources are allocated with priority to R&D related to solving common problems in the electric power industry, and we promoted research steadily to generate results. Specifically, we achieved results in a variety of fields in the electricity business, including “Enhancement of accuracy of the seismic performance verification method for outdoor important civil engineering structures of nuclear power stations” in the nuclear power field, “Development of high-accuracy solar radiation estimation and prediction system using satellite images” in the renewable energy field, and “Development of a method for evaluating the balance between electricity supply and demand in the event of a disaster” in the electricity distribution field. In addition, we have identified situations that are expected to emerge in the future, and have worked on research to solve issues that are expected to arise in these situations and to provide new value. We have developed a sensor network power source that can generate electricity from environmental vibrations.
➡ See p.18 to p.59 [2-2. Major Research Results] (21 in total)

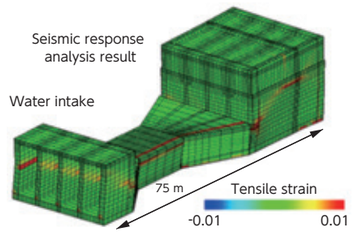


Fig.1 Example of three-dimensional nonlinear seismic response analysis of underground structure
(p.18 to p.19 [2-2. Major Research Results-1])

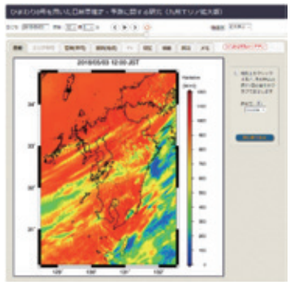


Fig.2 Estimated distribution of solar irradiances based on meteorological satellite images
(p.34 to p.35 [2-2. Major Research Results-9])

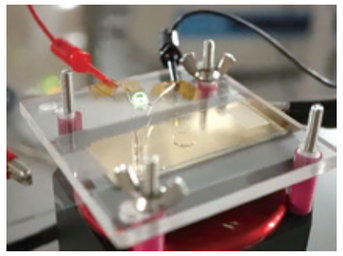


Fig.3 Vibrational energy harvester using electric double layer electret
(p.58 to p.59 [2-2. Major Research Results-21])

・In response to requests for research based on individual issues at each electric power company, such as accidents and trouble, we customized our accumulated knowledge, technologies, and research results for the actual conditions at each site and provided accurate solutions in a prompt manner.
・We worked on 71 commissioned research themes, including those commissioned by the Ministry of Economy, Trade and Industry and the New Energy and Industrial Technology Development Organization (NEDO), and carried out research that contributes to solving issues in the electric utility businesses and that challenges leading-edge themes.

■ Basic research capabilities

・As of the end of FY2018, there were a total of 748 employees, including 661 researchers and 87 administration personnel. The fields of specialization of research staff range widely from electricity, civil engineering and construction to socioeconomics (Fig. 4), and the number of doctorates awarded is 388.
・By promot ing challenging research and develop ment of element technologies, as well as long-term dispatch to electric power companies and other organizations, we worked to train researchers both with advanced expertise and a deep understanding of the electric power industry. We also promoted diversification of our human resources and recruiting with a perspective broad enough to include overseas.

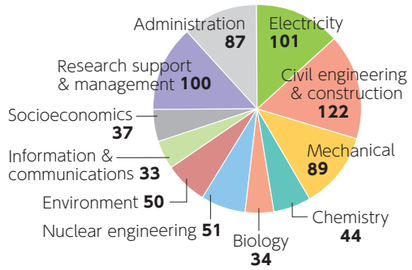


Fig.4 Personnel configuration by subject field as of the end of FY2018

・We carefully selected and installed/updated large-scale research facilities essential to solving the problems of the electric power industry, such as the “supercomputer system” that helps respond to the growing scale and complexity of numerical simulation models and promote efficient research.
➡ See p.15 [Major New Research Facilities]

Supercomputer system HPE SGI8600

Annual meeting with the EDF

・Under cooperation agreements made with overseas organizations, we promoted mutual dispatches of researchers and exchanges of information, thus developing our research network. In particular, we strengthened cooperation with the Électricité de France (EDF) in fields such as electric power storage, hydrogen, and heat pumps, in addition to existing areas of cooperation such as nuclear safety.
➡ See p.63 [Research Network]

■ Utilization of intellectual property, expertise and technology

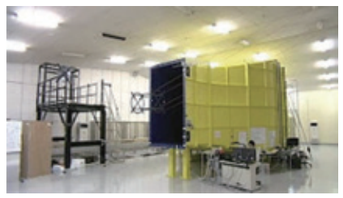
・Through disclosure of research reports and academic papers, as well as implementation and licensing of patents and software created by the institute, we focused on feeding back our research results to the electric power industry and to society. ➡ See p.62 [Research Results / Intellectual Property]
・In response to a series of large-scale and wide-area natural disasters in fiscal 2018, we supported use of the RAMP (Risk Assessment & Management system for Power lifeline). distribution facility damage estimation system, which we developed, at electric power companies, and conducted cause investigations based on scientific evidence, including verification of events through power system analysis.
・We contributed to formulation of energy-related criteria/standa rds and policies by participating in national and academic committees. In addition, we conducted activities with an eye to standardization in global scale, such as exploring the possibility of overseas businesses using the software we developed (eXpandable Transient Analysis Program (XTAP), etc.).
・We concluded agreements, such as partner graduate schools, with 16 universities, and dispatched visiting professors and accepted internships based on these agreements. We also made co ntributions both in research and education using our specialized expertise, such as establishing and operating a social collaboration course by working with the University of Tokyo.
・We conducted short-circuit tests of power equipment such as tra nsformers commissioned by electric power companies and manufacturers at our high-power testing laboratory. We also served as a “PD (Performance Demonstration) testing organization” that conducts licensing tests for ultrasonic flaw detection engineers for nuclear power generation equipment.

1. Outline of Business Activities

■ Activities of public relations

・To gain further understanding of our research activities and their results, we actively engaged in public relations activities, such as holding the “Research Symposium 2018” with the theme of digital transformation. Also, NRRC (Nuclear Risk Research Center) invited experts from Japan and overseas to hold a workshop and exchanged opinions on efforts to enhance risk management in the electric power industry. In addition, we co-organized an international symposium on nuclear materials research with Belgian Nuclear Research Centre (SCK CEN) and University of Rouen Normandy in France, and discussed future development of the research and international collaborations.
・We sent out messages based on scientific expertise on topics with high social interest through press releases (8 items), various public relations publications, SNS (Facebook), and newspapers and magazines, in a timely manner. In addition, through the video sharing site YouTube, we distributed an original video explaining stable power supply technology as well as a short video introducing researchers and research facilities.

Research Symposium 2018



Information through YouTube
- Indoor experimental system of galloping simulation using sector model of conductor -

■ Planning of future research strategies

・To take the lead in reformation of the electric power industries, we deepened our studies on issues we need to work on, which we identified from 3 panoramic views; total optimization of energy production, distribution, and utilization; digital transformation; and risk-based technology systems, and promoted formulation of a medium to long term research strategies. Going forward, we will conduct research based on these.

Overall optimization of energy production, distribution and utilization

From the viewpoint of achieving an economical decarbonization while maintaining a stable supply of electricity, we have clarified challenges to enable further introduction of renewable energy. And, we studied an ideal power system to cope with the spread of a large number of small-scale and distributed power sources and batteries, and the drastic increase in the electrification rate. Also, we identified issues we will face when promoting energy conservation and electrification through the construction of a carbon recycling system using CCS/CCU technology and sector coupling.

Digital transformation

We listed issues we will face in the development of technologies that support digital transformation in the electric power industry, such as next-generation power supply and demand platforms, including distributed energy management systems, and digital twins that constantly monitor and simulate electric power systems, and promoted studies about the environment for software development and solution provision.

Risk-based technology system

In the areas of nuclear power, thermal power, hydroelectric power, and electric power transmission and distribution, in order to enhance safety and to design, operate, and maintain facilities in a rational manner, studies were conducted on the definition and types of risks to be considered, on methods of using quantified risks, and on common strategies for each area toward the practical application of risk-based methods.

Deepening studies on research themes based on three panoramic views

■ Research base, operations, and cost control

・Aiming to strengthen research capabilities and reduce fixed management costs through consolidation of research centers, we are promoting alignment of research bases. To date, we have completed the alignment of the Yokosuka area as a “research base for technologies of the energy industry”. In fiscal 2018, as part of our efforts to align the Abiko area as a “research base for natural and environmental science”, we designed the details of the new main building, which will serve as a hub for researcher activities, etc.
・While maintaining a staff size of 750, we proceeded on building new mission-critical business systems and outsourced some operations.
・We worked steadily on controlling costs in both research and operations by continuously promoting competitive bids in procurement. As a result, the ratio of competitive bids in procurement and construction contracts was approximately 33%.

■ Rigorous business operation

・In accordance with the “Basic Policy on Internal Control”, we maintained and operated the “System for ensuring the appropriateness of operations”, implemented risk management steadily, worked to establish and improve compliance awareness among officers and employees, and operated our business rigorously to maintain sound management. We also worked continuously on securing safety and health, thorough control of information, and appropriate security trade controls.

■ Activities to local communities and in global environment

・We worked on control and reduction of the amount of energy and resources consumed along with our business activities, as well as on providing environmental education to newly hired employees, in an effort to operate our laboratories. In addition, each regional laboratory had opportunities to open to the public to introduce experimental facilities and give lectures by researchers. Further, we helped local governments with education for understanding electricity and energy. ➡ See p.66 [Environmental Activities]

Research laboratories opened to the public

Example of education support activities

We have carried out research on issues that the electric power industry faces, and have also engaged in research that creates new value while assuming social and technological changes going forward, and have produced various kinds of results.

Research was promoted in nine fields ranging from Nuclear power generation to Emerging technologies. See page 16 for the list of research subjects.
Following is an outline of representative research results in each field. In sections starting from page 18, we will introduce in detail research results that should be focused on in particular.

Nuclear Power Generation

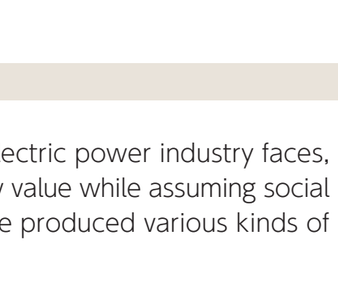
Advancement of the safety of light water reactors

Enhancement of systems and structures to secure safety

- We had probabilistic risk assessments (PRAs) of the domestic plants reviewed by overseas experts, and identified the areas for improvement to enhance the quality of PRAs. In addition, we have compiled data collection methods of component function failures required in PRA and developed a data collection guide after some improvements through trial applications. These results are expected to promote risk informed applications in nuclear facilities.

Establishment of evaluation techniques for low-frequency phenomena

- By steel plate perforation test which assumes tornado missile against to nuclear facilities, we confirmed that the previous evaluation formula can conservatively evaluate perforation resistance performance of steel plate subjected to tornado missile impact.
- To enhance the accuracy of seismic safety evaluations of plant piping, we developed a technology that enables high accuracy fracture evaluation under a mixed mode of bending and torsion, applying the extended finite element method (XFEM), based on results of fracture tests of stainless steel pipes with circumferential crack (figure on the right).
- By incorporating the three-dimensional nonlinear seismic response analysis method into the seismic performance verification process of underground reinforced concrete structures, which assumes emergency water intake facilities, as well as by devising and introducing deformation indices based on loading tests, more realistic and logical seismic performance verification system superior to the old edition has been established and become practical. See p.18



Fracture evaluation of stainless steel pipe with circumferential crack subjected to bending and torsion
(Top) External appearance of the specimen after the fracture test
(Bottom) Comparison between the experimental and the XFEM analysis results (displacement-load diagram)

Advancement of core damage assessment methodology

- To enhance the evaluation of severe accident progression at a spent fuel pool/pit (SFPs), a criticality map was created to evaluate criticality of spent fuel, taking into account complex water density distribution which is formed by boiling of cooling water due to heat generated by the spent fuel stored in the SFP rack and by spray water injection for cooling of the spent fuel.

Establishment of probabilistic risk assessment (PRA) technology

- We developed a probabilistic method to evaluate the amount of tsunami inundation water entering the reactor building through watertight doors as a function of the inundation depth outside the building. We have also developed some element technologies for establishment of a PRA method to evaluate the risk of a nuclear power plant attacked by tsunami. See p.20

Probabilistic Risk Assessment (PRA)
A quantitative evaluation method for identifying vulnerability of a nuclear facility in terms of safety, which systematically analyzes various potential accident scenarios in the facility as comprehensively as possible, and rank them in order of the risks determined by the combination of frequencies and impacts of the scenarios.

Extended finite element method (XFEM)
A structural analysis method that enables crack propagation analysis without subdividing elements near the crack tip during analysis.

Spent fuel pool/pit (SFP)
A water pool for storage of spent fuel at a nuclear power plant. It is called a "spent fuel pool" in a boiling water reactor (BWR) and a "spent fuel pit" in a pressurized water reactor (PWR).

Dose rate
Quantity of ionizing radiation absorbed in a person or substance per unit time.

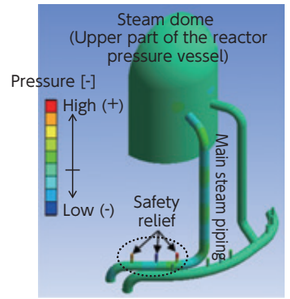
Metal cask
A cylindrical metal container for dry storage of spent fuel. Spent fuel is stored between metal partition plates (basket) installed inside of the cask.

- We have developed a human reliability analysis (HRA) guide that describes methods of identifying and analyzing those conditions such as physical environment or time constraints which affect human behavior, especially plant workers' operations during a severe accidents. The guide also includes specific example of the analysis.
- By arc test using a full-scale power supply facility, we identified the threshold energy of arc beyond which high-energy arc fault (HEAF) fire evolves, and developed a design method for HEAF fire protection, enabling rational implementation of measures to reduce the risk of HEAF fires in the safety power supply. See p.22

Safe and stable operation of light water reactors

Improvement of maintenance techniques for light water reactors

- To evaluate vibration fatigue caused by flow inside piping and components, we constructed a simplified vibration stress evaluation method that combines a simple sound source model for a side branch of steam piping, which is the main excitation source (acoustic source), and acoustic and structural analysis of the piping system (figure on the right).
- Based on thermodynamic calculations, we clarified conditions for chemical decontamination to selectively remove cobalt, a radiation source, but to leave zinc, which has high corrosion resistance, in the oxide film of equipment and piping in nuclear power plants where zinc is injected into coolant for the purpose of reducing exposure to workers.



Pressure distribution evaluated for the main steam piping of a boiling water reactor

Maintenance and expansion of radiation protection systems

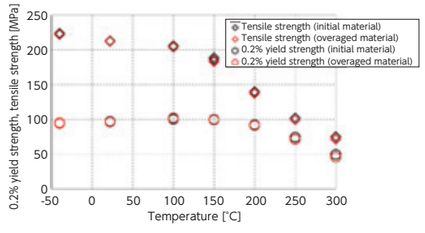
- Effects of dose rate on cardiovascular disease was evaluated by using epidemiological data with annual dose information. It was found the risk of death for the same dose was significantly lower at low dose rates.

Greater advancements in light water reactor technology

- To calculate core power accurately for reactor design, the existing calculation code was modified to enable evaluation of the whole core power distribution at high resolution. We also constructed a method theoretically that can calculate parameters related to the time variation of core power due to the insertion and withdrawal of control rods. See p.24

Establishment of nuclear fuel cycle technology

- Strength tests and measurement of physical properties were conducted on the aluminum alloy that has been developed for the basket installed inside of the metal cask. The results of them indicate that heat treatment equivalent to the service of 60 years does not significantly reduce material strength or alter the microstructure (figure on the right).
- In the event of an accident at a nuclear fuel reprocessing plant, such as a loss of cooling function, a generation of gas containing radioactive ruthenium is presumed consequent to the evaporation and drying of the concentrated high level radioactive liquid waste. We have confirmed experimentally that vaporized ruthenium can be effectively collected by using a specific solid adsorbent.



Comparison of material strength of aluminum alloy before and after heat treatment
Overaged material: A heat treated material at 300℃, for 1000 hours equivalent to storage conditions waiting for reprocessing for the maximum period, which is assumed to be 60 years.

Support for radioactive waste disposal operations

- A groundwater flow is important to evaluate long-term stability of geological disposal. 73 grandwater samples were collected from deep bore hole at coastal area all over the Japan. As a result, over 60% of groundwater samples were older than 20,000 year. It shows that most of groundwater at coastal area is stable for a long time.
- To rationalize the radioactive waste disposal project in compliance with the new regulatory standards, a probabilistic approach and the concept of radiation protection were compiled into the methodology of designing disposal facility by which performance and engineering/economic aspects are rationally balanced. See p.26

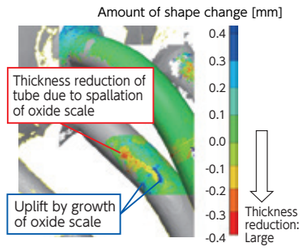
2-1. Outline of Results

Thermal Power Generation

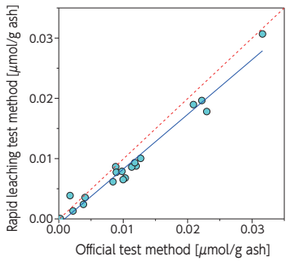
Ensuring reliability of existing thermal power plants

Pulverized coal fired power generation
A method of generating electric power by firing pulverizing coal in a boiler, and rotating a turbine with the generated steam.

- For the reduction of unscheduled shutdowns at pulverized coal fired power plants due to corrosion of heat exchanger tube, etc., the tube thickness reduction analysis method developed by us using a portable three-dimensional shape measuring instrument was applied to actual boilers, and we demonstrated that the thickness reduction of the outside surface of tube such as superheaters and reheaters can be measured (figure on the right). Also, for the prediction of sulfidation rate on the fire side surface of the water wall tube, we incorporated a new model to the numerical modeling of the pulverized coal combustion field owned by us, and made it possible to predict the H_2S concentration near the water wall tube, which is a contributing factor of the sulfidation rate.
- To establish an efficient monitoring method, we constructed a remote monitoring system using a stand-alone temperature sensor that does not require an external power source. We applied it to an actual boiler, and confirmed that the temperature of power generation equipment and combustion equipment can be monitored stably.
- For the rationalization of wall thinning management of the tube in the heat recovery steam generator of gas turbine combined cycle, we developed a method to evaluate the maximum thinning rate of the heating tube by an approximation formula.
- To expand the effective use of coal ash, we have developed a rapid leaching test method that can measure the amount of arsenic, selenium, and hexavalent chromium eluted from the same specimen (figure on the right). By this, the time required for pretreatment and measurement can be reduced to approximately 1/3 of the time required by the official method.



Analysis example of water wall tubes thickness reduction



Comparison example of measured values between the rapid leaching test method and the official test method for coal ash (case of hexavalent chromium)

Thermal technology to mitigate environmental load

Integrated coal gasification combined cycle (IGCC)
A high-efficiency gas turbine combined cycle that uses coal gasification gas as fuel.

- The national government and electric power companies are making efforts for earlier realization of the next generation thermal power technology such as the integrated coal gasification combined cycle (IGCC) that can decrease negative environmental impact. In order to improve generation efficiency, we analyzed thermal efficiency in the case of introducing steam into a commercial-scale IGCC gasifier and cleared the increase of 2% of net thermal efficiency of the IGCC.

