FY2016 Annual Report

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FY2016 Annual Report

CRIEPI

CRIEPI
Central Research Institute of Electric Power Industry

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Overview of the FY2016 Annual Report

In accordance with the Electricity System Reform, certain movements have become visible, such as the establishment of a competitive environment in the electric power retail market and diversification/company separation strategies by electricity utilities. Moreover, as part of efforts to achieve the goals of the Reform, the environment surrounding the electric power industry is undergoing significant change, exemplified by the establishment of various markets and so forth. Meanwhile, with electric power demand becoming saturated and related technology entering a stage of maturity, electric power supply is required to be both stable and rational, in addition to being in harmony with the environment.

In response to these changes in the environment surrounding the electric power industry, CRIEPI conduct research and development initiatives to contribute to solving issues and creating new values. In FY2016, we produced results relating to the further advancement of safety in nuclear power generation, stabilization of power distribution systems responding to expanded introduction of renewable energy and higher performance of thermal power generation equipment. Furthermore, as part of efforts to rationalize the maintenance management of electric power facilities, etc., CRIEPI has also proactively engaged in challenging R&D activities utilizing IoT and AI.

Also, at the same time as reinforcing the functions of our Nuclear Risk Research Center (NRRC) in order to better utilize risk information, we have established the Energy Innovation Center (ENIC), which aims to create new customer value leveraging leading digital technologies and formed a research promotion framework. Parallel to these efforts, with the aim of forging a sustainable business foundation, we are steadily proceeding with “structural reform” by promoting establishment of research bases, streamlining our organizational structure, rationalizing tasks, etc.

As an in-house research institution comprising of researchers possessing a wealth of expertise covering the electric power supply chain and unique research equipment, CRIEPI will continue creating and offering research results of value in an effort to transform technologies and systems relating to the supply and utilization of electric power and other energy, thus contribute to the electric power industry and society at large.

Masahiro Kakumu
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.

As the central research institution of the electric power industry, CRIEPI produced various research results useful for solving common issues faced by the electric power industry, engaged in research with foresight by predicting issues likely to occur in the future and, ultimately, contributed to society.

Promoting research to lead change and producing/providing results

- CRIEPI injected resources with priority to R&D useful for solving common issues faced by the electric power industry and produced/provided results steadily. Also, we used our foresight to predict issues that may surface in the future insofar as technologies and systems relating to electric power, energy supply and energy usage are concerned, then engaged in research to provide solutions to such issues and new value. Examples of our achievements include establishment of a systematic evaluation method for fault activity for application in the nuclear power generation field, a proposal for gas turbine power generation technology to help maintain supply/demand balance during times of large-volume naturally-fluctuating power in the thermal power generation field, establishment of a communications platform to support smart grids in the power distribution field, a detailed analysis for five new markets due to the Electricity System Reform in the utility management field and finally, development of efficient status monitoring technology for power generation equipment through IoT technology in common/cross-fields. ➡ See Fig. 1, p.16 to p.59 [2-2. Major Research Results] (22 in total)
- CRIEPI responded to accidents and issues at electric power industry worksites, as well as flexibly and swiftly provided suitable solutions for such situations. ➡ See Fig. 2
- In regards to consigned research at the request of the Japanese government, etc. CRIEPI undertook research such as the development of common infrastructure technology concerning the building of next-generation power distribution systems, etc. to contribute to solving issues faced by the electric power industry, as well as advanced research to enhance and refine our research capabilities.

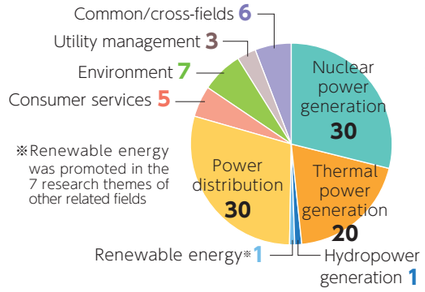


Fig. 1 No. of research themes by field for FY2016

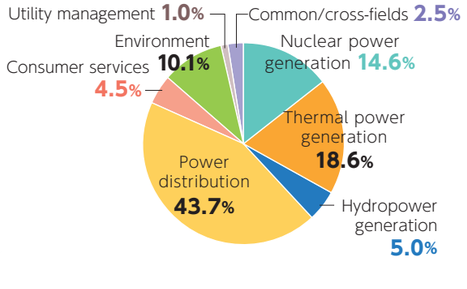


Fig. 2 Consigned research projects from electric power utilities for FY2016 (percentage of cases by field)

Formulation of business strategy and establishment of promotional systems to provide appropriate response to needs