Diversification of fossil fuels

- To reduce operating costs in pulverized coal fired thermal power plants, we developed a total management evaluation system that enables comprehensive evaluation of operating costs, taking into account effects of differences in coal types and operating condition on each equipment. ➡ See p.28
- Co-firing tests of pulverized coal and ammonia, which is expected a carbon-free fuel, was conducted using our coal combustion test facility. We found NO_X concentration and combustion efficiency in the case of ammonia co-firing can be at the same level as in the case of coal firing. ➡ See p.30

Response to large-scale introduction of renewable energy

- To support improvement of power supply-demand adjustment capabilities of thermal power generation systems, we proceeded in developing a dynamic characteristic analysis tool that can analyze startup speed and ramp rate in detail. This tool can be applied to not only the gas turbine combined cycle power plant model but also steam turbine system model. Analysis is now possible with various conditions changed, such as specifications and performance of components, output changing speed, and control parameters.

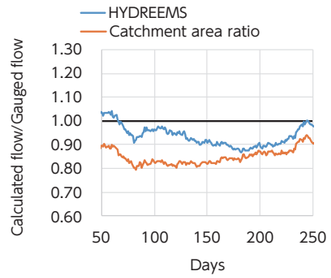
Response to risk of disasters

- To minimize the impact of natural disasters on thermal power plants, we developed a method to estimate the vulnerability of boilers, which are important equipment, with maximum acceleration, maximum speed and seismic intensity as indicators, using damage data from the Great East Japan Earthquake.

Hydropower Generation

Disaster prevention and maintenance and management for hydropower facilities

- We have been organized the seismic performance evaluation methods for hydropower facilities. Applying these methods in the assessment of structural integrity and seismic performance of the aging hydropower facilities, we supported electric power companies in keeping the assessment level and formulating countermeasures based on the results of the assessment. ➡ See p.32
- For the understanding of a river discharge, which is required for hydro-power plant project, we improved the model related to underground flow phenomena as well as the model for accumulated snow/snow melting, both of which are included in HYDREEMS, a water circulation analysis model we developed. As a result, it is now possible to estimate the flow rating curve more accurately than the conventional method estimating by catchment area ratio (figure on the right).

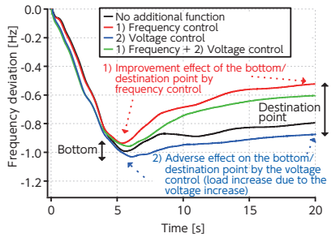


Comparison example of flow estimation accuracy

Renewable Energy

System resilience with high integration of renewable energy sources

- Dynamic model of frequency and voltage control functions, that are already in practical use overseas, are developed. By utilizing these models, system stabilization effect can be verified when these functions are added to a renewable energy power sources such as photovoltaic power generation (figure on the right).
- Regarding the amount of solar radiation on the ground that causes output fluctuation of photovoltaic power generation, we proceeded on developing a statistical method that incorporates estimated/predicted results from satellite images and weather models in addition to the current solar radiation values. As for estimation and prediction methods using satellite images, we worked to make their accuracy even higher. ➡ See p.34



* Power loss: 0 [s], Power loss ratio: 5.2%

Relationship between presence/absence of frequency/voltage control function and frequency stability

Explosion crushed wood pellet
A type of reformed biomass fuel, which is a pressure molded (pelletized) wood after decomposed by instantaneous decompression of the wood held in steam at high temperature and high pressure for a certain period of time. Compared with ordinary wood pellets, they are highly water-repellent and can be stored outdoors.

Sub-bituminous coal
A type of coal that contains lower carbon and higher moisture than bituminous coal that is mainly utilized in coal-fired power plants. The bituminous coal is anxious for short supply caused by increasing demand in the world. Sub-bituminous coal is a promising coal because of its large reserves next to bituminous coal and its relatively high calorific value, but issues exist in terms of quality and handling, etc.

Expanded introduction of biomass and geothermal power generation

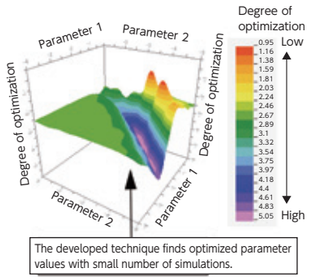
- As a reformed biomass fuel, explosion crushed wood pellets and bagasse (sugarcane pomace) carbonized pellets were selected and evaluated for their applicability to co-firing in coal-fired thermal power plant. We found that it is desirable to take measures in transportation and storage against spontaneous ignition equivalent to sub-bituminous coal.
- To expand introduction of geothermal power generation, we started research on operational improvements for small-scale geothermal power generation, and confirmed that continuous calculation of thermal efficiency based on running data over time is possible by using our thermal efficiency analysis software EnergyWin™ even at small-scale geothermal binary power plants.

2-1. Outline of Results

Electric Power Transmission and Distribution

Response to reforms in electric power system

- With further interconnections of renewable resources and creation of balancing market, requirements to consider wide-area procurement and operation of control reserves is increasing. In this context, we developed a simulation model that can accurately analyze frequency and tie-line power flows of cross-regional interconnected system under normal conditions by modeling the load frequency control (LFC) of the central load dispatching centers and major power plants in Japan. See p.36
- For the control design of ac/dc converters used in wide-area hvdc interconnections and renewable energy generation systems, a numerical technique to optimize parameter values of such control systems by performing multiple electromagnetic transient (EMT) simulations has been developed and implemented in XTAP (figure on the right).
- We have developed functional specifications that provide a common way to apply international standards (IEC 61850) to monitoring and control functions for substations in Japan. The common applications of IEC 61850 are expected to contribute cost reduction of system construction and maintenance. See p.38



Example of control parameter optimization of a power system equipment

Formation, maintenance and upgrades of substations and transmission lines

Advancing preservation technology for aged facilities

- Weather analysis and exposure test results were utilized to estimate the corrosivity such as corrosion rate and amount in each location of transmission towers. We developed an estimation method to judge the quantitative priorities in maintenance planning such as inspection and repair painting. See p.40
- For oil-immersed transformers, we developed a managing assets support program based on life cycle cost evaluation by considering actual condition and maintenance. This program supports evaluations for rational maintenance and cost cutting.

Support to streamline facility design and operate facilities

- To keep appropriate separation between overhead power line and vegetation, we developed a reliable method for evaluating the separation based on numerical survey of the 3D point-cloud made from images taken by low-cost small drones, and also revealed a method for suppressing the tree growth using chemicals with less impact on the environment, enabling us to reduce pruning frequency.
- For the purpose of improving the lightning resistance and earthquake resistance of microwave radio equipment, we constructed a microwave radio equipment in which the path connecting the antenna side and the radio side was changed from metallic waveguide to optical cable communication and optical fiber power feeding, and confirmed its effectiveness through evaluation using a prototype equipment.

Next-generation equipment technology anticipating future facility upgrades

- For SiC power semiconductor device, for which wide expansion of its practical application is expected in AC/DC converters and charge-discharge controllers for storage batteries used in interconnections of renewable energy sources, we demonstrated that significant reduction of dislocation densities, which can affect characteristics and reliability of the device, while establishing a technology to grow SiC bulk crystals stably at high speed for a long duration. See p.42

Response to changes in supply form and demand-side changes

Next-generation power distribution system technology compatible with greater activity in demand region

- We developed a large-scale harmonic analysis method that can calculate both inverters and distribution system together, enabling us to evaluate influence on power quality of harmonics generated by the interaction between the two.

XTAP

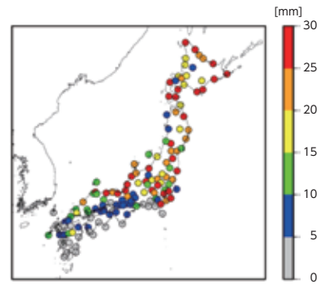
A computer program developed by CRIEPI for the waveform-level or EMT simulations of electrical circuits including power systems. It shows advanced performance especially for the simulations of power systems with power-electronics converters such as PV grid connection interters.

Forming, maintaining and update power distribution facilities

- As the number of wireless communication devices such as smart meters increases, it is required to assess human exposure to radio frequency (RF) electromagnetic field around the devices. In response, we developed a program to calculate specific absorption rate (SAR) in the human body, which is difficult to measure. See p.44

Response to disaster and human risks

- To effectively carry out system operation for supply-demand gap mitigation, strategy planning for equipment restoration, and implementation of proactive measures in the event of an earthquake, we developed a supply-demand balance evaluation method that stochastically models uncertainty regarding equipment damage and recovery and demand recovery based on past damage records. See p.46
- To rationalize design methods of power transmission and distribution facilities in response to the effects of extreme weather, we developed a method for reproducing/predicting strong winds using a numerical weather model, organized a strong wind database for the entire region of Japan, and improved accuracy of a computational fluid dynamics code when applied to areas with large changes in wind conditions. See p.48
- To rationalize the snow-resistant design of power transmission facilities, we improved the method for estimating the design volume of snow accretion on overhead power lines, by including our numerical model that can take a random shedding process into account. This enables us evaluating the temporal variation of snow accretion during several 10 years, and making a hazard map for heavy snow accretion (figure on the right).



Example of trial calculation of design snow accretion thickness for a 50-year return period (the maximum of values for all directions)

- For RAMP, a system for estimating damages on distribution facilities caused by typhoons and earthquakes, we organized facility information database of each electric power companies, and implemented it on a common RAMP platform. This led to active use of the system by each electric power company to restore its facilities when a typhoon hit in fiscal 2018.

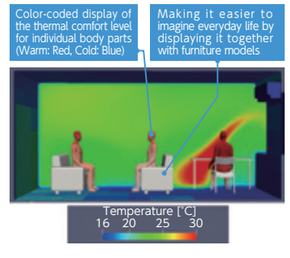
RAMP

A system that obtains real-time weather and earthquake information distributed by the Japan Meteorological Agency and others, and delivers damage information temporally predicted and spatially estimated based on distribution equipment information.

Customer Services

Promotion of energy conservation and electrification

- We conducted a numerical simulation of the cooling and heating cycle of the new heat pump system we devised for residential air conditioning, which uses a heat exchanger coated with an adsorbent, which in turn enables dehumidification without dew formation as well as humidification without water feed, to find out 20% of energy can be saved compared with the conventional air conditioning systems.
- To promote use of residential air conditioners for heating purpose, we developed a heating CFD database tool that allows easy visualization of indoor temperature distribution generated by heating air currents and of the thermal comfort of occupants (figure on the right).



Visualization of thermal comfort of room occupants when the room is heated by an air conditioner

Enhancement of customer satisfaction

- In order to create new services for households, we have built a platform to utilize energy information and life information that can be measured by IoT sensors and devices (OUCHI MONITOR KIT).
- For rationalization of facility formation by power distribution companies and decision making for sales strategy by retailers, we developed a regional power consumption estimation tool that allows them to take into account ratios of residentials and types of businesses. See p.50

OUCHI MONITOR KIT

"House monitoring kit" in Japanese. A sensor kit that can easily measure and collect power consumption, temperature and humidity, carbon dioxide concentration, etc. in a home.

2-1. Outline of Results

IPCC
United Nations Intergovernmental Panel on Climate Change. An organization established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to conduct a comprehensive assessment of human-induced climate change, impacts, adaptation and mitigation measures from scientific, technical and socio-economic perspectives.

CO_2 emmission per kWh generated
Amount of CO_2 emission when 1 kWh of electricity is generated.

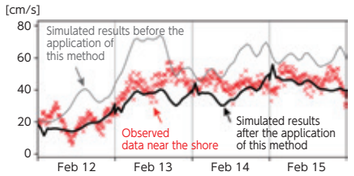
Environment

Response to environmental policy and regulations

- Summarizing issues that electric utilities should consider with regards to long term strategies for global warming countermeasures, using an IPCC scenario data base up to year 2100, we found further necessities to reduce CO_2 emission per kWh generated and to electrify demand side to achieve the 1.5℃ and 2℃ scenarios.
- We succeeded in creating a novel mice model to evaluate the risk of childhood leukemia associated with power frequency magnetic field exposure by implanting a human iPS cell line, which was established in fiscal 2017, into sever immunodeficiency mice.

Efficient environmental assessment

- To reduce cost of environmental impact assessment, which requires a prediction of complicated behavior of exhaust gas as stack of thermal power stations become lower, we developed a three-dimensional computational fluid dynamics model that can replace the conventional wind tunnel experiment, and confirmed that the dispersion of exhaust gas can be reproduced with high accuracy. See p.52
- To efficiently understand the coastal flow field necessary for prediction of warm water diffusion, we developed a numerical simulation method that can estimate velocities of surface layer flow in the vicinity of power stations more accurately by utilizing offshore flow velocity data observed by ocean radar (figure on the right).
- To efficiently understand habitat status of important wildlife at sites subject to environmental assessment, we developed a program that automatically detects and identifies species from audio files recorded without human attendance.



Example of surface flow velocity
Comparison between the simulated results with and without this method and observed near shore velocity data (February 2015).

Utility Management

Response to energy policy

- We demonstrated the non-fossil value trading market will not well function for feed-in tariff (FIT) power sources realistically, resulted in a failure to achieve any reduction in the renewable energy generation promotion charge, which is the objective of creating the new market. See p.54
- Regarding power generation mix assuming Japan's CO_2 emission in 2050 is 80% reduced from 2013, we demonstrated that nuclear power generation capacity of 29 million kW is still required, even if the maximum volume of renewable energy is introduced.
- With regard to personal data, which is attracting increasing attention with the progress of IoT technologies, we demonstrated quantitatively importance of mechanism that allows consumers to select third party data recipients and of clarifying data utilization purposes, in order to encourage consumers to supply their data voluntarily.
See p.56

Emerging Technologies

Overall optimization through supply/demand coordination

- To develop a supply-demand coordination technology utilizing electric vehicles (EV), we evaluated chargeable amount of EVs during demand response activation hours as a countermeasure for surplus of PV power using our traffic simulation. It was found that the chargeable amount of EVs can be effectively utilized significantly increased by discharging to grid before the activation hours start.

Common technology for application in diverse fields

- For rational maintenance and operation of electric power facilities, we worked toward reducing the cost and improving efficiency of energy harvesters which is required for maintenance-free monitoring. As a result, we developed the magnetostrictive vibrational energy harvester using an inexpensive polycrystalline Fe-Ga alloy. Also, we optimized fabrication conditions of the vibrational energy harvester using our original electric double-layer electret technology, and succeeded in generating 1.2 mW/cm^2 from the low frequency environmental vibration of less than 10 Hz which was difficult to generate by conventional technologies, and clarified that the fabricated device can turn on LED light. See p.58

Major New Research Facilities

Supercomputer system (Update)

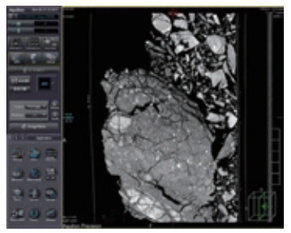
We are conducting in various fields of research large-scale numerical simulations of material sciences, structural mechanics, thermal hydraulics, weather, etc., using supercomputers. For example, we have utilized these to support the restart of nuclear power plants, to evaluate the remaining life of thermal power equipment, and to support disaster countermeasures for power distribution facilities. In fiscal 2018, we upgraded to the latest supercomputer to efficiently analyze larger scale and more complex phenomena. This supercomputer saves power while ensuring a calculation speed approximately three times that of our previous supercomputer. By utilizing the updated supercomputer, we will continue to promote efficient research and create innovative research results.
See p.24, 40, 48, and 52 for research results using the facility.

Supercomputer (HPE SGI8600)
<Specification> 660 CPU nodes, 26,400 CPU cores
Processing speed: 2.02 PFLOPS

Helical X-ray CT scanner

Our activity of geologic fault-activity analysis based on the observation of fault zone by helical x-ray CT scanners have been used in conformity review for the new regularity requirements for the restart of nuclear power plants. In fiscal 2018, we introduced the state-of-the-art facility with the spatial resolution greatly improved. CT images by the facility enable more detailed analysis and evaluation of geologic fault activities, and we will continue contribution to preparation for the review for the restart of nuclear power plants and continuous improvement of safety.

Introduced state-of-the-art facility



CT image of a fault crush zone using this facility

List of Research Subjects

Nuclear power generation

Advancement of the safety of light water reactors

Enhancement of systems and structures to secure safety
- Promotion of Risk Informed Decision Making Process at Nuclear Power Plants

Establishment of evaluation techniques for low-frequency phenomena
- Development of Evaluation Method of Fault Activity for Nuclear Facilities
- Development of Evaluation Method of Earthquake Motions for Nuclear Facilities
- Assessment for the risk and hazard of volcanic eruption on Nuclear Facilities
- Development of Extreme Weather Assessment and Countermeasure Technologies for Nuclear Power Plants
- Development of Tsunami Risk and Impact Assessment Technologies for Nuclear Facilities
- Development of advanced seismic safety assessment technologies for buildings, equipment and pipes of nuclear power plants
- Development of advanced seismic safety assessment technologies for grounds and structures of nuclear power plants

Advancement of core damage assessment methodology
- Development of safety evaluation techniques prior to core damage
- Technology Development for Performance Evaluation of Nuclear Fuel and Reactor Core during Severe Accidents
- Research on Evaluation Technology of Accident Progression and Related Phenomena after Core Damage

Evaluation of impact of major accidents
- Development of evaluation method of radioactive material in environment

Establishment of probabilistic risk assessment (PRA) technology
- Development of risk assessment methodology for nuclear facilities
- Development of internal fire and flooding prevent methodology introducing risk informed evaluation in nuclear facilities

Safe and stable operation of light water reactors

Improvement of maintenance techniques for light water reactors
- Development of evaluation techniques for pipe thinning at light water reactors
- Improvement of preventive maintenance technology for light water reactor components and piping
- Improvement of water chemistry for dose rate reduction
- Improvement of water chemistry management of light water reactors
- Improvement of integrity evaluation method for reactor pressure vessels
- Improvement of integrity evaluation method for core internals, piping and other components
- Development of nondestructive inspection techniques for components and piping in nuclear power plants

Maintenance and expansion of radiation protection systems
- Quantitative evaluation of low-dose radiation risk and reflection to radiation protection systems

Greater advancements in light water reactor technology
- Technology improvement for performance evaluation of nuclear fuel and reactor core

Establishment of nuclear fuel cycle technology
- Development of long-term storage management technologies for spent fuel
- Development of technology to improve safety and stable operations of nuclear fuel reprocessing plants
- Safety assessment for overseas return waste storage
- Securement of options for future nuclear fuel cycle

Support for radioactive waste disposal operations
- Improving the reliability in long term safety assessment of low level nuclear waste disposal
- Development and systematization of long-term safety assessments for geological disposal
- Development of streamlined approach for the implementation of radioactive waste disposal project

Ongoing long-term use of nuclear reactors
- Technology development for metal fuel fast reactors and pyroprocess

Decommissioning nuclear reactor facilities
- Fundamental technology development for decommissioning and dismantling of nuclear facility
- Development of decommissioning, defueling and remediation technologies for severe damaged nuclear site

Thermal power generation

Ensuring reliability of existing thermal power plants
- Development of condition diagnostic and maintenance management technologies of thermal power plants
- Development of on-site diagnostic technique for boiler tube failure in thermal power plant
- Improvement of remaining life assessment, diagnosis and maintenance for boiler and steam turbine components in thermal power plant
- Development of preventing technology for corrosion and corrosion fatigue on feed water and steam system components in thermal power plant
- Development of the hard clinker countermeasure in pulverized coal fired boilers
- Development of preventing technology for sulfide corrosion on boiler tube in thermal power plant
- Development of life assessment technology for high temperature structural components made of high chromium steels in thermal power plants
- Development of maintenance and management technologies for gas turbines
- Development of countermeasures for biofouling and jellyfish invasion at cooling water intake structure of coastal power plant
- Development of performance degradation assessment and enhancement methods for thermal power civil engineering and building RC structures
- Development of technologies for increasing use of coal ash

Thermal technology to mitigate environmental load
- Development of maintenance and improvement technology of environmental facilities for thermal power plants
- Investigation and Evaluation of the influence on trend of the environmental regulation for thermal power station
- Study on technologies to evaluate the structural integrity of components in next-generation fossil-fuel power generation
- Development of technologies to improve operation of IGCC plant and reduce environmental loading
- Feasibility study of triple combined cycle system based on pressure performance of SOFC bench-scale cell
- Development of technologies for expanded use of biomass in thermal power generation

Diversification of fossil fuels
- Diversification Technologies of Fuel Types for Thermal Power Generation

Response to large-scale introduction of renewable energy
- Development of technology to improve load following capability of thermal power systems
- Improvement of flexible operations of coal pulverized thermal power plant and estimation of the value of its flexibility

Response to risk of disasters
- Natural disaster assessment and measures for thermal power plants

Hydropower generation

Disaster prevention and maintenance and management for hydropower facilities
- Development of disaster prevention and maintenance technologies for hydropower facilities

Renewable energy

System resilience with high integration of renewable energy sources
- ▽Development of next generation power distribution network system
- ▽Development of power system technology contributing to transmission system resilience with high integration of renewable energy sources
- ▽Development of supply-demand operation and control technology using energy storage system
- ▽Development of accurate power output estimation and forecast techniques of photovoltaic and wind power generation
- ▽Performance evaluation of stationary energy storage battery systems for stabilizing power grid connected with renewable energy generation
- ▽Ensuring Consistency between Electric System Reform and Energy Policy

Expanded introduction of biomass and geothermal power generation
- Development of innovative technologies for promoting the introduction of geothermal power
- ▽Development of technologies for expanded use of biomass in thermal power generation

Electric power transmission and distribution

Response to reforms in electric power system
- Greater advances in systems to analyze surveys and forecast economic and electric power markets to project demand
- Development of support technology for widening system operation and reinforcing system interconnection
- Development of techniques to maintain supply reliability of power system under Japanese Electricity System Reform
- Development of technologies related to electromagnetic transient simulations of power systems
- Development of technologies to construct power utilities' communication infrastructure utilizing general-purpose communications technology

Formation, maintenance and upgrades of substations and transmission lines

Advancing preservation technology for aged facilities
- Diagnostic technology for overhead transmission facilities
- Diagnostic technology for underground transmission cable system
- Diagnostic technology for substation equipment

Support to streamline facility design and operate facilities
- A study on rationalization of insulation design of the power apparatus and systems based on the lightning risk management
- Solutions for electromagnetic compatibility and electromagnetic interference (EMC/EMI) caused by HV substations and transmission lines
- Development and estimation of countermeasure technology for fault currents to secure public safety
- Expansion of economical cleaning process for low level PCB-contaminated equipment
- Development of countermeasures against wildlife causing trouble in electric transmission facilities
- Development of maintenance and replacement technologies of communication systems used for power system monitoring, protection and control

Next-generation equipment technology anticipating future facility upgrades
- Evaluation techniques for power semiconductors
- Development of high efficient electric power distribution facilities for next generation

Response to changes in supply form and demand-side changes

System resilience with high integration of renewable energy sources
- Development of next generation power distribution network system
- Development of power system technology contributing to transmission system resilience with high integration of renewable energy sources
- Development of supply-demand operation and control technology using energy storage system
- Development of accurate power output estimation and forecast techniques of photovoltaic and wind power generation
- Performance evaluation of stationary energy storage battery systems for stabilizing power grid connected with renewable energy generation

Next-generation power distribution system technology compatible with greater activity in demand region
- Power quality preservation and enhancement for distribution systems with advanced customer devices

Forming, maintaining and update power distribution facilities
- Development of evaluation technology on lightning risk management and fault current countermeasures for distribution systems
- Diagnostic technology for power distribution equipment

Response to disaster and human risks
- Evaluation of and countermeasures against earthquake damage to distribution facilities
- Development of extreme weather forecasting and hazard evaluation methods for distribution facilities
- Evaluation of and countermeasures against damages meteorologically caused to distribution facilities
- Application of disaster mitigation and restoration support technologies for electric power distribution equipments
- Development of cyber attack corresponding technology for power equipment monitoring and control system

Customer services

Promotion of energy conservation and electrification
- Development and evaluation of advanced heat pumps
- Development of energy-saving and electrification technology in consumer and industrial sectors
- Research and development for electrification promotion of the transportation sectors

Enhancement of customer satisfaction
- Development of Customer Satisfaction Measures utilizing Energy Related Information
- Assessment of the value of next-generation electricity demand management
- Power Retail Business Strategies and Issues in the Post FIT Era

Environment

Response to environmental policy and regulations
- Research on domestic and international climate change policies
- Scientifically and economically rational scenarios to reduce CO_2 emissions
- Health Risk Analysis of Electromagnetic Fields and Other Environmental Factors
- Analysis of environmental expenditures and source apportionment of pollutants associated with air quality regulations

Efficient environmental assessment
- Development of advanced and efficient impact assessment methods for atmospheric environment
- Development of advanced and efficient impact assessment methods for coastal environment
- Improved efficiency of assessment of impact on plants, animals and ecosystems and development of new evaluation methods

Utility management

Response to energy policy
- Ensuring Consistency between Electric System Reform and Energy Policy
- Analysis for economic impact and political, regulatory and legal risk of nuclear power in Japan
- New Value Creation in the Changing Power Industry
- Structural analysis of energy and electricity demand

Emerging technologies

Overall optimization through supply/demand coordination
- Optimization of advanced power supply and demand management

Trend of develop technology in an overall electric power industry
- Analysis of global trends of technology development under changing business environment in electric power industry

Common technology for application in diverse fields
- Development of advanced sensing technology for power plant components
- Development of high precision and high reliability analysis evaluation technique
- Trend survey of technology utilizing hydrogen
- R&D of Next Generation Electric Energy Storage Technologies
- Development of IoT solutions for Value Added Energy
- Construction of Futuristic Technical-Platform for Mechanics of Materials

● : Major categories grouping research subjects related to each field
■ : Sub-categories grouping research subjects related to major categories
• : Names of research subjects
▽ : Research subjects promoted in research issues in other fields (listed multiple times)

Nuclear Power Generation

Enhancement of seismic performance verification on reinforeced concrete underground structures in nuclear power plants

Support for responding conformity review of the new regulatory standards for nuclear power plants

Background

Nuclear power stations are required to maintain functions such as water intake from sea in order to cool their reactors safely even in the event of a major earthquake. The new regulatory standards, which were established after the accident at the Fukushima Daiichi Nuclear Power Station, set stricter reference earthquake ground motion. For this reason, a more accurate and reliable standardized review method is required for the earthquake resistance evaluation of reinforced concrete underground structures such as water intakes and intake channels. We are promoting research to enhance the accuracy of seismic performance verifcation method.

Reference earthquake ground motion
The maximum intensity of seismic motion that can occur in the vicinity of a facility during the plant operation and is used as a basis for seismic design and safety evaluation of a power plant.

Outline of Results

◇ Development of a realistic safety evaluation method by introducing a three-dimensional nonlinear seismic response analysis

We introduced a three-dimensional nonlinear seismic response analysis with soil-structure interaction for the analysis of deformation and cracks of underground structures that are assumed to be caused by an earthquake, and conducted a simulation analysis. Through validity evaluation by comparing the analysis result and a result of a shear-soil-box vibration test, we demonstrated that the method enables more realistic seismic response evaluation than the conventional two-dimensional analysis (Fig. 1).

◇ A deformation criteria that enables rational performance verification

Deformation criteria
Deformation point and its amount to be focused in order to objectively understand seismic performance.

Evaluation criteria used in conventional seismic design and performance verification of critical civil engineering structures were based on seismic response analysis of two-dimensional models and their accuracy was conservative. Therefore, loading tests were carried out on reinforced concrete specimens with three typical shapes of structures (straight, bent and butt-up sections) to obtain data on displacement and strain during the course of progressive damage. Based on these data, we proposed a reasonable deformation criteria that is not affected by local damage or size/shape.

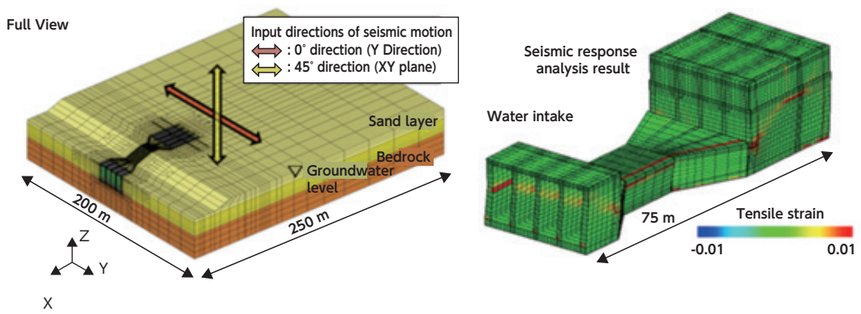
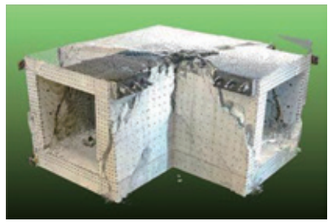


Fig. 1 Example of three-dimensional nonlinear seismic response analysis of underground structure

Vibration exciter The facility is to apply loads and displacements simulating earthquakes to structures, enabling evaluation of loading capacity.



Reinforced concrete structure used in the loading test

Seismic performance verification guideline revised in FY2018

Application Examples of Research Results

These results were incorporated into the “Seismic performance verification guidelines, manuals, and examples for RC underground structures in nuclear power plants” (Revised October 2018) published by the Japan Society of Civil Engineers. This method can be applicable not only to critical civil engineering structures in nuclear power plants but also to seismic safety evaluation of wide range of general reinforced concrete underground structures.

References: Matsuo et al., Japan Society of Civil Engineering 73 Annual Scientific Lecture I-330 (2018)
Miyagawa et al., Japan Society of Civil Engineering 72 Annual Scientific Lecture Meeting VII-015 (2017)

Nuclear Power Generation

Development of element technologies for tsunami probabilistic risk assessment

Contributing to the voluntary and continuous improvement of safety of the nuclear power plants

Probabilistic Risk Assessment (PRA)
→ See p.8

Background

The new regulatory standards established after the accident at the Fukushima Daiichi Nuclear Power Station require the measures against severe accidents and continuous safety improvement based on their effect. In the review of compliance with the new regulatory standards for restart of the nuclear power plants, the electric utilities use probabilistic risk assessment to identify the significant accident scenarios to be prepared for. On the other hand, we are developing PRA technologies for the electric utilities to continuously improve safety. PRA is conducted postulating internal events such as equipment failures, human errors, fires and flooding, as well as external events such as earthquakes, tsunamis and tornadoes. PRA assesses the risk of reactor core damage due to these events (level 1 PRA) and, furthermore, radioactive material release due to reactor containment failure (level 2 PRA). However, some of the related element technologies are under development. With the cooperation of the electric utilities, we are working on the development of technical infrastructure for level 1 and 2 integrated tsunami PRA.

Outline of Results

◇ Development of evaluation method for water leakage through a watertight door

In the process of developing technologies for tsunami PRA, the displacement amount of watertight doors on building wall due to water pressure caused by tsunamis was estimated by finite element analysis (Fig. 1). Based on the result, we developed a method to evaluate probability that the water amount entering the building through the watertight door (water leakage) exceeds specific amount according to the inundation depth (Fig. 2).

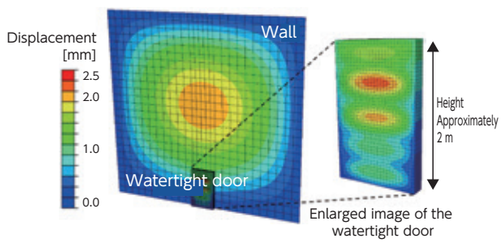


Fig. 1 Displacement of the wall and watertight door due to tsunami

In addition to the displacement amount of the wall and watertight door, we considered deformation of the door seal material for watertight. Both situations in which the deformed seal is functioning, and in which the seal is crushed and not functioning are considered in evaluation.

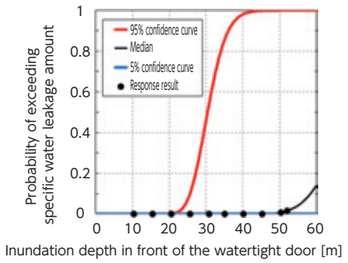


Fig. 2 Fragility curve related water leakage rate

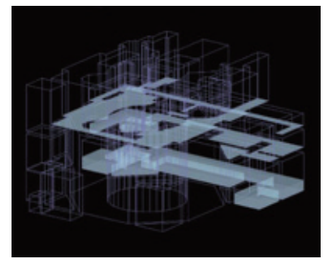
The result shows that there is little possibility (probability) of water leakage exceeding the specified level. The median and the 95% confidence curves specifically indicate little water leakage at inundation depth of 50 m and 20 m respectively.

◇ Development of human reliability analysis method considering influence of tsunami inundation

We have developed a human reliability analysis method for operator behavior at the nuclear power plants affected by tsunami inundation. Particularly, we have developed a specific and rational method to estimate the human error probabilities of operating outdoor mobile equipment and closing the watertight door-to prevent inundation flooding into the buildings.

Evaluation example of inundation in the building

It is possible to evaluate the time change of inundation. The right figure shows a snapshot of inundation in buildings. The area inside the building is drawn with the thin lines. The inundated area is displayed in white.



Application Examples of Research Results

The results are expected to be utilized by electric utilities as a shared technology to identify plant vulnerabilities and improve plant safety, and to contribute to the continuous safety improvement of the plants.

References: Kirimoto et al., CRIEPI Research Report O18011 (2019)
FY2018 Report on results of technology development commissioned work for developing common infrastructure contributing to improvement of nuclear safety (Agency for Natural Resources and Energy) "Development of infrastructure for risk assessment and research at nuclear power plants" (2019)

Nuclear Power Generation

Development of a fire protection design method for high-energy arc faults

Contributing to improvement of nuclear power plant safety through rational fire prevention measures for safety power supply equipment

Background

When arc discharge occurs (High Energy Arcing Fault: HEAF) due to short-circuit, etc., of electrical equipment, heated air may blow out of the electrical cabinet or blow into an adjacent electrical cabinet, resulting in not only damage to adjacent equipment but fire (HEAF fire). If a HEAF fire occurs at a nuclear power plant, it will greatly affect safety of surrounding equipment. Therefore, measures assuming a HEAF fire are required for safety power supply equipment such as electrical cabinets. We are developing rational preventive measures for HEAF fire by conducting full-scale demonstration tests, etc.

Arc discharge
A type of discharge phenomenon that occurs in gas between two electrodes. It occurs at low voltage and high current, with high temperature and intense light.

Outline of Results

◇ Understanding of conditions leading to HEAF fire

Using our high-power test facility, we conducted tests to generate arc discharge inside an electric panel on a full-scale 6.9 kV class high voltage electrical cabinet and 480 V class low voltage electrical cabinet. We made clear from the test results that the conditions leading to the HEAF fire are dependent on released amount of arc energy during the arc discharge (Fig. 1), and the threshold varies depending on the type of electrical cabinet.

Arc energy amount
Energy amount in an arc discharge. It depends on the arc voltage and current, and the duration of the arc discharge.

◇ Proposal of HEAF fire prevention evaluation method

We determined an equation for estimating the arc discharge duration that does not lead to a fire from the threshold of the arc energy amount , the arc voltage which is determined by the facility configuration and the short circuit current when an arc occurs. Proper shut-off settings for electrical equipment, etc., based on this formula enables prevention of HEAF fire.

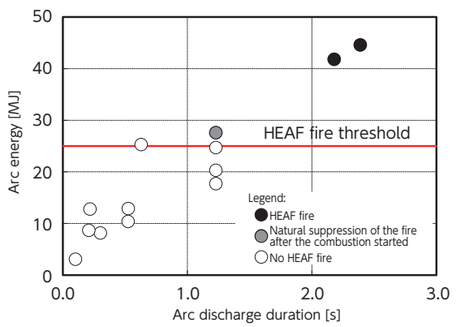


Fig. 1 Test result of HEAF fire by internal arc tests of a high voltage electrical cabinet

Tests were conducted using various electrical cabinets with different arc durations to check for HEAF fire. From the results, we determined the threshold value of arc energy of HEAF fire.

Koji SHIRAI
Risk Assessment Research Team,
Nuclear Risk Research Center

Tsukasa MIYAGI
Large Current and Arc Phenomenon Sector,
Electric Power Engineering Research Laboratory

Cone-calorimeter experimental facility
This equipment measures combustion characteristics of materials, such as ignitability, heat release rate, and heat generation during combustion. We measured the combustion characteristics of resin inside the electrical cabinet, which was the fire source in the HEAF fire.

Internal arc test
We understood conditions leading to the HEAF fire by generating arc discharge inside an electrical cabinet.

Application Examples of Research Results

Based on the HEAF fire prevention evaluation method we proposed, appropriate fire protection measures are being implemented for electrical cabinets in power plants.

References: Shirai et al., CRIEPI Research Report, O18003 (2019)
Miyagi et al., CRIEPI Research Report, O18002 (2018)
Shirai et al., CRIEPI Research Report, O16001 (2017)

Development of a highly accurate calculation method for core power characteristics of nuclear reactors

Contributing to safer reactor design

Nuclear Power Generation

Design code
A calculation program used to evaluate shut down margin, fuel temperature, and whether a reactor can be operated for a planned period. Generally applied to analytical derivation of technical data necessary for the license application of nuclear facilities in accordance with laws and regulations.

Continuous energy Monte Carlo method (MC method)
A calculation method for reactions between neutrons and nuclei, which occur stochastically, by using simulation technique (Monte Carlo method) with a random number.

Burnup
Thermal energy release per unit fuel weight generated by fission reactions while the fuel stays in the reactor.

Background

A design code is used to evaluate reactor properties at the time of refueling or introduction of new type fuels. When the latest knowledge is reflected in the design code, verification, for which it is compared with high fidelity calculation of core power distribution, etc., is required. Since the continuous energy Monte Carlo method (MC method), which has been regarded a high fidelity calculation method for this purpose, requires a great deal of calculation costs, it is essential to devise methods for calculations such as power distribution in a whole reactor core and composition of spent fuel. In addition, conventional the MC method was unable to calculate the reactor kinetics parameters that characterize the time variation of core power. To contribute to the verification of design codes, we are developing and expanding a calculation method for core characteristics using the MC method.

Outline of Results

◇ Resolution enhancement of power distribution for the whole core

We evaluated power distribution in the whole core three dimensionally in high resolution by extending the existing domestic MC code into a 64 bit version program, which enables large-scale computation, such as dividing each fuel rod in the whole core into fine meshes vertically (Fig. 1).

◇ Calculation of burnup distribution of spent fuel

Considering inflow and outflow of neutrons between fuel assemblies by the MC method, calculation of nuclide compositions such as uranium and plutonium that reflect the variation in burnup of adjacent fuel assemblies is enabled (Fig. 2).