- In line with the advancement of the Electricity System Reform, CRIEPI formulated mid-to-long term business strategies in order to respond to changing R&D needs in each business field, such as power generation/distribution and retail. Moreover, we ensured multilayered communication with electricity providers, and collaborated with them to establish and update an R&D roadmap. In the process, we clarified CRIEPI's roles and research projects for promotion.
- Towards the realization of our business strategies, CRIEPI established a Risk Informed Decision Making Promotion Team within our Nuclear Risk Research Center (NRRC) in order to more efficiently achieve the introduction of safe nuclear power plant operation and further safety enhancement from a risk management perspective. We also established other promotional systems, such as the Energy Innovation Center (ENIC). This Center aims for the sophistication of electric power supply/demand management for the coordination of the consumer side and electricity provider side, as well as support of digital transformation of the electricity business.

Strengthening and developing fundamental research ability with a mid-to-long term perspective

- With consideration to the issues predicted to occur in the future concerning the electric power industry, CRIEPI has clarified the fundamental technologies necessary to solve such issues and enhanced new technological fields while at the same time scaling down technologies we judged to be of low priority to better utilize researchers where necessary. As of the end of FY 2016, we have a total staff of 725, consisting of 642 researchers and 83 administrative staff members. These researchers are specialized in a wide range of diverse research fields, from electricity through civil engineering and construction to socioeconomics and more (Fig. 3), where 396 researchers completed their doctorates. ➡ See Fig. 3

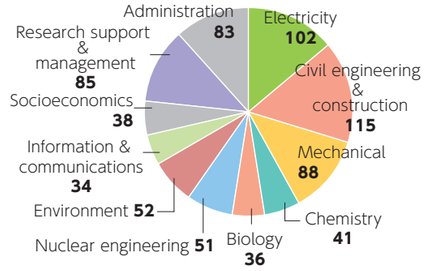


Fig. 3 Personnel configuration by subject field as of end of FY2016

- CRIEPI carefully selected, introduced and renewed large research facilities critical to solving issues in the electric power industry based on research strategies for each field. These included the Micro Focus X-ray CT and Transmission Electron Microscope which make it possible to evaluate activity within a nuclear power plant's grounds and nearby faults with greater accuracy, and Measurement Equipment for Leakages During Distribution Pipe Breakages, which simulates breakages in the grid pipes of power generation equipment and quantitatively evaluates the impact of leaked gas, thus leading to more efficient facility maintenance systems. ➡ See p.13 [Major New Research Facilities]
- We promoted the development of personnel with highly-specialized knowledge and in-depth knowledge on the electric power industry through dispatching our researchers on a long-term basis to research institutions and electric power utilities, etc. both in Japan and abroad.
- We strengthened and expanded our research networks through actively promoting joint research and human interaction with institutions both in Japan and abroad possessing sophisticated technology in energy-related R&D (EDF in France, EPRI in the U.S., etc.) in an effort to enhance our research abilities. ➡ See p.67 [Research Networks]

Contributed to a society that utilizes our intellectual property and proprietary technologies

- CRIEPI broadly disclosed its research results to the general public through research reports and academic papers so that such results could give back to the electric power industry and society at large. Moreover, CRIEPI's proprietary patents and software were broadly offered to and utilized by electricity providers, manufacturers and universities, such as the licensing of CALDG (a power distribution grid comprehensive analysis tool).
  ➡ See p.66 [Research Results / Intellectual Property]
- Through participation in various committees run by government bodies and academia, CRIEPI contributed to the establishment of various policy, standards and technical guidelines relating to energy, such as the Implementation Standard for Probabilistic Risk Assessment of Nuclear Power Plants (level 3 PRA version)
- In addition to fulfilling our responsibility as a PD Examination Center under the PD (Performance Demonstration) certification program which involves performing ultrasonic flaw detection on nuclear power generation equipment, CRIEPI performed short-circuit tests on power equipment such as circuit breakers, etc. upon request from electric power utilities, manufacturers, etc. at our High Power Testing Laboratory.

Steady promotion of research base development, task rationalization and cost reduction

- CRIEPI continued to steadily promote development of research bases in order to strengthen research ability and reduce fixed management overheads through initiatives such as completing a new building within Yokosuka Area and relocating research functions from Komae Area.
- In order to build a sustainable business foundation, CRIEPI streamlined its organizational structure and reduced fixed management overheads at the same time as engaging in ongoing initiatives to reduce costs for both research and operations aspects, such as promoting competitive quotations in procurement, and rationalizing operational tasks through outsourcing.