◇ Development of calculation method for reactor kinetics parameters

We built up a theory and calculation methods of reactor kinetics parameters, which characterizes time variation of core power due to insertion and withdrawal of control rods into the core, and implement the method into a MC method code and, in addition, we conducted verification and validation jointly with the French Alternative Energies and Atomic Energy Commission (CEA). This method has been implemented into the MC code in France, the United States, China, and other countries, and has become a global standard.

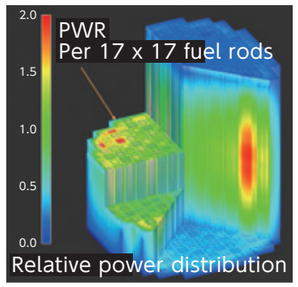


Fig. 1 Calculation example of power distribution for the whole core

Assuming a core of a pressurized water reactor (PWR), we divided more than 50,000 fuel rods into 24 regions vertically and calculated the power distribution with high resolution.

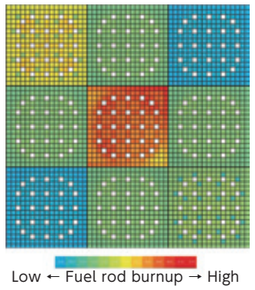
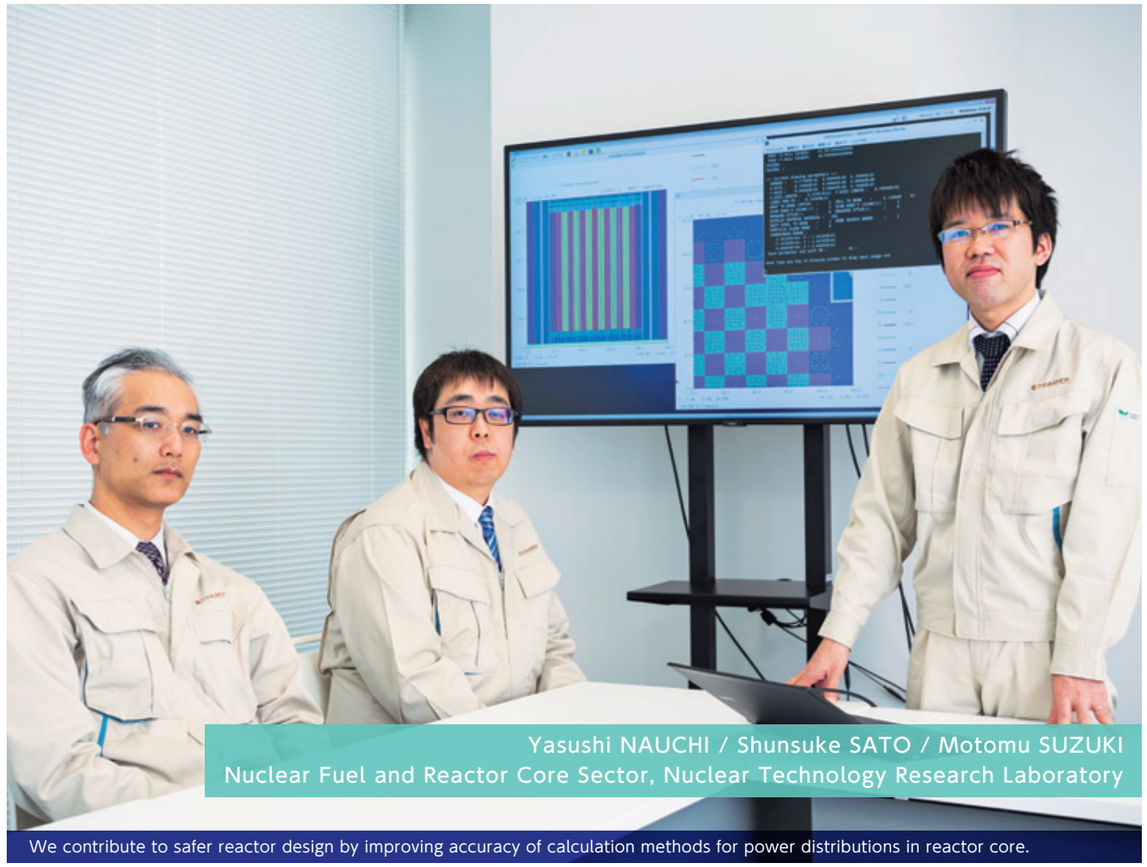
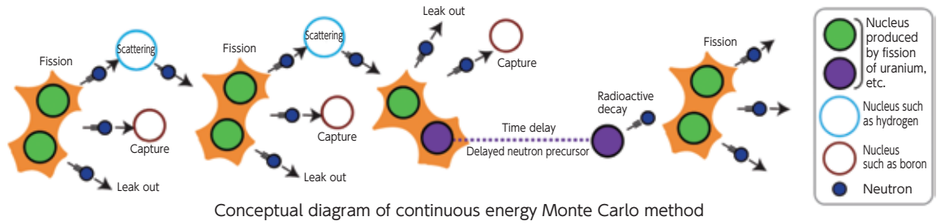


Fig. 2 Calculation example of burnup distribution of spent fuel

Asymmetric burnup distribution influenced by surrounding fuel assemblies with different burnups can be calculated for PWR fuel assemblies (17 x 17 fuel rods).



We contribute to safer reactor design by improving accuracy of calculation methods for power distributions in reactor core.



Conceptual diagram of continuous energy Monte Carlo method

Tracks reaction between neutrons and nuclei one by one in a stochastic manner, and calculates spatial distribution of fission in a reactor and time variation of fission chain reactions.

Application Examples of Research Results

Calculation results based on these results will be provided as reference solutions for verification of reactor design codes, and the calculation and the results are expected to contribute to safer reactor design by encouraging introduction of the latest knowledge into the design codes.

References: Sato et al., CRIEPI Research Report L18001 (2019)
Nauchi et al., Proc. of PHYSOR2018 (2018)
Suzuki et al., Proc. of M&C2017 (2017)

2-2. Major Research Results-5

Nuclear Power Generation

Development of a method to support the optimal design of radioactive waste disposal facilities

Contributing to implementation of disposal projects in compliance with the new regulatory standards

Background

When regulatory standards concerning the intermediate depth disposal of some low-level radioactive waste is revised, the concept of "keep as low as reasonably achievable, taking into account social and economic factors (ALARA)" is determined to be applied to radiation exposure. This implies a shift from compliance with conventional deterministic dose standards to an approach that represents optimization of radiation protection. To support reasonable designing of disposal facilities in line with this new concept, we are developing a safety assessment method based on the concept of optimization of radiation protection.

Intermediate depth disposal
A method of disposing low-level radioactive waste with relatively high radioactivity at a depth with enough margin compared with the depth for general underground use. Securing a depth of 70 m or more is required for at least 100,000 years in the future even at the presence of erosion.

ALARA
An abbreviation for "As Low As Reasonably Achievable", which indicates the basic concept of radiation protection provided by the International Commission on Radiological Protection (ICRP).

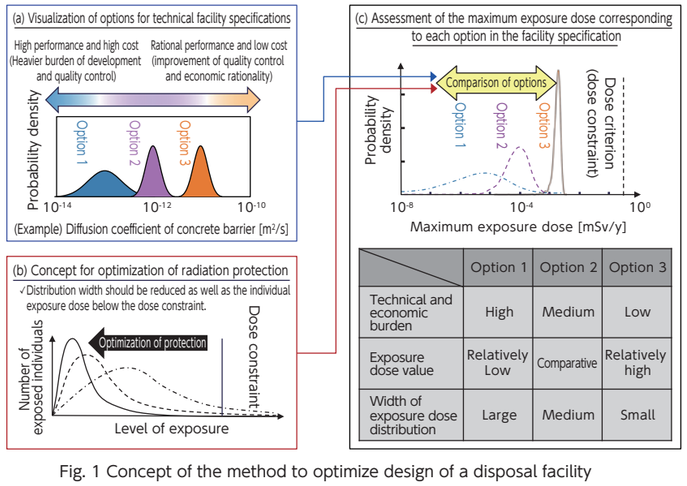
Outline of Results

◇ Application of a probabilistic approach to the design of a disposal facility

By applying a probabilistic approach to a technical specification design of a disposal facility, we developed a method to visualize and compare options of facility specifications from viewpoints of disposal facility performance as well as load of quality control and economic burden (Fig. 1 (a)).

◇ Proposal of a selection method for design of a disposal facility

In the optimization of radiation protection, it is desirable that the individual exposure dose is kept as low as reasonably achievable below the dose criterion (dose constraint), and that the distribution width is narrow and the individual difference (inequity) is small (Fig. 1 (b)). Combining the technical/economic impact of the facility specifications mentioned above and the optimization of radiation protection, we developed a method that enables selection of a reasonable facility design that achieves ALARA (Fig. 1 (c)).



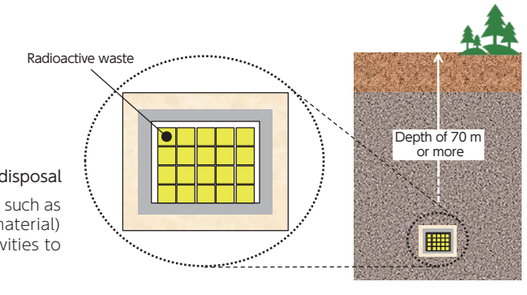
	Option 1	Option 2	Option 3
Technical and economic burden	High	Medium	Low
Exposure dose value	Relatively Low	Comparative	Relatively high
Width of exposure dose distribution	Large	Medium	Small

Fig. 1 Concept of the method to optimize design of a disposal facility

In a disposal projects, several alternative options can be assessed for barriers to isolate radioactive waste from the surrounding environment in terms of its performance, technical experiences in development and quality control, and economic burden. To achieve ALARA, the optimal option shall be selected by making quantitative evaluation of balance between magnitude (barrier performance) and distribution width (quality control, etc.) of the maximum exposure dose assessed.

Daisuke SUGIYAMA / Ryo NAKABAYASHI
Radiation Safety Research Center, Nuclear Technology Research Laboratory

By developing safety assessment methods based on the concept for optimization of radiation protection, we support design optimization of radioactive waste disposal facilities.



Concept of intermediate depth disposal

Disposal facilities using materials such as concrete and bentonite (clay material) are installed in underground cavities to dispose waste.

Application Examples of Research Results

Safety assessment methods developed in this study are being organized as an academic technological methodology through publication of academic papers. It is also being incorporated into the standards of the Japan Atomic Energy Society and is expected to be used as a guideline for regulatory compliance when applications for disposal projects are submitted.

References: Nakabayashi et al., Japanese Journal of the Atomic Energy Society of Japan, Vol. 8, p. 6 (2019)
Ogino et al., Japanese Journal of Health Physics, in press (2019)
Nakabayashi et al., Journal of Nuclear Science and Technology, Vol. 55, p. 335 (2018)

Thermal Power Generation

Development of total management evaluation system for pulverized coal fired power plant contributing to cost reduction

Contributing to diversification of coal types and reduction of operating costs in pulverized coal fired power plants

Pulverized coal fired power generation
→ See p.10

Sub-bituminous coal
→ See p.11

Background

In pulverized coal fired power plants, not only cost reduction but also securing a stable fuel supply are important for power generation. From the view point of cost reduction of fuel, demand for sub-bituminous coal increases. However, as the type of coal and its operating condition influence boiler efficiency, ash disposal cost, and other factors, low-grade coal may not lead to cost reduction. We investigate to contribute to total cost reduction through optimization of operating condition for each type of coal in a pulverized coal fired power plant.

Outline of Results

◇ Development of total management evaluation system for pulverized coal fired power plant

We developed a total management evaluation system for pulverized coal fired power plant, which calculates cost benefits, CO_2 emissions, as well as boiler efficiency and gas temperature and other factors directly, by forecasting situations for each piece of equipment that are caused by types of coal fired in thermal power plants and its operating condition (Fig. 1). This system is software that runs on an usual PC, etc., with the Microsoft® Office Excel® and is designed to allow addition and improvement of evaluation items and functions as required individual specifications of a power plant. Using this system, analysis of each operating case in a pulverized coal fired power plant for each type of coal enables to establish the operation guideline for total cost reduction, and helps in understanding equipment status by comparing estimated values with actual operation data.

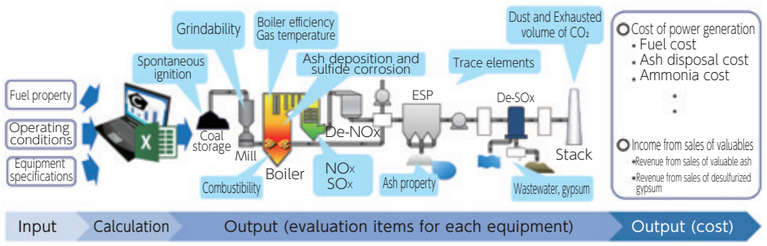
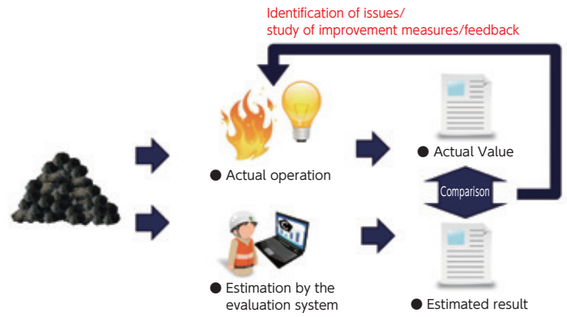


Fig. 1 Image of evaluation system for coal fired power plant management

It can calculate efficiency, power on each equipment and emission characteristics such as NO_x, which depend on fuel properties, operating conditions, equipment specifications, and a type of coal in pulverized coal fired power plants, and it can also calculate related cost items.

Nobuyuki WAKABAYASHI
Thermal Power Plant Operation and Maintenance Sector, Energy Engineering Research Laboratory

Coal combustion test facility
It has a mill, furnace with three staged burners, flue gas treatment equipment, etc., and evaluates various type of solid fuels in the same grinding, combustion and gas flow process as actual pulverized coal fired power plants



Application image of this evaluation system

Application Examples of Research Results

The total management evaluation system for pulverized coal fired power plant can be used as an effective tool to evaluate applicability and optimum (economical) operation for low-grade coal in pulverized coal fired power plants. The next step is to contribute to cost reduction by applying this technology to actual power plants.

References: Wakabayashi, et al., CRIEPI Research Report M15007 (2016)

Thermal Power Generation

Development of ammonia co-firing technology applicable to pulverized coal fired boilers

Contributing to reducing CO_2 emissions by using carbon-free fuels

Background

To realize a low-carbon society that significantly reduces CO_2 emissions, it is desirable to establish a system that converts renewable energy into hydrogen or hydrogen-containing chemical substances (energy carrier) and return them to energy appropriately as required. Ammonia (NH_3), one of the energy carriers, has high expectations as a carbon-free fuel because of its advantage for storage and transportation properties. As a means of using ammonia as fuel, a co-firing method by which ammonia is used as part of fuel at an existing pulverized coal fired power plant is studied. In order to apply ammonia co-firing method to existing pulverized coal fired power plants, we clarify characteristics of NO_x emission caused by nitrogen in ammonia and develop technologies to reduce NO_x emissions*.

* This research was conducted with financial support from the Japan Science and Technology Agency (JST).

Outline of Results

◇ Impact of ammonia injection on pulverized coal combustion

We evaluated co-firing characteristics using a coal combustion test furnace, in which ammonia was injected through three staged burners equally using a coal combustion test furnace (Fig. 1). We identified that NO_x concentration at the exit of furnace tends to increase slightly with the increase of co-firing ratio of ammonia, but the conversion ratio of nitrogen content in ammonia to NO_x is extremely low (Fig. 2). Furthermore, we found that there was almost no unburned ammonia even in case of co-firing with 20% ammonia, and that the combustion efficiency of combustible matter was same as that in case of coal combustion without an ammonia injection (Fig. 3).

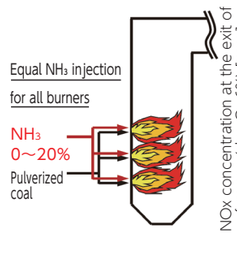


Fig. 1 Injection method of ammonia into furnace with three staged burners

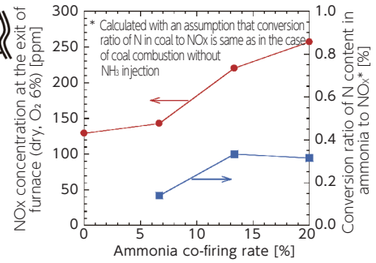


Fig. 2 Influence of ammonia co-firing rate on NO_x concentration and NO_x conversion ratio

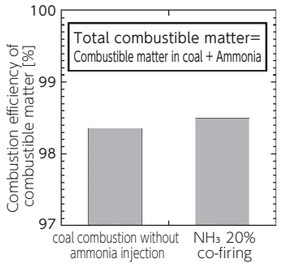


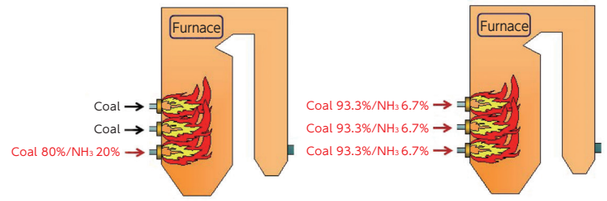
Fig. 3 Influence of ammonia injection on Combustion efficiency

◇ Impact on combustion characteristics by changing ammonia injection methods

We clarified that NO_x emission can be reduced further by concentrating ammonia to the lower burner instead of injecting equally to the three burners, when co-firing ratio to the furnace is the same. As far as the co-firing ratio is low, co-firing ammonia at an existing pulverized coal fired power plant can be achieved by simple modification of only adding ammonia injection nozzle to the burner.

Akira YAMAMOTO
Thermal Power Plant Operation and Maintenance Sector,
Energy Engineering Research Laboratory

Coal combustion test facility
The coal combustion test furnace with single burner mainly used for preliminary study of influence of three staged burners. We are investigating and developing ammonia co-firing technology using two coal combustion test facilities.



Concentrating NH_3 to one lower burner NH_3 injection to all burners equally

Ammonia injection method into a furnace with three staged burners

Application Examples of Research Results

Ammonia co-firing technology is one of the promising technologies to significantly reduce CO_2 emissions and realize low-carbon society. We will continue to contribute to realization of a low-carbon society through development of related technologies.

References: Report on the Completion of the Strategic Innovation Program "Energy carrier", Japan Science and Technology Agency
"Examination of ammonia utilization in existing thermal power plants" (2019)

Hydropower Generation

Systematization of methods for evaluating soundness and seismic resistance of hydraulic facilities

● Support for independent safety measures for hydropower facilities

Background

To cope with natural disasters and aging of facilities, there is an increasing need for maintenance and management of hydropower facilities, as well as for assessment of their integrities and seismic performance, as part of independent safety measures by electric utilities. In addition, the national government and other entities are requesting confirmation of safety of dams in the event of a large-scale earthquake, assessment of risk of public disasters resulting from damage to hydropower facilities caused by natural disasters, and implementation of countermeasures. Each technical method for maintenance, evaluation of integrity and evaluation of seismic performance is generally established. To further improve reliability of evaluation results, we are organizing these evaluation methods.