Overview of financial statement

Current revenue for fiscal 2016 was a total of 30,950 million yen, which comprised of 25,240 million yen in ordinary benefits and 5,410 million yen in business profit from consigned research projects undertaken at request by the Japanese government, electric power utilities, manufacturers and so on. Current expenditure was a total of 29,800 million yen, which included 9,730 million yen in personnel expenditures and 20,060 million yen in overheads. The ordinary net increase for FY2016 was 1,150 million yen. ➡ See p.60 to p.63 [II. Financial Statement]

2–1. Outline of Results

With an awareness of a timeline to lead change in the electric power industry, CRIEPI broadly engaged in initiatives on topics in urgent necessity as well as those predicted to arise in the future, and produced/provided research results on a timely basis.

In addition to the eight areas, comprising of nuclear power generation, etc., corresponding with the electric power industry supply chain, we newly established a "common/cross-area" category that looks at issues common across the individual areas and promoted research by closely liaising with each area. Please refer to p.14 for a list of these research subjects. Below is an outline of the research results best representing each area. Also, from p.16 onwards, we have provided detailed descriptions of the major research results worthy of special mention.

● Keywords used in the index (p.70) are shown in bold. Explanations have been provided for some keywords in the Major Research Results (p.16 – 59).

Nuclear Power Generation

Greater advancements in safety of light water reactors

Greater advancements in evaluation techniques for core damage

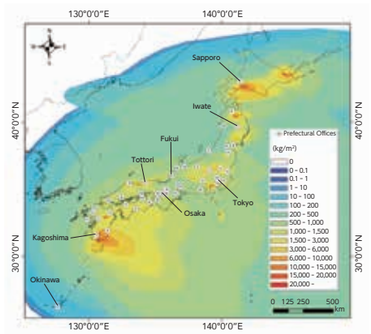
- In order to improve the reliability of preventative measures against core damage in beyond design-basis accidents of nuclear reactors, CRIEPI conducted experiments which simulated a rapid boiling state (high temperature/high pressure) due to falling of BWR control rods and clarified the behavior of steam generation of a fuel conglomerate which accompanies the rapid rise in temperature of a fuel cladding surface. ➡ See p.16
- In addition to expanding the database on the transition behavior of radioactive materials, the effectiveness of the spray in the containment vessel under the accident was confirmed by the temperature evaluation by the numerical thermal-hydraulic analysis code.
- Test data on the removal characteristics of major radioactive materials in various filters were acquired using an actual scale filter vent apparatus, and a filter vent performance evaluation tool was developed.

Filter Vent

An exhaust unit connect to a nuclear reactor containment vessel to suppress abnormal pressure rise within the vessel. This unit is equipped with a filter to suppress the release of radioactive substances in the environment.

Establishment of evaluation techniques for low-frequency phenomena

- CRIEPI established a fault activity analysis flow to systematically assess the activity of faults which exist in and around nuclear power plant sites. Using this flow, we conducted field surveys in areas affected by the Kumamoto Earthquake of April 2016, etc. and clarified it was possible to appropriately assess fault activity. ➡ See p.18
- In preparation to introduce a probabilistic risk assessment technique for the evaluation of earthquake hazards, CRIEPI gathered and analyzed the latest case studies from both Japan and abroad and, positioning the Ikata Power Plant as the pilot plant, formulated a plan for the implementation of a probabilistic earthquake hazard assessment.
- In order to contribute to the assessment of impact on nuclear power facilities due to volcanic eruption, CRIEPI compiled information on volcanic ash fall from the past 330,000 years and created a chart showing the distribution of amount of the accumulated ash fall in Japan (top right).
- In order to assess the structural soundness of major equipment in nuclear power plants against earthquakes, CRIEPI conducted a vibration test on the motor-operated valve actuators used in nuclear power plants and confirmed the motor-operated valves moving function under vibration conditions up to a maximum acceleration of 20G through appropriate anti-earthquake reinforcement.



Distribution of amount of the accumulated ash fall in Japan over the past 330,000 years

Probabilistic Risk Assessment (PRA)

PRA is a quantitative method of evaluating the vulnerability of nuclear facilities by systematically and exhaustively analyzing various potential accident scenarios in the facilities and prioritizing the scenarios in order of their risk evaluated with the combination of their frequencies and consequences.

Good PRA

Plant specific PRA which is comparable to the international state-of-the-practice and improved with the Japanese operating experience.