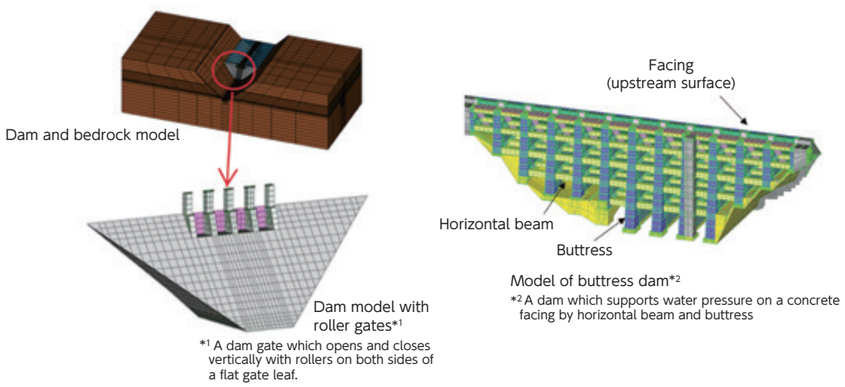
Outline of Results

◇ Technical support for evaluation of structural integrity and seismic performance

Using technologies we systemized, we technically supported the electric power companies in about 50 waterpower facilities. The representative supports are as follows; verifying field measurement results of gravity concrete dams and dam gates, evaluating seismic performance using finite element analysis and formulating countermeasures after the evaluation, and inspecting and formulating disaster prevention measures for water tanks and penstock pipes which are close to residential areas and railways.

◇ Identification of potential problems and support for efficient resolution

Based on our experience in providing technical support for many hydropower facilities, we identified potential problems, which would occur commonly in each facility, e.g., water leakage problem due to damage near boundary of bedrock and concrete of an arch dam. And we proposed efficient solutions for such problems.



Example of a 3D finite element analysis model used in seismic evaluation

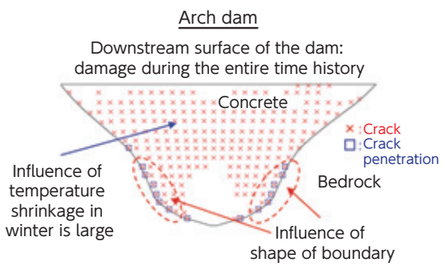
Gravity concrete dam
A type of dam that resists external forces such as water pressure by the gravity of the dam itself.

Dam gate
A facility installed in overflow area of a dam to adjust flow rate by its opening and closing.

Arch dam
A dam sticking out upstream in an arch shape

Tatsuo NISHIUCHI / Yuzo SHIOGAMA
Structural Engineering Sector,
Civil Engineering Research Laboratory

For the more reliable evaluation of structural integrity and seismic performance of the hydropower facilities, we are systematizing the evaluation methods.



Analysis example of seismic damage of an arch dam under a winter temperature condition. It was assumed that water leakage may occur near the boundary between bedrock and concrete due to temperature shrinkage and the effect of the shape of the dam body.

Application Examples of Research Results

We are providing structural integrity evaluation methods of water facilities against aging and large-scale earthquakes and technically supporting the evaluation of existing facilities by applying the provided methods. Through these actions, we are contributing to reducing risk of public disasters around waterpower facilities caused by large-scale earthquakes and other natural disasters.

References: Nishiuchi, CRIEPI Reseach Report N18001 (2018)
Nishiuchi, CRIEPI Reseach Report N15009 (2016)

2-2. Major Research Results-9

Renewable Energy

Development of high-accuracy solar radiation estimation and prediction system using satellite images

Support for appropriate supply and demand operations by improving accuracy of solar power output forecasts

Background

In recent years, introduction of photovoltaic power generation has been rapidly expanding, and measures for their interconnection with the electric power system are required based on this situation. In particular, when power output of renewable energy, including photovoltaic power generation, exceeds power demand, such as during a period of low power demand, balance between demand and supply is expected to collapse, appropriate power supply operations will be required with accurate understanding/forecasting of fluctuations of photovoltaic power generation output. As solar power output is affected most by the amount of solar irradiances, we are working on development of methods to estimate current amount of solar irradiances and to forecast it several hours in advance by using meteorological satellite images.

Outline of Results

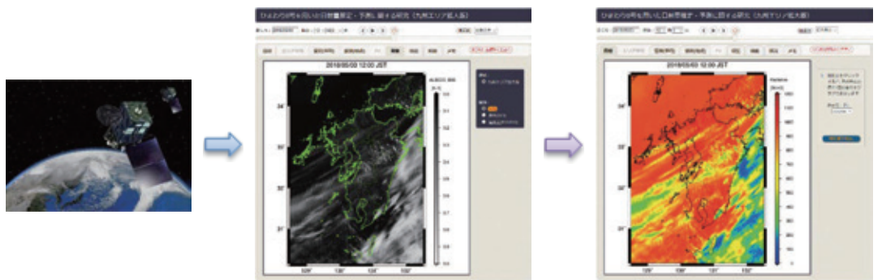
◇ Development of a solar irradiance estimation method

We developed a method to the estimate current amount of solar irradiances using satellite image data of HIMAWARI-8, which can take high resolution data of 0.5 km at a short interval of 2.5 minutes over Japan area. This method enables estimation with high calculate accuracies by updating correction parameters, which are required for making estimations of solar irradiances from satellite images, automatically by using past satellite images of the target region and solar irradiance observation data from JMA observation sites.*

*Solar irradiance data from meteorological observation site: Meteorological surface observation data from meteorological offices and special local meteorological stations of the Japan Meteorological Agency (JMA).

◇ Development of a solar irradiance forecasting method

To predict the amount of solar irradiances for several hours ahead, a method of calculating the cloud motion vectors by comparing past and present satellite images was developed. To improve prediction accuracies, considering the rapidly temperature changes from morning to noon, and improving the method of advection when a clear sky area moves from sea to land. Using this method, we evaluated the calculate accuracies about solar irradiance between forecasting and observation data over the Kyushu district, and confirmed that this method has practical accuracies.



Images for estimating and forecasting solar irradiances from meteorological satellite images

(Left: HIMAWARI-8 (image courtesy of Japan Meteorological Agency), Center: Meteorological satellite image, Right: Estimated distribution of solar irradiances based on meteorological satellite images)

HIMAWARI-8

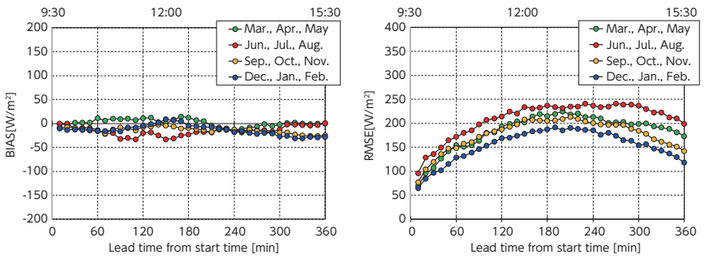
A geostationary meteorological satellite operated by the Japan Meteorological Agency since July 2015. Compared with its predecessor, HIMAWARI-7, it has a larger number of sensors and enables observation of data in a short timeframe with high resolution.

Atsushi HASHIMOTO
Fluid Science Sector, Civil Engineering Research Laboratory

To enable expansion of the introduction of photovoltaic power generation, we are working on development of a high-accuracy solar irradiance estimation and prediction system.

Mean error (BIAS) and Root-Mean-Square Error (RMSE) between solar irradiance forecasting and observation data starting at 9:30

The figures indicate seasonal mean errors for spring (Mar. to May), summer (Jun. to Aug.), fall (Sep. to Nov.) and winter (Dec. to Feb.) in 2017. And, these errors are calculated based on eight observation sites (Fukuoka, Saga, Nagasaki, Kumamoto, Kagoshima, Miyazaki, Oita, Shimonoseki) in the calculation domain for Kyushu district. Since the mean error is low enough compared with the measured value of solar irradiances at noon in Dec. (about 600 W/m^2) and at noon in Jun. (about 1,000 W/m^2), these results show this method has practical calculation accuracies.



Application Examples of Research Results

The solar irradiance estimation and forecasting system based on these methods is applied by electric power companies to forecast and control photovoltaic power generation and to make the plans for supply-demand operations.

References: Hashimoto et al., CRIEPI Research Report N18003 (2019)
Hashimoto et al., CRIEPI Research Report N16001 (2017)

Development of supply-demand balance and frequency simulation models of all TSO's control area in Japan

Contributing to wide-area procurement and operation of control reserves of power system

Electric Power Transmission and Distribution

Balancing market

A market in which control reserves (△kW value + kWh value) are traded to cover supply and demand gaps, respond to changes in supply and demand, and maintain frequency.

Load frequency control (LFC)

Automatic control of generation output from a central load dispatching center, in order to cope with load fluctuations (time period is several minutes to tens of minutes) and supply/demand mismatches, for which forecast is difficult. The control signal is calculated according to fluctuations of frequency and interconnected tie-line power flows.

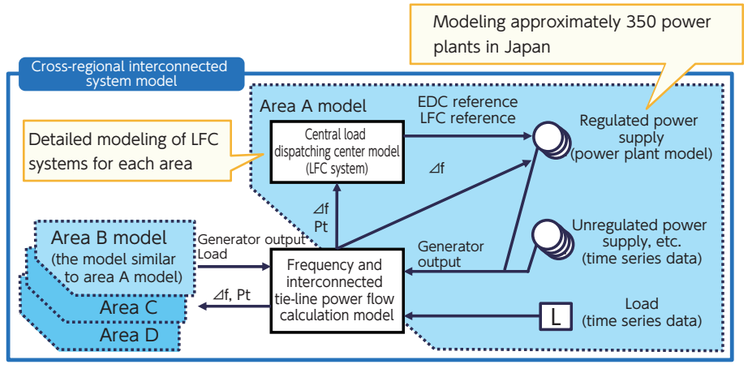
Background

As the reform of electric power systems progresses, there is a growing need to consider wide-area procurement and operation of control reserves due to expansion of the introduction of renewable energy and establishment of the balancing market. In particular, with regard to the operation of control reserves by load frequency control (LFC), since the current control logic is different in each transmission system operator (TSO)'s control area, in-advance studies by simulations are required with respect to technical challenges and countermeasures in Cross-regional cooperation of LFC. We are developing the supply-demand balance and frequency simulation models of all TSO's control area in Japan, which can accurately analyze frequency and tie-line power flows under normal conditions.

Outline of Results

◇ Development of a high-precision analytical model for frequency and tie-line power flows in a cross-regional interconnected system

We modeled LFC systems of central load dispatching centers and major power plants in Japan. The developed models are able to accurately analyze frequency and interconnected tie-line power flows under normal conditions. Simulations using this model enable identification of technical challenges related to the cross-regional cooperation of LFC and their countermeasures, and to propose new control methods.



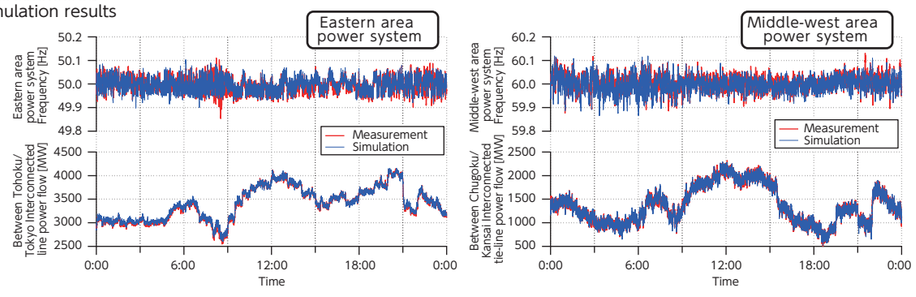
Developed cross-regional interconnected system model and expansion of the functions for cross-regional cooperation of LFC

Transmission system operator are maintaining frequency at the reference by conduncting load frequency control (LFC) and economic load dispatching control (EDC)* etc, according to the time period of supply and demand fluctuations.
*Economic load dispatching control (EDC): A control made in advance by calculating output for each thermal and hydraulic power generation with different efficiency from the viewpoint of overall supply cost, meeting demand forecast, in order to follow relatively long period load fluctuation (time period is tens of minutes to several hours).

We will support the realization of stable cross-regional cooperation of supply and demand control by using the simulations.

The cross-regional interconnected system model and simulation results

There is a good agreement between the measurements and the simulation results for the frequency and tie-line power flows.



Application Examples of Research Results

By highly accurate simulation using the developed model combined with the "Cross-Regional Cooperation system model of LFC", we contribute to procurement and operation of control reserves in wide areas by electric utilities going forward.

References: Tokumitsu et al., CRIEPI Research Report R18003 (2019)

Electric Power Transmission and Distribution

Establishment of a method to Apply International Standards to Monitoring and Control Systems at Substations in Japan

Realize cost reduction by preparing functional specifications to be used in common

Background

Electric power companies have structured and operated their own monitoring and control systems that are arranged for their power facilities and related communication systems thereof. However, in the process of the reform of electric power systems, there is a demand for the introduction of monitoring and control systems on a standard-technology basis, which have common specifications and are advantageous in terms of cost over the medium long term. International standards for power system telecommunications have been established by the International Electrotechnical Commission (IEC). To effectively apply these standards in Japan, however, it is desirable to prepare functional specifications for detailed procedures of monitoring and control and the handling of measurement information that can be commonly used, based on the monitoring and control systems actually operated by electric power companies.

Outline of Results

◇Functional specifications for common applications of international standards to substations in Japan

We have set our research scope on the monitoring and control functions of substations because we can take an advantage of a large number of devices employing the functions and refer to the results of latest overseas research. Thus far, we have picked up items that should be specified based on the current requirements for the devices, and developed functional specifications for common applications of IEC 61850 in Japan. Specifically, we have examined the necessity of optional elements, developed specifications to implement monitoring and control functions used only in Japan, and set parameters to realize a telecommunication method that meets various requirements necessary for domestic applications, all of which are the design items not stipulated in IEC 61850. Furthermore, we have developed a method to easily and practically realize monitoring and control functions by dividing the logic circuit into blocks based on the details of the functional specifications and allocating the processes in these blocks individually (Fig. 1).

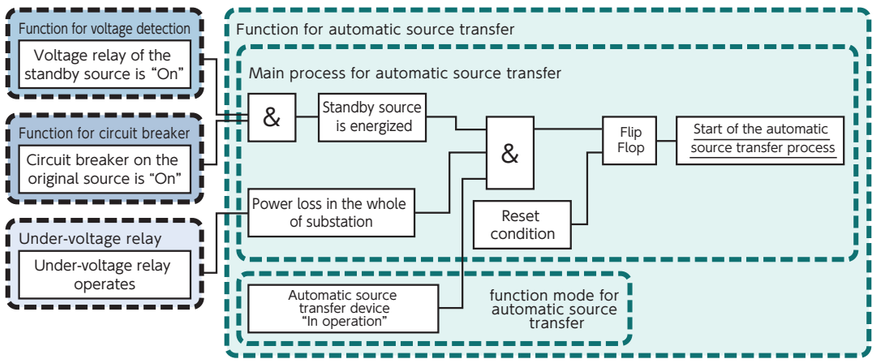


Fig. 1 An example of logical circuit diagram for monitoring and control function in case of automatic source transfer

IEC 61850

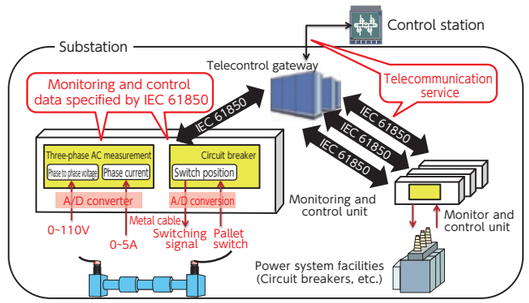
A standard established by the IEC to standardize the exchange of information between electronic devices and to achieve interoperability, focusing on protection and control systems used in substations, etc.

Tetsuo OTANI
Communication Systems Sector, System Engineering Research Laboratory

We have developed functional specifications that enable common applications of the international standards to monitoring and control units in Japan.

Scope of IEC 61850 for Substation Monitor and Control System

The client (the telecontrol gateway) operates power system facilities (e.g. opens/closes a circuit breaker through the access to the data specified by IEC 61850 in the monitor and control unit.



Application Examples of Research Results

Applications of IEC 61850 based on the functional specifications to the systems related to operation, monitoring, and control not only in substations but also in other types of power systems, enable the use of systems in common through multi-vendors and in the electric power industry, making it possible to use control devices in a sustainable manner and to reduce the cost of system construction and maintenance.

References: Saka, et al., CRIEPI Research Report R18004 (2019)
Otani et al., CRIEPI Research Report R18002 (2019)
Otani et al., CRIEPI Research Report R15010 (2016)

Electric Power Transmission and Distribution

Development of a Corrosion Evaluation Method for Transmission Towers, Reflecting the Corrosion Environment at the Site

Supporting the drawing up of a plan of modification and renewal of transmission towers through highly accurate estimation of corrosivity

Background

Among the total 250,000 transmission towers operating in Japan, 70% of them has been installed for more than 30 years. Aging magagement is required because they are facing to concerns mainly related to corrosion problems. Methodology for corrosivity evaluation is then required in power industry to level the load of maintenance activities such as painting, repair, and reconstructions. Such maintenance planning can avoid over-concentration of major loads at the same period. Hot dip galvanized steels are generally used in transmission towers. Corrosion of steels and zincs are attiributed to environment factors such as airborne salinity, sulfur oxides, temperature and humidity. Such environment factors differ in tower locations. We are therefore evaluating corrosivity for each tower by taking into account the local environment.

Outline of Results

◇ Precise corrosivity evaluation with atmospheric environment in each transmission tower location

The corrosivity estimation formula for steel and zinc are established in international standards. We have sophisticated them to fit to Japanese environment using exposure test results in Japanese testing sites, in order to establish corrosivity evaluation methodology. Corrosion environment at each tower site can be analyzed by several maps of corrosion factors such as temperature, bumidity, airborne salinity, and SO_2 concentrations (Fig. 1). Such maps are realized by the long term weather re-analysis data called CRIEPI-RCM-Era2, compiled with the weather prediction and analysis system NuWFAS. Combination of the new formula with the calculated corrosion factors provides cumultive corrosivity values at each towers from their installation. The maps visualized for steels and zincs enable regional comparison of corrosion rate (Fig. 2)

NuWFAS

Prediction and analysis system for the several days in future. Core of the system is the meteorological model developed by National Center for Atmospheric Research (NCAR).The spatial resolution can be set finely from 3 to 5 km.Long term climate changes can also be calculated by taking into account seasonal changes in ground level weather conditions.

Long-term meteorological re-analysis data CRIEPI-RCM-Era2

Meteorological factors such as wind speed, temperature, atmospheric pressure, and precipitation in every hours calculated for a long period on a 5 km mesh at 20 km above the ground. The calculation was conducted based on re-analysis data of the whole global sphere (resolution approx. 120 km), provided from the European Medium Term Forecast Center.