Establishment of probabilistic risk assessment (PRA) technology

- In preparation for conducting the Japanese first Good PRA at the Ikata Nuclear Power Plant, CRIEPI gathered the latest information about the advancement of PRA from international experts.
- To improve the human reliability analysis (HRA) technique in Japan, CRIEPI established a qualitative method considering the failure of human cognitive processes and combined this with the conventional quantitative method to create an HRA guide for use in Japan. ➡ See p.20
- In order to establish protective measures against HEAF fires (secondary fires caused by high energy arcing faults), CRIEPI conducted internal arc tests using high voltage metal-enclosed switchgear components and clarified fire propagation conditions.

Evaluation of impact of major accidents

- WinMACCS code, developed by the U.S. Nuclear Regulatory Commission (NRC) to probabilistic risk assessment for environmental accident release (level 3 PRA), have been applied, and we clarified that the atmospheric dispersion coefficient of radioactive substances had a relatively large influence to the dose estimation.
- We developed a simple calculation tool to evaluate the atmospheric dispersion of radioactive substances during normal and accidental released cases with consideration of wet and dry deposition, building effects, etc.

Promotion and advancement of independent public safety activities

Non-technical Skills

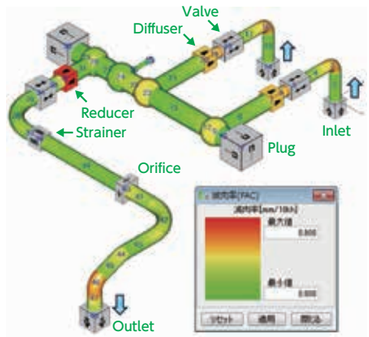
In contrast to individual technical skills such as specialist knowledge and skills, non-technical skills refers to skills such as communication and teamwork mainly engaged in within an organization.

- Regarding non-technical skill training for emergency response team personnel, CRIEPI standardized the method to assess training content and applied the same training technique at the Shimane Power Plant.

Safe operation of light water reactors

Advances to safety technology for light water reactors

- CRIEPI developed and improved prediction software for pipe wall thinning (FALSET) which makes it possible to predict the thinning rate and remaining life of power plant pipes (right).
- As it is important that the paint inside nuclear reactor containment vessels does not peel away during loss-of-coolant accidents, CRIEPI conducted mock tests for the 39 types of paint specifications in accordance with the related guideline (JEAG 4628-2010) and assessed their soundness. As a result, we confirmed that 13 types complied with this guideline.
- As preparation for the establishment of an assessment technique for embrittlement caused by neutron irradiation in reactor pressure vessels (RPVs) we clarified that the fracture toughness evaluation technique using a miniature test specimen developed by CRIEPI could also be applied to welded metal material in the same way as the base metal material. ➡ See p.22



Example of thickness reduction prediction using FALSET

Maintenance and expansion of radiation protection systems

- CRIEPI proposed a surface contamination dosage evaluation model employing rational exposure scenarios for formulating guidelines for moving out of commodities with radioactive contamination in emergency, existing (post-accident) and planned (normal times) exposure situations, and reflected this to the relevant guideline (Committee for Radiation Protection Committee of the Japan Health Physics Society). We also proposed a new indicator for radiation risk evaluation and clarified that, in regards to the effect of radiation on circulatory diseases, the current standards relevant to cancer provided sufficient protection. ➡ See p.24

Support for radioactive waste disposal operations

- In order to establish a technique to easily control the quality of bentonite, an artificial barrier material, we verified that the filter paper method known to be effective could achieve a measurement accuracy on par with the colorimeteric method, which utilizes an apparatus, if the instruments and steps used in measurement were regulated and standardized. Standards are expected to be established for this technique. ➡ See p.26

2-1. Outline of Results

Thermal Power Generation

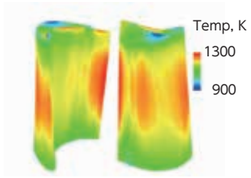
Ensuring reliability of existing thermal power plants

・In order to reduce the number of unscheduled stoppages at thermal power plants due to corrosion damage, etc. CRIEPI developed a rapid profile measurement technique and thinning analysis technique for the water wall tubes of boilers. These techniques utilize a portable 3D profile measuring device and aim to establish boiler tubes diagnosis technology that can be utilized in the field.