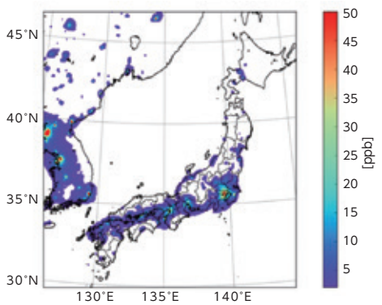


Fig. 1 Map of the annual average density for SO_2 (Example in 1980)

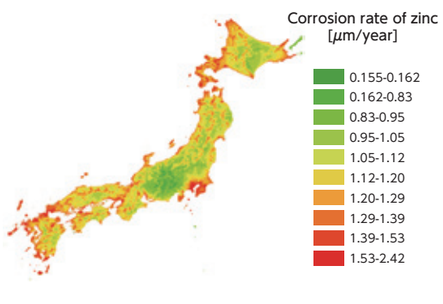
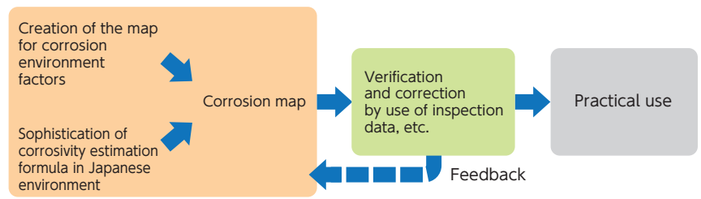


Fig. 2 Map of the annual average amount of zinc corrosion (All directions)

Yasuhiko HORI
Gas Insulation and Electric Discharge Phenomenon Sector, Electric Power Engineering Research Laboratory

We are tackling on precise evaluation of corrosivity in transmission towers by taking into account the local corrosion factors in each location. The evaluation can be utilized to achieve the smooth and efficient works on improvement and replacement.

Image of applying this evaluation method



Application Examples of Research Results

Priority of inspection and repair painting can be quantitatively determined in electric power companies. This leads to achieve the smooth and efficient works on improvement and replacement.

References: Hori et al., CRIEPI Research Report H18009 (2019)

Development of A Technology to Enable Expansion of Applicable Scope of High-Voltage SiC Devices

Leading the improvement in next-generation power electronics technologies

Electric Power Transmission and Distribution

SiC power semiconductor
Low-loss power semiconductors using single crystal SiC. Since single crystal SiC has a dielectric breakdown electric field strength of about 10 times greater than that of an single crystal Si, the power loss can be drastically reduced when it is applied to a power semiconductor device.

Background

To reduce the loss in semiconductor power conversion equipment, the application of next-generation power semiconductors using SiC (silicon carbide) instead of the wide-spread Si (silicon) is expected. SiC power semiconductors has been started in practical use in power conditioners for photovoltaic power generation systems, quick chargers for electric vehicles, and driving systems for railway vehicles. To apply these technologies to power system control equipment with higher voltage and larger capacity, we are working on the development of technologies to ensure long-term reliability and produce high-quality crystals by low costs*.

*A part of this research was conducted by the Council for Science, Technology and Innovation (CSTI), Cross-ministerial Strategic Innovation Promotion Program (SIP), "Next-generation power electronics/Consistent R&D of next-generation SiC power electronics" (funding agency: NEDO).

Outline of Results

◇ Development of high-speed and high-quality SiC crystal growth technology by gas source method*

Aiming at the development of a mass production technology using the crystal growth method that employs a gas as the raw material (the gas source method), we have worked on the development of technology that enables the high-speed and stable production of SiC bulk crystals for a long period of time. As a result, SiC crystals were successfully grown stably over a long period of time (4 hours) at a high growth rate (3 mm/h) approximately 10 times that of the conventional technologies. In addition, it turned out that even at high growth rates, the density of crystal defects, which may affect the characteristics and reliability of SiC power semiconductors, can be significantly reduced.

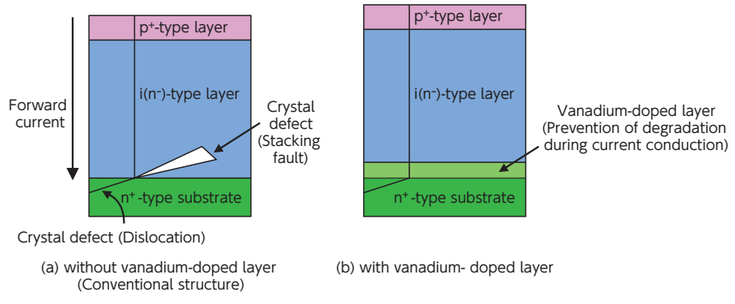
*Studies on SiC crystal growth by gas source method have been conducted in collaboration with Denso.

◇ Suppression of degradation during current conduction in SiC power semiconductors

Carrier lifetime
The period during which excessive electrons and holes are pair-annihilated in the crystal.

A technique has been established to control the carrier lifetime in single crystal SiC over a wide range by adding (doping) vanadium elements during crystal growth. By applying a single crystal SiC film with a short carrier lifetime as a buffer layer to a PiN diode, we have demonstrated that no degradation during current conduction occurs even at a high current density of 600 A/cm^2.

PiN diode
A diode with an insulating layer acting as an intrinsic semiconductor layer between PN junction, which improves blocking voltage when a backward voltage is applied.

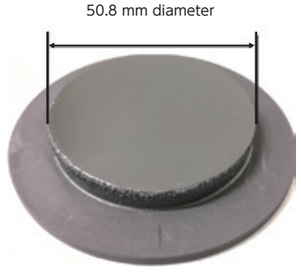


Cross-sectional schematic illustration of an SiC PiN diode

By inserting a single crystal SiC layer with a short carrier lifetime (vanadium-doped layer), which has been shortened by doping technique, to a high-voltage SiC device, we have demonstrated that stacking faults formation (degradation) during current conduction can be prevented.

Koichi MURATA / Norihiro HOSHINO
Electrical Materials Sector,
Materials Science Research Laboratory

We are working on development of technologies to apply SiC power semiconductors to control equipment for high-voltage and large-capacity power system.



SiC bulk crystals grown by gas source method

Application Examples of Research Results

Technologies towards lower-loss and higher-reliability for high-voltage SiC devices can improve the efficiency, downsize, and reduce operating costs of various power conversion equipment.

References: K. Murata et al., Journal of Applied Physics Vol. 126, p. 045711 (2019)
Tsuchida et al., Materials Science in Semiconductor Processing Vol.78, p.2 (2018)
N. Hoshino et al., Journal of Crystal Growth Vol. 478, p. 9 (2017)

Development of a Calculation Program for Assessing Human Body Exposure to Radio Frequency Electromagnetic Field

Contributing to the safety assessment of RF electromagnetic field generated by a smart meter

Electric Power Transmission and Distribution

Radio frequency (RF) electromagnetic field
A generic term for "electric fields" and "magnetic fields" used for wireless communication, and the frequency of 100 kHz to 300 GHz is generally used.

Radio wave protection guideline
An exposure guideline indicates the values of an electromagnetic field that do not affect the health of the human body and the concept for protecting the human body, with regard to the effects of RF electromagnetic fields on the human body.

Specific absorption rate (SAR)
A measure of the amount of energy absorbed in a human body exposed to an RF electromagnetic field. This is defined as the absorbed power per unit mass of human tissues.

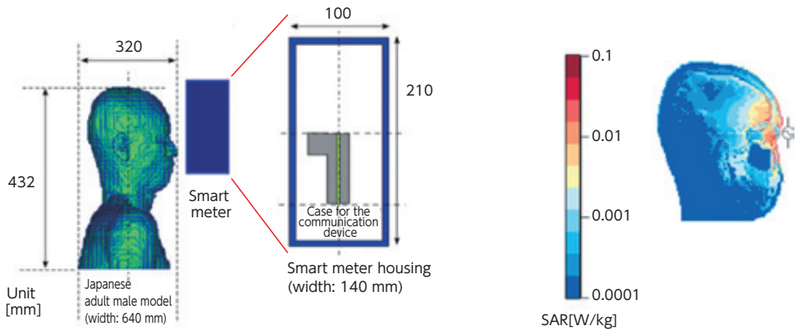
Background

In recent years, various types of wireless communication devices, including smart meters, have become popular and, to use these devices without worry, the safety of human bodies when exposed to radio frequency (RF) electromagnetic fields should be considered. The Radio Wave Protection Guideline in Japan specifies the values obtained by using the specific absorption rate (SAR) as a basis for assessing the safety of the human body exposed to RF electromagnetic fields around wireless communication device. However, since SAR in the human body is difficult to measure, an indirect assessment is required. We are developing a calculation program that can calculation SAR in the human body for various types of wireless communication device.

Outline of Results

◇ Development of a calculation program to assess the SAR in the body, focusing on wireless communication device

Using the electromagnetic field analysis method, we developed a calculation program for assessing the human body exposure of RF electromagnetic fields. With this program, you can calculate SAR distribution in the human body due to the RF electromagnetic field in the vicinity of wireless communication device, with an electrical constant allocated to each human tissue. The calculation results obtained by this program targeting on the SAR calculation when the human body is exposed to a uniform RF electromagnetic field (plane wave) have been confirmed to agree well with those calculated by other organizations. Applying this program to the calculation of spatial averaged SAR in the human body makes it possible to assess, for example, the safety when approaching a smart meter that uses the 920 MHz band as the communication frequency (Fig. 1).



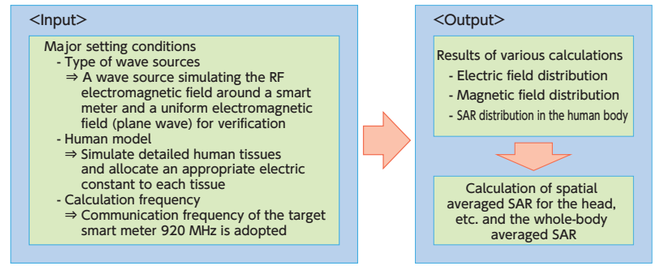
(a) Calculated placement (b) SAR distribution in the head

Fig. 1 Example of SAR calculation when approaching a smart meter
The calculation results of the SAR distribution in the head of an adult male approaching a smart meter.


Takeo SHIINA
Surge and Electromagnetic Phenomena Sector, Electric Power Engineering Research Laboratory

Experimental facility of EMC (Electromagnetic compatibility) It is possible to measure the RF electromagnetic field around the wireless communication device such as a smart meter.

Overview of the calculation program of the human body exposure assessment for RF electromagnetic fields



Application Examples of Research Results

When introducing a smart meter, it should be used as a risk communication tool for the safety of a human body exposed to an RF electromagnetic field.

References: Shiina et al., CRIEPI Research Report H18006 (2019)

Electric Power Transmission and Distribution

Development of an Evaluation Method for Power supply-demand balance in Case of Disasters

Supporting the formulation of effective measures by electric utilities to improve the power supply-demand balance

Background

When power generation facilities and power distribution facilities are damaged by a large-scale earthquake, it is important to secure supply capacity in accordance with the degree of recovery of power demand, which has temporarily declined due to the stagnation of socioeconomic activities. As a prerequisite for this, the power grid and supply facilities should be intrinsically structured to avoid a long-term power shutoff against these events. We are working on the development of a method to evaluate the power supply-demand balance in case of a disaster, in order to support electric utilities in developing reasonable and highly accountable pre- and post-measures against large-scale disasters.

Outline of Results

◇ Development of seismic damage and recovery model of power supply facilities

We have developed a model to estimate the damage probability of power station, substation and transmission line and their recovery time using instrumental seismic intensity as an input parameter based on the analysis of past earthquakes.

◇ Development of a method for estimating power demand in case of a disaster

We have developed a method to estimate the decrease in power demand after an earthquake and its recovery process, using the results of past studies on the recovery process of industrial activities and changes in power demand in households after a large-scale earthquake.

◇ Development of a method for evaluating the power supply-demand balance in case of a disaster

Based on the results described above, we have develop a method for probabilistically evaluating the transition of power supply and demand after an earthquake for each district covered by a substation (Fig. 1). By using this method, it is possible to evaluate the anticipated damage patterns of facilities and its frequency, and to identify power supply facilities that would be a bottleneck in the process of recovery.

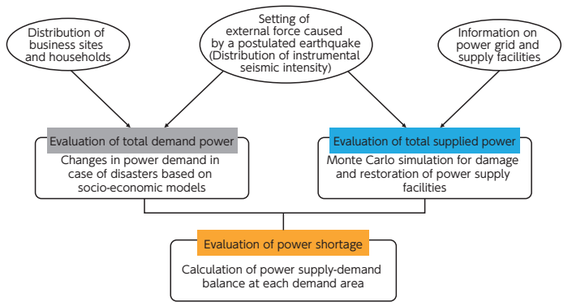


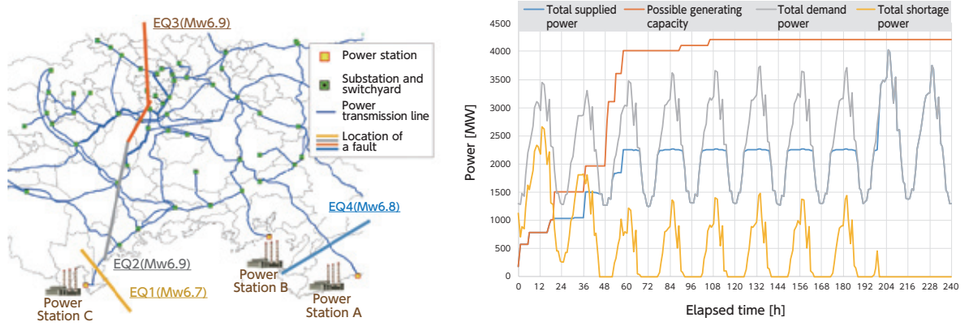
Fig. 1 Calculation flow of power supply-demand balance

Based on the proposed method, it is possible to evaluate the amount of demand power, supplied power, and power shortage due to postulated earthquakes by setting socio-economic data (distribution of business sites and households) of target areas and information on power supply facilities.

Ayumi YUYAMA
Earthquake Engineering Sector,
Civil Engineering Research Laboratory

Daisuke TAKABATAKE
Structural Engineering Sector,
Civil Engineering Research Laboratory

We are working on the development of a risk assessment method for electric power distribution facilities in the event of natural disasters.



A virtual power grid (the left figure) and example of its power supply-demand balance after a postulated earthquake (EQ4) (the right figure).

Application Examples of Research Results

The results obtained through the developed method will enable us to formulate prevention measures and support post-disaster restoration activities, which are effective to improve the power supply-demand balance in case of a large-scale earthquake.

Electric Power Transmission and Distribution

Improvement of the Accuracy of Predictive Estimation for Strong Winds Using Numerical Weather Model and Computational Fluid Dynamics Technologies

Contributing to the rationalization of wind-resistant design of power transmission and distribution facilities and response to storm damage

Background

In recent years, large typhoons and storms caused by rapidly developing low pressure have occurred frequently. Since it is necessary to maintain the functions of distribution facilities in the event of such storms, there is a need to more accurately assess the conditions of strong winds, such as during abnormal weather, and reflect the results in the wind-resistant design of power transmission and distribution facilities. However, power transmission and distribution facilities have been installed in mountainous areas where observation date is extremely small, urban areas and forest areas where changes in wind are significant and, thus, an analysis method for strong winds applicable to these areas is expected. We are working on the development of an analysis method for strong winds that utilizes numerical weather model and computational fluid dynamics technologies.

Outline of Results

◇ Development of a high-resolution analysis method for winds all over Japan

We have improved resolutions of weather prediction and analysis system, NuWFAS, developed by CRIEPI by expanding the computable scale to take local topographic effects into consideration, as well as improving the accuracy of the method by accumulating observation cases such as typhoons and local winds from mountainous areas in recent years and comparison cases with analysis results. With the results obtained, to support the rational design of wind resistant power transmission and distribution facilities, we have developed a high-resolution strong wind database (the Basic Wind Speed Map) covering all over Japan, including mountainous areas (Fig. 1).

◇ Development of an analysis method for strong winds in urban and forest areas

We are developing an wind field analysis software that analyzes the effect of buildings such as high-rises and forests on wind strength and wind direction based on computational fluid dynamics models. The software has been improved to easily calculate detailed wind conditions in forests and urban areas by incorporating digital data from the Geographical Survey Institute and the satellite data (Fig. 2). Based on the results of this analysis, a quantitative evaluation of the wind load acting on power distribution facilities will enable the rational design of the facilities.

NuWFAS
→See p.40

Local wind
The wind specific to a particular region. This includes a downwind attributed to the topography of mountain areas.

Computational fluid dynamics
A method of analyzing gas flows by solving equations (the Navier-Stokes equation, etc.) representing fluid motion directly through numerical analysis.

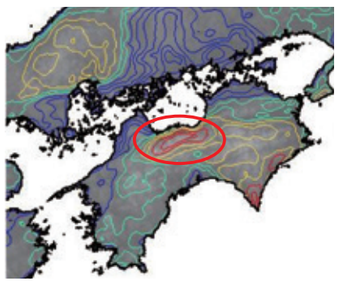


Fig. 1 Basic wind speed map of the Shikoku Region

An example of analysis of strong winds in various areas due to the southern wind in summer. It reproduces the strong wind area (red-circled) caused by the down slope wind due of the Shikoku Mountains.

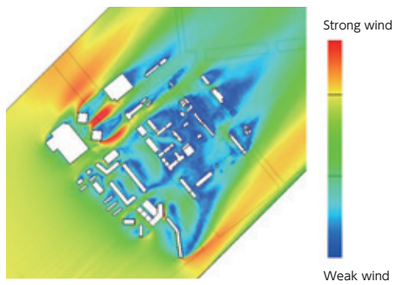
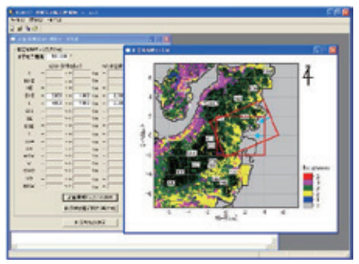


Fig. 2 Example of wind field analysis in urban areas

Example of detailed wind speed distribution calculated by using digital building data of urban areas. You can see how the southwest wind with a steady wind speed is affected by high-rise buildings.

We are working on the development of a strong wind analysis method that utilizes numerical weather model and computational fluid dynamics technologies.



Operation screen of the software to analyze wind fields, etc.

We have packaged the numerical codes so that they can be operated on a PC. We are also building a data distribution system required for analysis.

Application Examples of Research Results

The results of this analysis are used by electric power companies to select routes of power transmission and distribution facilities and to develop renewal plans. In addition, our method is used to examine detailed wind conditions at the site of facilities affected by typhoons and to predict damage caused by typhoons.

References: Nakao et al., Boundary-layer meteorology, Vol. 170, p.235 (2019)
Kitano et al., The 25th Wind Engineering Symposium p.43 (2018)

Customer Services

Development of a Tool to Estimate Power Consumption on a Regional Basis, Considering the Ratio of Houses and Business Sites by Industry

Contributing to the rationalization of power distribution systems and facility structuring and the formulation of sales strategies by electricity retailers

Power supply and demand management method

This is a control method to maintain electric power quality through cooperation between customer facilities such as energy storage equipment installed at the customer's site and power distribution facilities.

Background

Amid complicated changes in demand due to the introduction of photovoltaic power generation (PV) and storage batteries into households, a new power supply and demand management method by collaborating power distribution facilities and customer facilities is deemed effective for maintaining and improving the comfort and other benefits of individual customers while maintaining a stable supply of power within the distribution system. To establish an electric power supply and demand management method, it is necessary to estimate the current status and the future of electric power consumption on a regional basis. We have developed a model to estimate the power consumption of homes in consideration of local conditions, such as the number of detached residences and condominiums, the number of people per household, and the weather.

Outline of Results

◇ Construction of a regional power consumption model for business sites and houses combined

Using four types of statistical data on energy consumption at business sites, we have constructed a model to estimate the total power consumption at business sites in each area from the demand curve by industry and from the number of people of each industry in the area. This model is designed so that the annual total values for all areas in the prefecture are consistent with the energy consumption statistics for each prefecture prepared by the Agency of Natural Resources and Energy. Together with the power consumption model for houses constructed so far, it is now possible to calculate the power consumption by area on the town-block level (Fig. 1).