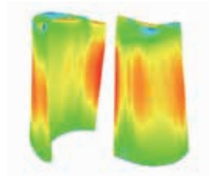
・Through analysis of a database for creep experiments on high-Cr steel scrap, CRIEPI clarified that the variation in welded joint life depended on the life of the base material as well as clarified that a correlation existed between base material life and fine precipitates through analysis using an aberration-corrected transmission electron microscope (Cs-TEM). By combining these observations with microscopic sample technology, we proposed a life evaluation method able to consider the specific properties of pipes in each power plant.
➡ See p.28

・To reduce the maintenance cost of gas turbines, CRIEPI developed an estimation method of turbine blade temperature which controls life of a gas turbine blade. The developed method uses a polynomial to describe a correlation between the blade temperature and parameters in operation, enabling rapid and easy estimation of the blade temperature at various operating conditions. Estimated distribution of temperature on a 1000℃ class gas turbine blade with the developed method agrees well with a computational simulation (right figure).

・To expand the effective utilization of coal ash, we developed a neutron boron gauge which focuses on the properties of boron that cause it to specifically capture neutrons in order to rapidly measure the boron content in coal ash. ➡ See p.30



(a) Computational simulation



(b) The developed method

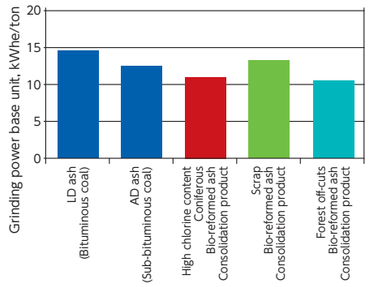
Comparison of estimated temperature distributions of a gas turbine blade

Gas Turbine
A rotational-type motor that converts the energy of high-temperature/high-pressure gas into mechanical power.

Thermal technology to mitigate environmental load

・In order to establish a life evaluation method under creep-fatigue conditions for material which has not yet been used in actual high temperature components, CRIEPI confirmed that creep lives of notched specimen were predicted with the same accuracy as a round bar specimen by considering the effect of stress multiaxiality on the creep damage evaluation.

・As part of efforts to expand the use of bio-reformed ash as the ingredient for woody biomass, CRIEPI clarified that by improving the energy density of bio-reformed ash through consolidation, an equivalent result to that of bituminous coal, which is commonly used for pulverization, could be obtained (right).



Comparison of pulverization properties of coal and biomass ash

Wood Biomass
A renewable resource derived from wood less expensive than petroleum and with lower carbon dioxide emissions.

Pulverized Coal-fired Thermal Power Generation
A method of generating power by pulverizing coal into a powder form, combusting this in a boiler and driving turbines using the generated steam.

Diversification of fossil fuels

・With the aim of reducing fuel cost due to fuel type expansion in thermal power generation, as part of efforts to utilize, high-fuel ratio bituminous coal (fuel ratio 2.5 – 4) which does not burn easily and is not utilized in Japanese pulverized coal-fired thermal power plants, CRIEPI evaluated the grinding characteristic when bituminous coal and high-fuel ratio bituminous coal were blended and clarified the effect of coal blending ratio on grinding power and pulverized coal particle diameter.

・In order to achieve optimal operation of pulverized coal-fired thermal power plants, the coal operation evaluation system has been developed the function enabling calculation of boiler efficiency considering coal properties and operation conditions was incorporated into this system and cost calculation accuracy was improved.

Fuel Ratio
A factor indicating the combustibility of a coal which focuses on the weight ratio of fixed carbon with poor combustibility to volatile matter with good combustibility.

Response to large-scale introduction of renewable energy

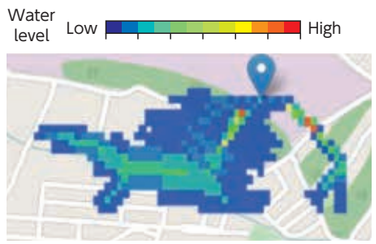
・As a countermeasure for unstable power output by high penetration of variable renewable energy, CRIEPI reviewed target performance values to be developed for gas turbine combined cycle (GTCC), which has superior start-up performance and load following performance. The target performance values examined included shortening start-up time and improving load following speed. At the same time, we assumed the future supply/demand situation predicted to have high penetration of variable renewable energy and tentatively calculated the effect that GTCC with the target performance values had on supply/demand management. ➡ See p.32

Hydropower Generation

Disaster prevention and maintenance and management for hydropower facilities

・As a part of risk assessment to prevent public damage resulted by overflowing or flooding from hydropower facilities, CRIEPI developed an analysis program to easily calculate the water arrival time, water depth and flow speed through minimal data entry, such as the target area, etc. (right).