Area subject to provisional estimate	Area A	Area B	Area C
Major land use zones	Commercial zone	Industrial zone	Category I exclusively low-rise residential zone
Area of the town [km²]	0.220	0.432	0.276
Number of households [houses]	2,519	4,146	1,571
Number of workers [persons]	16,787	3,130	478

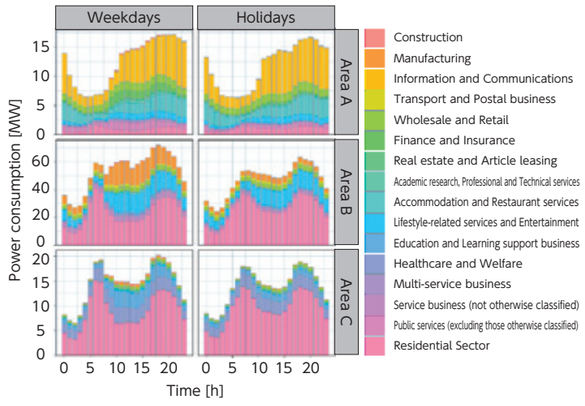


Fig. 1 Example of provisional estimate by a power consumption estimation tool by region

In the industrial area B and the residential area C, a large difference was identified in the demand curve between weekdays and holidays. On the other hand, in the commercial area A, no significant differences were identified between weekdays and holidays.

Tsuyoshi UENO
Customer Service Unit, Energy Innovation Center

We are working on the development of a method to estimate the current and future power consumption of each area, in order to establish a power supply and demand management method.

Four types of statistical data used to construct the business site model

Name of Statistics Data	Outline
Report data on actual results of subsidies for promotion of introduction of energy management systems (BEMS) in FY2011	The data on BEMS measured for 8,760 hours in 1 year at 5,700 business sites has been disclosed.
Statistical data on buildings	Data such as the total floor area by building type have been compiled for each administrative division (290,000 regions nationwide).
Basic survey on economic census compiled by town/village and by large village section	The number of business sites and employees by town/village and by large village section (160,000 regions nationwide) has been publicized for all business establishments in Japan.
Energy consumption statistics by prefecture	The annual electricity and oil consumptions by prefecture and by industry have been disclosed.

Application Examples of Research Results

The tool developed will be used to implement measures to ensure a stable supply of electricity, including rationalization of the operation of distribution systems and facility structuring, and to help electricity retailers formulate sales strategies. It will also be used to study scenarios for efficient regional energy use and reduction of CO_2 emissions in the future.

References: Ueno, CRIEPI Research Report C18003 (2019)
Ueno, et al., CRIEPI Research Report C16003 (2017)

Environment

Development of a Simple and Rapid Atmospheric Environmental Assessment Method

Contributing to cost reduction in prediction of air pollutant concentrations

Background

LNG thermal power stations tend to lower the height of their chimneys as the concentration of pollutants discharged has been reduced in recent years. At power stations with low chimneys, however, the concentration of pollutants on the ground surface may increase due to the exhaust gas entrained by vortices that are generated downwind of the buildings. For this reason, more detailed diffusion prediction is required, and wind tunnel experiments that are expensive and time-consuming are being conducted. In addition, Doppler sodas, which are used to observe upper-layer weather, such as wind direction and wind velocity near the height of chimneys, have drawbacks such as poor portability and noise caused by sound waves.

Doppler sodar
A device that measures wind direction and velocity by emitting a sound wave pulse into the sky.

Outline of Results

◇ Numerical model for predicting exhaust gas diffusion

Using a three-dimensional numerical model that takes into account the combined effects of buoyancy and buildings, we have developed a prediction method having the same precision as wind tunnel experiments with shorter period and lower cost (Fig. 1). With this method, the diffusion of exhaust gas from the chimney can be evaluated without conducting wind tunnel experiments even in LNG thermal power plants with relatively low chimney height levels.

◇ Upper-layer weather observation using a Doppler lidar

Doppler lidar
A device that measures wind direction and velocity by irradiating laser light into the sky.

A Doppler lidar, which is highly portable and does not generate noise by using laser light instead of sound waves, was used to observe the upper-layer weather. Based on test results at four power stations with different weather conditions and surrounding topographic characteristics, we have confirmed that the upper-layer weather observation with higher efficiency and lower cost than conventional methods is possible.

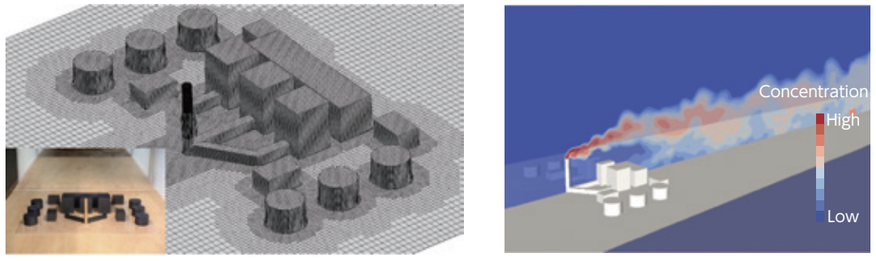


Fig. 1 Computational grid used in the numerical model to predict exhaust gas diffusion (left) and an example of predicted results (right)

Similar to the wind-tunnel test model (photograph in the figure), a simulation can be carried out by faithfully reproducing the plant building, chimney, etc.

Ayumu SATO / Takeshi KISHIDA
Atmospheric and Marine Environment Sector, Environmental Science Research Laboratory

We are making efforts to simplify and speed up the atmospheric environment assessment by introducing a three-dimensional numerical model and a Doppler lidar.

Demonstration test of Doppler lidar at a thermal power station

Comparison with conventional upper-layer meteorological observation methods

Precision, operability, and feasibility of installation Cost and noise: ○ △ × ; High ⟷ Low ; Low ⟷ High

	Anemometer (Chimney)	Doppler sodar	Doppler lidar
Precision	△	○	○
Cost	△	△	○
Operability	○	×	○
Feasibility of installation	×	△	○
Noise	○	×	○

Application Examples of Research Results

The results will be published in academic papers and will be reflected in the guidelines for environmental impact assessment of power stations, thereby contributing to the shortening of the environmental assessment period and cost reduction.

References: Kishida, et al., The 25th Wind Engineering Symposium, p.19 (2018)
Ono et al., Atmospheric Environment Society of Japan, Vol. 51, p.161 (2016)

2–2. Major Research Results -19

Utility Management

Analysis of Issues on New Markets Created as a Result of Electricity System Reform

Supporting the rational design and operation of new markets through analyses of case studies in Japan and other countries

Balancing market
→See p.36

Non-fossil-value trading market
A market in which non-fossil values are certified and traded separately from the value of electricity. It was created to encourage electricity retail suppliers to procure non-fossil fuel power, on the premise of procuring it.

Imbalanced price
Fee that the power generator and the electricity retail supplier pay to adjust the difference between the planned value and the actual value (the imbalance).

Background

Markets such as the balancing market and the non-fossil-value trading market, which will be newly introduced as a result of electricity system reform, not only aim at improving economic efficiency through the promotion of competition, but also address the issues of public interest such as securing a stable supply of electricity and reducing CO_2 emissions. Therefore, the system design becomes complicated, and continuous evaluation of operations is required even after introduction. We are supporting a detailed design and appropriate operation of the system for new markets by presenting the results of evaluation and theoretical analysis of overseas precedents in light of the unique circumstances in Japan.

Outline of Results

◇ Analysis of issues on the imbalanced rate system in consideration of the ancillary services market and recommendations for measures

We investigated the trend of the imbalance pricing system in Germany, a leader in the policy of electricity deregulation and promoting renewable power generation. We evaluated the changes in the current system and future directions in order to control the imbalanced quantity while avoiding a sharp rise in the imbalance price, and made recommendations for a detailed system design in Japan.

◇ Recommendations for the detailed system design of the non-fossil-value trading market

A review of the issues on the non-fossil-value trading market has revealed that auctions focusing on the non-fossil fuel power under the Feed-In Tariff (FIT) Scheme to reduce the cost for promotion of renewable power generation failed to achieve their original objectives (Fig. 1). The report proposed that the main reason for this was the allocation of certificates for free that had not been cleared in the auction. It also suggested that the detailed system design of the non-fossil-value trading market requires a mechanism in line with the purpose of introducing the system to make non-fossil values explicit.

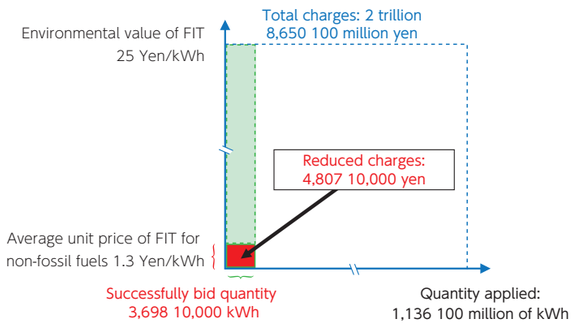


Fig. 1 Auction results of FIT for non-fossil fuels (until the 3rd auction conducted in 2018)

Since there were no incentives for electricity retailers to obtain non-fossil fuel certificates, the quantity of successful bids was extremely small, the contract price was tied to the lower limit (1.3 yen/kWh), and the promotion charge for renewable energy power generation was not reduced.

We have analyzed the challenges facing new markets created as a result of electricity system reform, and provided useful information for stakeholders.

Review of Electricity Economics No. 66 (March 2019)
"Challenges of New Markets Created by Electricity System Reform"
https://criepi.denken.or.jp/jp/serc/periodicals/index.html

Application Examples of Research Results

An explanation on the issues of the imbalance pricing in consideration of the balancing market was published in industry publications to share our insights. Issues on the new market created as a result of the electricity system reform will be reported in "Review of Electricity Economics No. 66", an academic journal published by the Socio-Economic Research Center, thereby hoping that market mechanism will be appropriately utilized in the electric power industry through publicizing the issues related to the institutional design such as the balancing market and the non-fossil-value trading market.

References: Hattori et al., Research on Electric Power Economics, Central Research Institute of Electric Power Industry No.66 (2019)

Utility Management

Analysis of Consumers' Decision-Making Factors for Providing Personal Data

Contributing to the development of personal data utilization businesses from the consumers' perspective

Personal data
Extensive information on person, including both personal information and anonymized information. Examples include gender, Internet browsing history, positional information, and residential power consumption.

Information bank
Businesses that manage personal data based on the contracts with individuals and provide the data to third parties on behalf of individuals based on the conditions specified in advance by the contracts.

Background

As IoT technology advances, there is an increasing interest in utilizing personal data. In Japan, systems for data distribution and utilization, such as the information bank, are being developed with the aim of improving the quality of life of the people through distribution and utilization of personal data. In order for such systems to successfully work, voluntary provision of personal data from consumers is essential. However, the factors behind consumers' decision making to provide data are not fully understood.

Outline of Results

◇ Analyzing factors that consumers value when they make decision on data provision

A web survey was conducted for 8,000 people on their intentions to provide personal data, such as power consumption data per 30 minutes and household information including family structures. Analyses focusing on four factors that can influence on decision making to provide personal data have revealed that consumers place importance on monetary rewards, purpose of use, anonymity of data, and the mechanism of providing data to third parties, in this order.

◇ Detailed analysis of how the mechanism of providing data to third parties and the purpose of data utilization affect consumers' willingness to provide their data

We have confirmed that consumers would be more willing to provide their data if the system allows them to participate in the selection of a third party to whom the data will be provided. In particular, it was revealed that consumers would be most willing to provide their data when they are able to participate "partially" in the selection, for example, by selecting only the type of corporations or organizations to which their data will be provided (Fig. 1). In addition, it was also revealed that, even if the purpose is to develop new services that take time to provide benefits to consumers or to improve the efficiency of operations that do not directly generate benefits for consumers, a clearly indicated purpose of use would enhance consumers' willingness to provide data (Fig. 2).

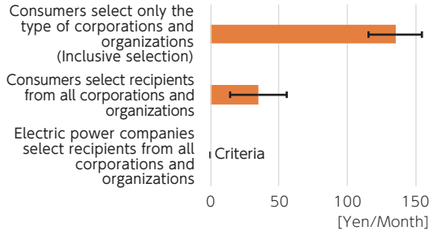


Fig. 1 Preferences for the mechanism of providing to third parties

Fig. 2 Preferences for the purpose of usage of data

The horizontal axis is the monetary equivalent (Yen/month) of the consumer's preference for each condition, indicating that the higher the value, the more preferred the condition. The error bar at the top of the bar graph represents the 95% confidence interval.

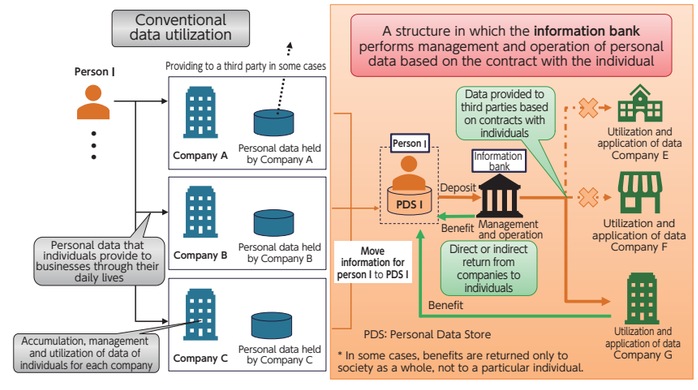


Image of an information bank

Application Examples of Research Results

By utilizing the results of this analysis, consumers are encouraged to voluntarily provide their data, thereby leading to the development of personal data utilization businesses.

References: Tanaka, CRIEPI Research Report Y18004 (2019)

2-2. Major Research Results-21

Emerging Technologies

Development of Power Supply for a Sensor Network to Monitor Power Facilities

Succeeded in generating electricity using environmental vibrations from electric power facilities and structures

Background

As the need for inspection and monitoring of aging social infrastructures is growing, the use of a standalone wireless sensor network that combines sensors, information processing, communications, and networks is being considered for upgrading the operation and maintenance technology of electric power facilities. To materialize such a standalone wireless sensor network, the development of an energy harvester that can supply electric power to sensors which is free from battery replacement is expected. We are working on the development of vibrational energy harvester, focusing on unused environmental vibrations of various frequencies generated from electric power facilities.

Environmental vibration

Daily vibrations that occur imminent environment due to the vibration of facilities or running vehicles. This is distinguished from natural vibrations such as earthquakes and wind-induced motions.

Outline of Results

◇ Successfully improved the efficiency of a vibrational energy harvester using an electric double-layer electret

We have succeeded to develop new type of vibrational energy harvester using an electric double-layer electret in which permanently sustain electric double layer, which is our original technology and to generate electric power more than 1.2 mW/cm^2 from the environmental vibration of less than 10 Hz, which was difficult to generate by conventional technologies, by optimizing materials and fabrication conditions. We have also confirmed that LEDs can be turned on using a prototype device (Fig. 1).

Electric double-layer electret

Electric double layer electrets are formed by anchoring the motion of ion after formation of electric double layer by applying voltage to the electrolyte between two electrode.

◇ Fabrication of a magnetostrictive vibrational energy harvester using polycrystalline Fe-Ga alloy and its performance evaluation

To reduce the cost of energy harvesters, we fabricated a magnetostrictive vibrational energy harvester using an inexpensive polycrystalline Fe-Ga alloy instead of an expensive single crystal Fe-Ga alloy, and found that the electric power generation of more than 1 mW can be obtained which is enough to drive a wireless temperature and humidity sensor that have developed in CRIEPI.

Magnetostrictive vibration power generator

An element that generates an electric power based on the fact that the stress (distortion) caused by mechanical energy such as vibration can change magnetic flux density. The characteristics of materials with large magnetostriction such as Fe-Ga alloy are used.

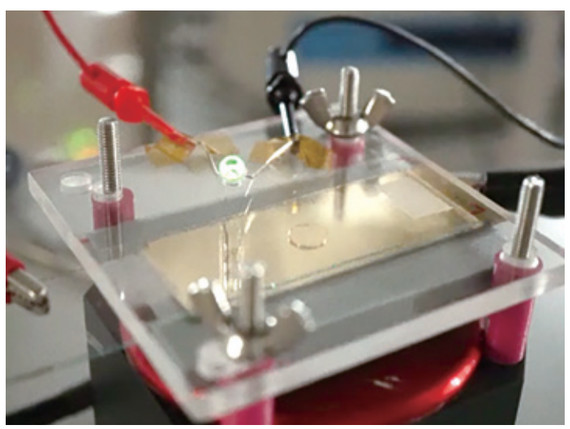
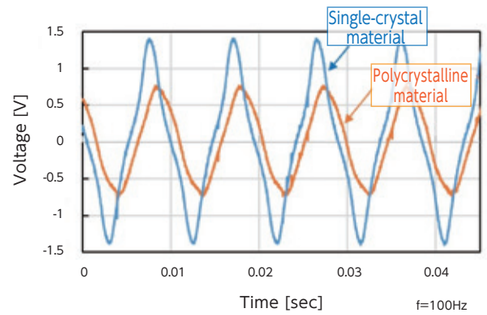


Fig. 1 Vibrational energy harvester using an electric double-layer electret

A device consisting of an electric double-layer electret sandwiched between two electrodes.

Camilla MOIR / Shimpei ONO
Electrical Materials Sector,
Materials Science Research Laboratory

We are working on the development of energy harvesters capable of supplying power to sensors free from battery replacement.



The waveform of generated voltage when the vibrational energy harvester is connected to a load resistance of 510 Ω. We have demonstrated that a magnetostrictive vibrational energy harvester fabricated from polycrystalline Fe-Ga alloy can provide an output of more than 1 mW, although the output is lower than that of a single-crystal-based element.

Application Examples of Research Results

By spreading standalone sensor network using our technology which is free from battery replacement, we will contribute to the rational maintenance and operation of electric power facilities by reducing the labor and costs associated with daily maintenance work.

References: Ono, Applied Physics No.87 p.917 (2018)
Ito et al., Proc. of Power MEMS 2018, PT-23h (2018)

Ⅱ. Financial Statement

1. Overview of Financial Statement

While ordinary expenses were the same level as those in the previous fiscal year, ordinary profit turned negative due to a decrease in ordinary revenue, which was mainly attributable to a decrease in ordinary benefit received and operating revenue from commissioned research.

Net Assets Variation Statement

(Unit: 1 mill yen)

Change in general net assets

	FY2018	FY2017	Difference		FY2018	FY2017	Difference
Ordinary expenses	29,522	29,576	△53	Ordinary revenue	29,288	30,010	△722
Labor costs	10,177	9,909	267	Ordinary benefit received	25,074	25,385	△311
General running costs	19,345	19,667	△321	Operating revenue	3,906	4,204	△297
				Other revenue	145	233	△88
				Transfer from designated net assets	161	186	△25
Current ordinary profit	△234	433	△668				
Current general net assets change	△265	3,640	△3,906				

Change in designated net assets

	FY2018	FY2017	Difference		FY2018	FY2017	Difference
Transfer to general net assets	161	186	△25	Subsidy etc. received	150	108	42
Current designated net assets change	△11	△78	67				
Current net assets change	△276	3,561	△3,838				

Balance Sheet

(Unit: 1 mill yen)

Assets

	FY2018	FY2017	Difference
Current assets	4,954	5,659	△705
Fixed assets	52,164	53,326	△1,162
Total assets	57,118	58,986	△1,867

Liabilities

	FY2018	FY2017	Difference
Current liabilities	4,260	5,238	△977
Fixed liabilities	8,743	9,357	△613
Total liabilities	13,004	14,595	△1,591
Net assets			
Designated net assets	313	324	△11
General net assets	43,800	44,066	△265
Total net assets	44,114	44,390	△276

Facts & Figures

Research Reports / Research Papers / Intellectual Property

This section introduces key data on CRIEPI's activities, including the number of report publications, number of paper presentations and number of patent applications.