・In order to efficiently measure the thickness of water turbine vanes used in hydropower even in the narrow space between individual vanes, CRIEPI developed a method to photograph the front and back faces of the water turbine vane using a small line laser and small camera, then accurately reproducing a cross-section profile of the water turbine vane based on image data. ➡ See p.34



Simulation of virtual flooding assuming overflow (The background figure uses OpenStreet Map data)

Renewable Energy

System stabilization on large-scale introduction of renewable energy

・From the perspective of power grid stability (particularly during accidents), it is necessary to operate a synchronous generator of a certain scale even during high penetration of renewable energy. CRIEPI proposed the “generator stop ratio” as a useful indicator to evaluate an appropriate ratio of the synchronous generator. ➡ See p.36

Expanded introduction of biomass and geothermal power generation

・In order to contribute to the advancement of geothermal reservoir exploration technology to increase the efficiency and lower the costs of geothermal development, CRIEPI conducted a survey relating to the development of existing geothermal power plants and clarified the importance of fracture belts and alteration belts as well as appropriated items to suit depending on the strata type thereof.

Geothermal Reservoir
A “reservoir” refers to a rock layer or stratum where water that has seeped through the ground surface has accumulated and if the water in the reservoir is heated due to being in a geothermal region, etc., this is then referred to as a “geothermal reservoir”.

Fracture Belt
An area where a force is being applied in a fault adjacent to a strike-slip fault in the same direction.

Alteration Belt
An area where the rock bed has been altered due to heated water from deep underground in a geothermal region, etc.

2-1. Outline of Results

Electric Power Transmission and Distribution

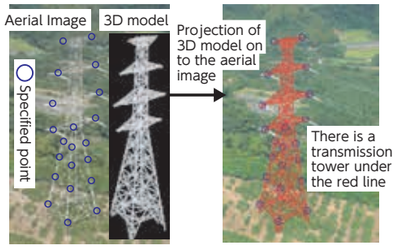
Response to reforms in electric power system

・Services utilizing smart meters and IT are expected to become more established due to the introduction of smart grids. However, the interoperability between the applications for the services is a problem due to the difference among the communication standards for each application. In order to solve this issue, CRIEPI developed a communication platform that enables the applications to use each standard via a common API (Application Program Interface). ➡ See p.38

Formation, maintenance and upgrades of substations and transmission lines

Advancing preservation technology for aged facilities

・Aiming at establishing a preventive maintenance for operation of transmission towers, CRIEPI developed a method for corrosion evaluation of each overhead transmission tower. Moreover, in order to efficiently assess the state of corrosion, CRIEPI developed a technique to extract the transmission tower's steel portion from an aerial image (right).



Example of results of transmission tower extraction from an aerial image

・In order to detect water-tree degradation in an insulation layer of XLPE cables for power distribution, CRIEPI found a potential solution involving applying current integration method to the XLPE cables for the first time and detecting short water trees before they bridge the cable insulation, which was previously difficult to achieve.

・In order to efficiently measure density of deposited salt, which leads to the deterioration in insulation performance of porcelain insulators, CRIEPI established a method utilizing laser-induced breakdown spectroscopy (LIBS) which shows potential as a means of performing remote measurement rapidly on-site without the need to remove insulators from power transmission equipment.

Support to streamline facility design and operate facilities

・As part of efforts to save labor spent on surveillance rounds and inspection of transmission/transformer equipment in line with lightning strikes, CRIEPI has developed the advanced lightning location system, which able to pinpoint lightning strikes at high accuracy (with an error margin of 50 m) as well as estimate the lightning energy necessary for damage level evaluation. ➡ See p.40

・In order to prevent electric wire (power line wire, ground wire) melting/breaking caused by high current arc discharge such as lightning, as part of efforts to select electric wires which do not melt/break easily, CRIEPI developed a technique to calculate the extent of melting/breaking in strands which comprise an electric wire, then predict the number of strands that have been melted/broken from the calculated melting amount. ➡ See p.42

・CRIEPI made progress in the development of cable cleaning technology used in the removal of trace PCB found in transformers in use and newly proposed an area-specific cleaning making it possible to clean each individual portion of a transformer. ➡ See p.44

・In order to control the distance between power cables and surrounding trees, CRIEPI developed a method to easily and inexpensively measure distance using a drone and showed it was possible to measure distance with the same accuracy as the conventional aerial measurement. ➡ See p.46

Next-generation equipment technology anticipating future facility upgrades

・As a part of efforts for the practical application of high-voltage SiC power semiconductor devices, CRIEPI developed a technology to effectively modify the electric properties of SiC by adding vanadium element during the crystal preparation process. This is expected to help prevent conduction degradation and improve switching performances.