Fig. 1 Transition in number of reports published

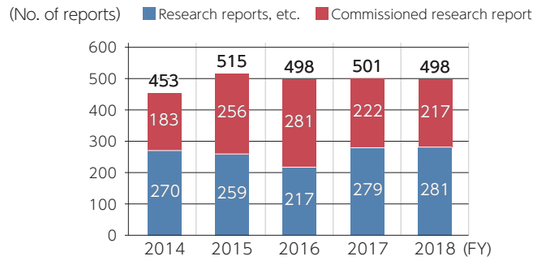


Fig. 2 Breakdown of no. of FY2018 reports by subject field

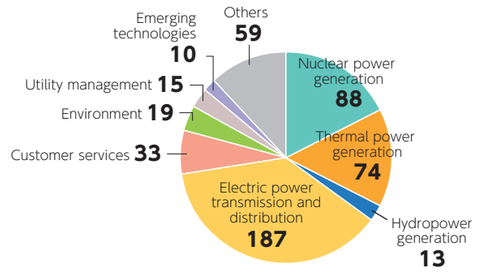


Fig. 3 Transition in no. of papers presented

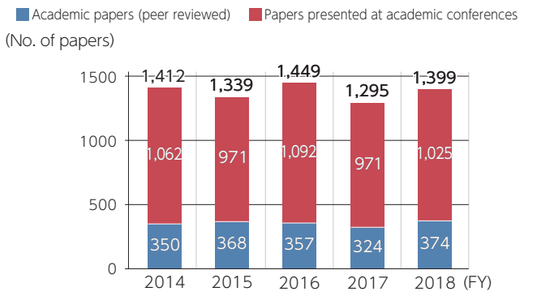


Fig. 4 Breakdown of no. of FY2018 papers by subject field

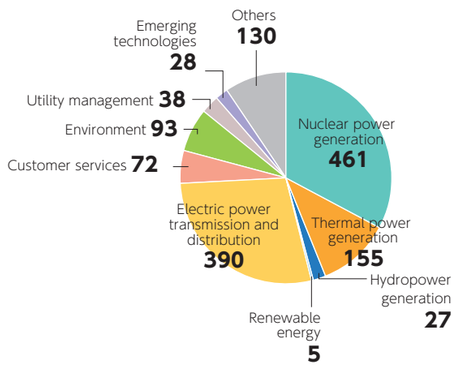


Fig. 5 Breakdown of no. of FY2018 patent applications by subject field

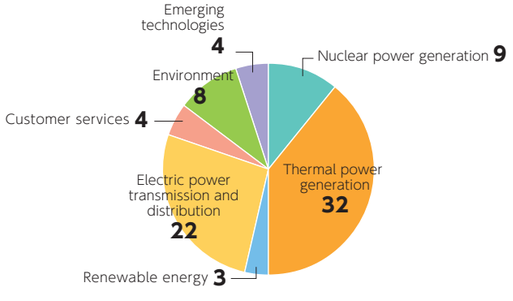
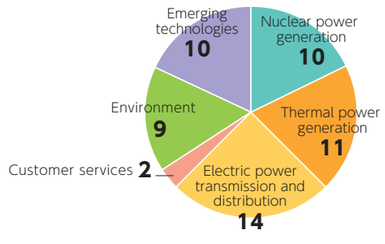


Fig. 6 Breakdown of no. of FY2018 patent registrations by subject field

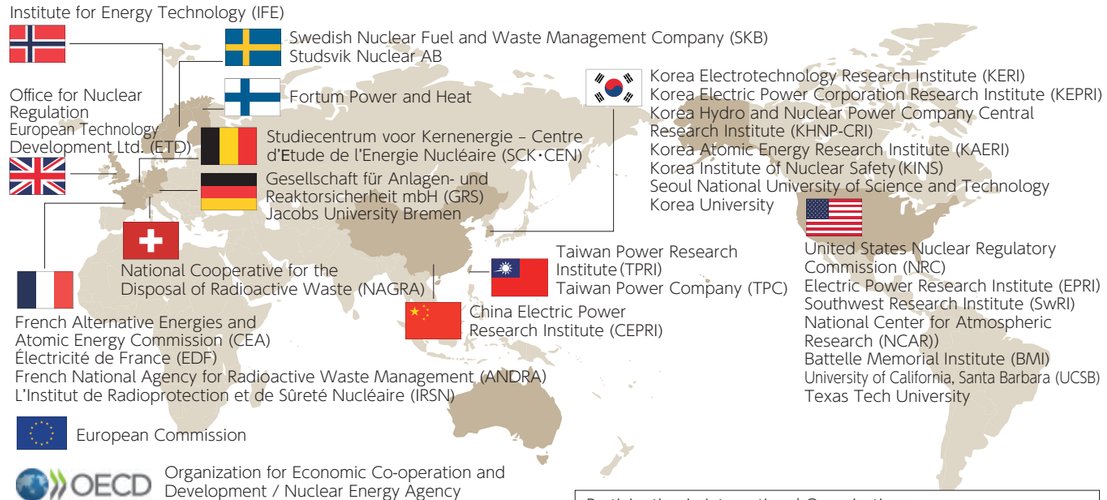


Research Network

With the aims of identifying trends in forefront energy-related R&D as well as strengthening and enhancing research networks, CRIEPI proactively promotes research cooperation agreements and engages in joint research with international partners.

In recent years, CRIEPI has been strengthening its collaborative relationships with Électricité de France (EDF) and the Electric Power Research Institute (EPRI) in particular. In FY2018, the MOU was updated with EDF in May, and an annual meeting was held in October to exchange opinions on the acceptance and dispatch of researchers, for the purpose of further enhancing cooperation and exchanges.

Main Partners for Research Cooperation Agreements and Joint Research



Participation in International Organizations
Union of the Electricity Industry (EURELECTRIC)
Association of the Electricity Supply Industry of East Asia and Western Pacific (AESIEAP)
World Nuclear Association (WNA)
International Electric Research Exchange (IERE)
Electromagnetic Transients Program-Development Coordination Group (EMTP DCG) Committee

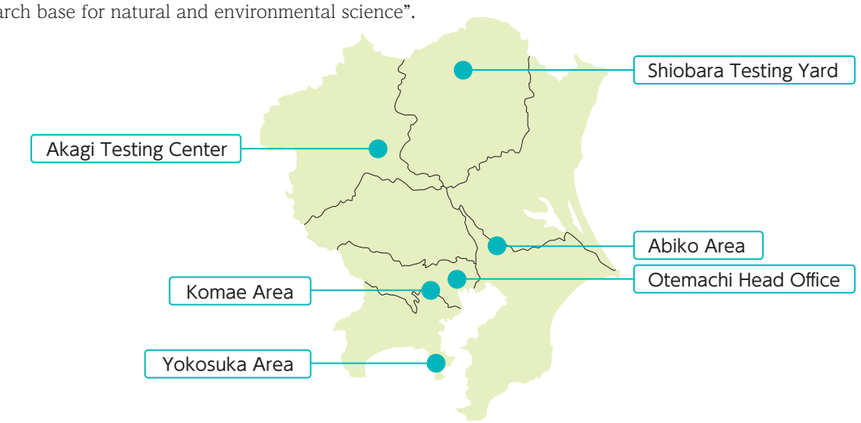
Main overseas institutions with whom CRIEPI has comprehensive cooperation agreements and the content thereof

Partner organization	Overview of partner organization	Cooperation content
Électricité de France (EDF)	France's largest electric power company founded in 1946. Conducts in-house R&D activities covering all electric power business sectors.	Cooperation agreement: Since 2012 (Main) Nuclear power generation (PRA, SA), power transmission and industry infrastructure, next-generation grid, hydrogen, customer side (Other) Nuclear power generation (maintenance/operation of power plants, life management, spent fuel management), renewable energy, power transmission infrastructure
Electric Power Research Institute (EPRI)	A nonprofit research institution established in Palo Alto, California, U.S.A. in 1973.	Cooperation agreement: Since 1976 Nuclear reactor material, low-dose-rate radiation, nuclear power risks and safety management, hydrochemistry/geothermal utilization, electric power transmission and distribution and the utilization thereof
Southwest Research Institute (SwRI)	A nonprofit research institution established in San Antonio, Texas, U.S.A. in 1947.	Cooperation agreement: Since 1997 Information exchange, personnel interaction and conducting of experiments which CRIEPI cannot conduct due to Japanese regulations, etc.

Organization

Locations

CRIEPI facilities are located in Tokyo and four surrounding prefectures in the Kanto region. These facilities consist of four research and business activities bases and two testing bases.
To date, we have completed the development of a base in the Yokosuka area, which aims to become a “research base for technologies of the energy industry” and are currently proceeding with the development of the Abiko area, which aims to become a “research base for natural and environmental science”.



Otemachi Area

Internal Audit Office, Head Office, Nuclear Risk Research Center, Socio-economic Research Center
1-6-1 Otemachi, Chiyoda-ku, Tokyo 100-8126　　TEL: +81-3-3201-6601

Yokosuka Area

Energy Innovation Center, Nuclear Technology Research Laboratory, Energy Engineering Research Laboratory, System Engineering Research Laboratory, Electric Power Engineering Research Laboratory, Materials Science Research Laboratory, Yokosuka Operation & Service Center
2-6-1 Nagasaka, Yokosuka-shi, Kanagawa 240-0196　　TEL: +81-46-856-2121

Abiko Area

Civil Engineering Research Laboratory, Environmental Science Research Laboratory, Abiko Operation & Service Center, Procurement Center
1646 Abiko, Abiko-shi, Chiba 270-1194　　TEL: +81-4-7182-1181

Komae Area

Komae Operation & Service Center
2-11-1 Iwadokita, Komae-shi, Tokyo 201-8511　　TEL: +81-3-3480-2111

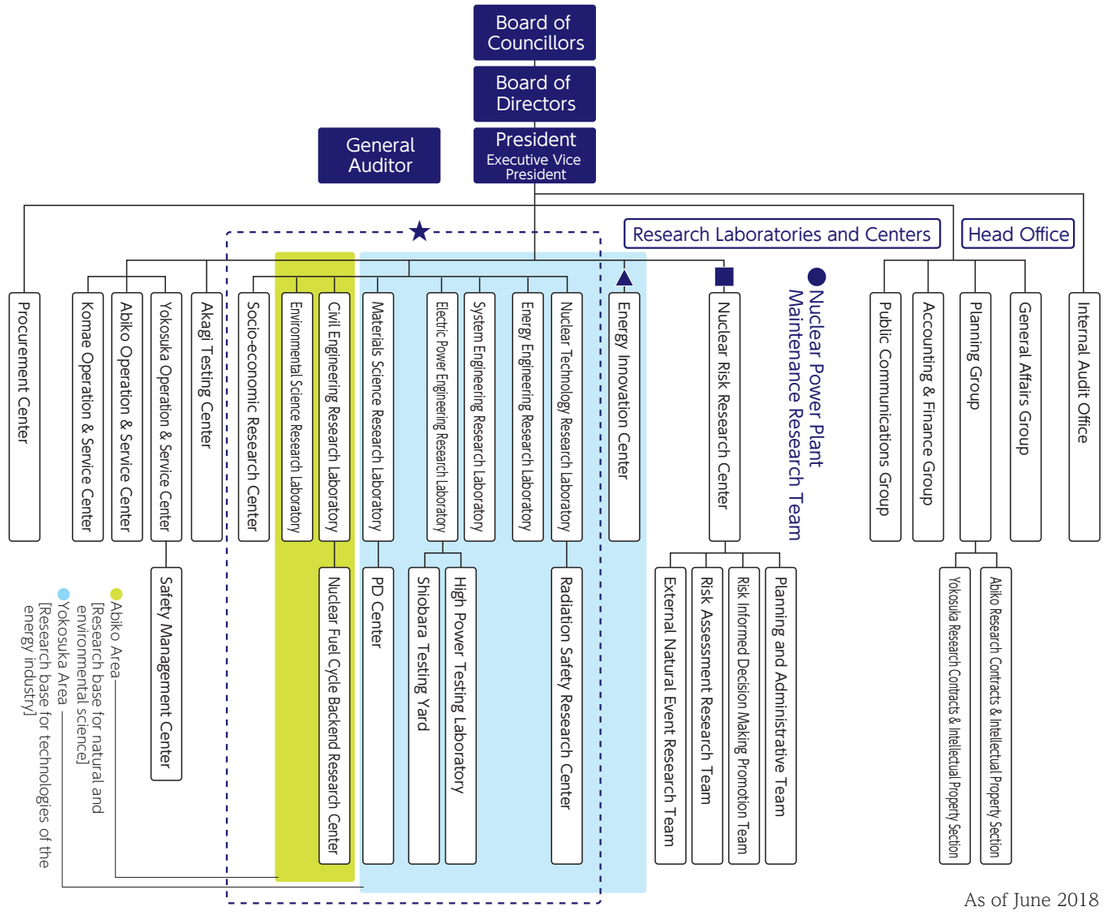
Akagi Testing Center

2567 Naegashima-machi, Maebashi-shi Gunma 371-0241　　TEL: +81-27-283-2721

Shiobara Testing Yard

1033 Sekiya, Nasushiobara-shi Tochigi 329-2801　　TEL: +81-287-35-2048

Organization



As of June 2018

★ Eight Research Laboratories

CRIEPI’s research division essentially consists of eight research laboratories, each specializing in a specific subject field, with the aim of strengthening consistent research capability in each field to cover everything from basic to applied research. In addition, by forming cross-laboratory projects, CRIEPI conducts a matrix-type research framework able to respond flexibly to the needs of the electrical power industry.

■ Nuclear Risk Research Center (NRRC)

NRRC was established in October 2014 to contribute to voluntary efforts and continuous improvement of nuclear power plant safety by electric power companies. Through close liaison with business operators, the NRRC is promoting research into large-scale natural disasters and other low-frequency natural external events, probabilistic risk assessment (PRA), decision-making utilizing risk information, development of the latest risk communication techniques and other R&D aimed at risk mitigation.

▲ Energy Innovation Center (ENIC)

ENIC was established in October 2016 with the aim of comprehensively and efficiently solving issues of both the electric power sales and power distribution divisions and contributing to electric power business reform through utilization of IoT and AI. ENIC engages in research relating to advancement of electric power supply-demand management and the digital transformation of the electric power business. It also strives to achieve swift solution proposals through the Technology Promotion Unit set up within ENIC.

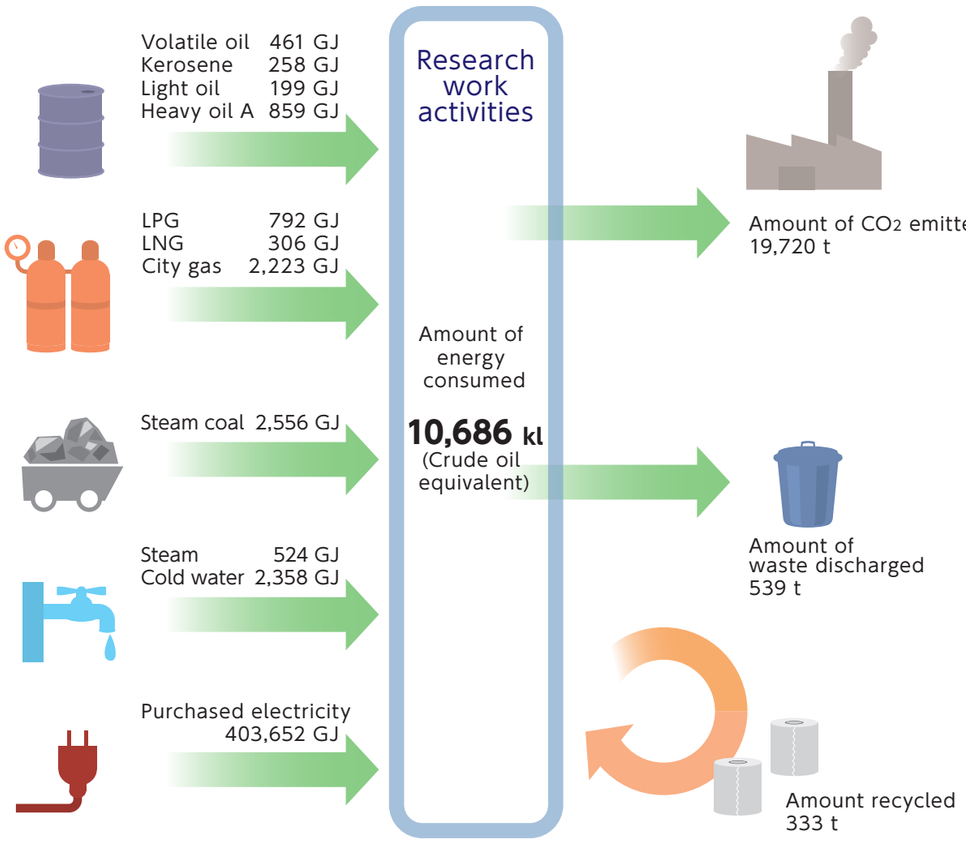
● Nuclear Power Plant Maintenance Research Team

This special research team leverages the combined strengths of CRIEPI’s experts in a diversity of fields including nuclear power engineering, materials science and electrical engineering, to promote research in the name of securing light water reactor safety, such as countermeasures for the aging of nuclear power equipment.

As part of our Environmental Guidelines, we aim to create a prosperous and sustainable society. We conduct research and development activities concerning environmental conservation not only in local communities but also on a global scale, and use the outcome of these activities to contribute to society. In addition, we regard “the environmentally conscious laboratory management” as one of our most important management policies, and are carrying out improvement activities on a continuous basis.
Environmental Guidelines: https://criepi.denken.or.jp/en/aboutcriepi/mission.html

The performance data for our environmental activities in FY2018 is as follows:
The total energy consumption of the laboratory was 10,686 kl crude oil equivalent (3.0% reduction from the previous year), and CO_2 emissions were 19,720 tons (5.3% reduction from the previous year). The amount of waste discharged was 539 tons (23.9% reduction from the previous year), and the recycling rate was 61.8% (decrease of 1.1 points from the previous year). We will make ongoing efforts to improve our environmental performance.

[Energy Input and Output]



Keyword Index

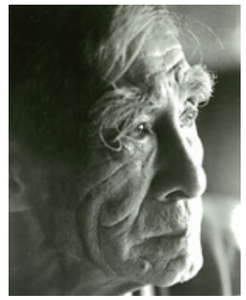


Photo by Kira Sugiyama

“Industrial research is the cultivation of wisdom, and should therefore contribute to society”

Yasuzaemon Matsunaga (1875-1971)
CRIEPI Founder, 2nd President

[About the Cover Design]

The lines of different colors and angles signify CRIEPI’s tireless efforts to create a better future ————

These lines, which are the unraveled form of CRIEPI’s first letter “C”, appear in many colors to represent the diverse subject fields of CRIEPI’s research and each of these fields converge at a single point.
That point of convergence is CRIEPI.