Water Tree/Bridging

A phenomenon whereby an extremely small amount of water diffuses into the insulation layer of XLPE (cross-linked polyethylene) cables, condensates at localized points where the electric field is high and forms branches (tree). "Bridging" is when the water tree grows to the length equal to the thickness of the insulation layer between inner and outer conductors of XLPE cables.

Laser-Induced Breakdown Spectroscopy (LIBS)

A technology whereby laser pulses are focused on the material being measured causing a plasma to form, then the light emitted from the plasma is analyzed, making it possible to perform identification and concentration measurement of elements contained within the material being measured.

SiC Power Semiconductor

A semiconductor element for power equipment made from silicon (Si) and carbon (C), with excellent voltage resistance and high-frequency operation.

Smart Meter

An electric power meter equipped with a communication function. Smart meters utilize the network between electric power companies and consumers to provide services such as visualization of electricity usage.

Cable Surfing Phenomenon

A phenomenon whereby underground power cables move due to the vibration from vehicles passing overhead. In the worst case scenario, the movement of the cable core could trigger insulation damage.

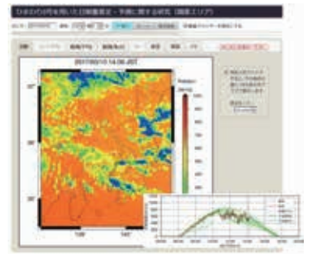
Bi-directional Non-contact Power Supply

Non-contact power supply is one form of electric power supply and is also referred to as "wireless power transmission". Its use is anticipated in electric vehicles (EV). If power can be supplied not only from the power grid to an EV but also vice-versa, the method is referred to as "bi-directional non-contact power supply".

Response to changes in supply form and demand-side changes

System stabilization on large-scale introduction of renewable energy

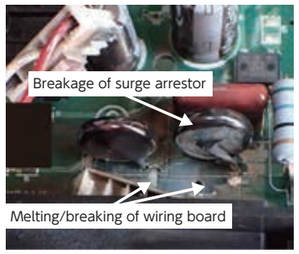
・As part of efforts to accurately assess the output variation in photovoltaic power generation, CRIEPI developed a solar radiation estimation/prediction system with high accuracy by utilizing satellite imagery from Himawari 8, which has significantly improved performance compared to Himawari 7, such as shortened monitoring time interval (right).



Example of a screen display for the solar radiation estimation/prediction system

Forming, maintaining and update power distribution facilities

・CRIEPI clarified the circumstances when a smart meter is damaged due to energy from lightning current passing through arrester equipment inside smart meters when power distribution lines are struck by lightning. We also clarified that the further away a smart meter was from a pole transformer, the greater the energy from lightning current passing through the arrester became, meaning the smart meter was more likely to be damaged (right).



Failure of a smart meter due to energy from a lightning current

Response to disaster and human risks

・CRIEPI proposed a model to express the surfing phenomenon observed in underground power transmission cables and verified the adequacy of this model through comparison with the result of a mock cable movement test conducted on a small-scale indoor mock-up one-tenth of actual size.

・In regards to the three types of snow damage to power transmission equipment (heavy snow accretion, galloping, salt/snow damage), CRIEPI established a method to predict regions with high potential of snow damage based on the latest findings and proposed a flow to select appropriate snow damage countermeasure products to suit region-specific weather patterns and equipment specification. ➡ See p.48

Customers Services

Promotion of energy conservation and electrification and enhanced customer satisfaction

・As part of efforts to increase heat pump efficiency, in order to prevent the accumulation of mist on the unit outside of the heat pump chamber (heat exchanger), CRIEPI developed a non-mist heat pump which utilizes a heat exchanger coated in adsorbent. By doing this it is anticipated that efficiency will improve by 10 to 30% of conventional heat pump hot-water supply systems. ➡ See p.50

・In order to optimize the design of ventilation fans for electric kitchens for further promotion of saving energy activity, CRIEPI conducted a test to evaluate the required amount of ventilation. The electric kitchen ventilation design guideline draft prepared based on the result of this test has been reflected in JEHC103 - 2017 (Japan Electro-Heat Center).

・As a part of efforts for the practical application of bi-directional non-contact power supply using a magnetic resonance method as a means to supply power to electric vehicles, we revised the material used in power supply coils and improved transmission efficiency.

2-1. Outline of Results

Environment

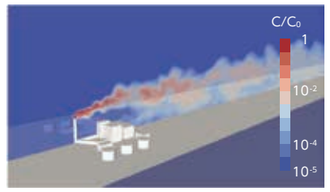
Response to environmental policy and regulations

- CRIEPI analyzed precedents on introduction of carbon pricing by Europe and the US, regions leading the way in this area, and extracted issues in preparation for future policy study. Moreover, in regards to implicit carbon price, we organized a definition, evaluation methods, etc. See p.52
- Toward the next IPCC (Intergovernmental Panel on Climate Change) report, CRIEPI developed a method to compare the uncertainties relating to climate, policy and technology in long-term CO_2 emissions reduction scenarios and quantitatively showed that the uncertainty of climate prediction is large compared to that of policy and technology.
- In order to assess changes in the source apportionment of fine particulate matter ($PM_{2.5}$), CRIEPI conducted a numerical analysis utilizing a chemical transport model. The result clarified that the contribution of domestic anthropogeninc sources between the years 2000 and 2010 was practically steady (around 40%) and, of this, the impact of power plants was around 2.8 to 3.9%.

Efficient environmental assessment

Environment Assessment
A process of assessing the likely environmental impacts of a proposed project or development in advance by business operators to prepare a better project plan from the perspective of environmental conservation.

- As a substitute to the wind tunnel experiment, CRIEPI developed a 3D numerical model to predict exhaust gas dispersion of low-stack LNG thermal power plant and wind speed distribution around coal-storage yard (right). Moreover, we improved the 3D warm effluent dispersion prediction model developed by CRIEPI, making it possible to predict the recirculation ratio of warm effluent when taking cooling water (sea water) from the sea near the power plant.



3D numerical model for the prediction of exhaust gas dispersion as a substitute for the wind tunnel experiment

Utility Management

Ensuring consistency of power system reforms and energy measures

Gross Bidding
A system whereby the generation division and retail division within an incumbent power utility trade power through power exchange in order to boost liquidity of wholesale power market.

- We clarified that the share of new suppliers in various areas of Japan after retail market fully opening up could be around the same as European countries, taking account of potential price reduction rate due to switching.
- We investigated the liquidity of European wholesale markets and clarified that trading volume of spot market was expected to increase through the adoption of gross bidding, which is already set to be introduced in Japan, and implicit auctions for capacity of interconnection. We also demonstrated that the volume could be influenced by the wholesale electricity price.
- After investigating overseas precedents relating to new markets design created based on electric system reform, and conducting a quantitative analysis of the model Japanese wholesale market, we clearly indicated that, for coexistence of high penetration of renewable energy and security of supply, it is advisable to create a capacity market, etc. See p.54

Common Cross-Cutting Field

Overall optimization through supply/demand coordination

Electric Power Supply/ Demand Management Technique
A technique to manage the supply and demand of electric power and maintain electric power quality through the coordination of energy equipment possessed by consumers and the electric power grid.

- With the aim of establishing an electric power supply/demand management technique, CRIEPI has added a function to calculate electrical device power consumption depending on regional weather conditions and PV power into the electric power supply/demand simulation tools developed to date, making it possible to arbitrarily simulate electric power supply/demand for any given area in Japan.

Common technology for application in diverse fields

- As part of efforts to establish a rational maintenance & operation technology for electric power equipment, CRIEPI engaged in activities for the advancement of energy harvesters (for energy harvesting), which is necessary for maintenance-free monitoring of them. We succeeded in prototyping a vibrating power generation device capable of power generation even at frequencies of 100 Hz or less, which had been difficult to use up until now. See p.56
- In order to alleviate the workload and improve efficiency regarding maintenance of electric power equipment, CRIEPI engaged in the development of an AI technique which is both simple and capable of high-level pattern awareness. By applying this technique to the analysis method for insulation oil widely used in judgement of OF cable condition, we succeeded in improving the correct judgment rate from around 50% to around 80% See p.58

Major New Research Facilities

Micro Focus X-ray CT and Transmission Electron Microscope

Major new research facilities are a micro focus x-ray CT with an extremely small beam diameter which enables to obtain 3D structure at a high spatial resolution in the range of around 10 μm and a general-purpose transmission electron microscope. By using these facilities it is possible to evaluate the activity of the faults within and around power plants based on microscopic structural analysis.

Measurement Equipment for Leakages during Distribution Pipe Breakages

This equipment is capable of high-accuracy monitoring and measurement of the outflow behavior of gas from breakages in the grid distribution pipes of power stations by simulating such a situation then utilizing a high-speed camera and laser. Findings obtained from this equipment, when combined with the results obtained from pipe defect analysis and cognitive analysis, will help to choose a suitable maintenance method for grid distribution pipes used in power stations.

List of Research Subjects

Nuclear power generation

●Greater advancements in safety of light water reactors

■ Greater advancements in evaluation techniques for core damage

- 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 in Severe Accident

■ 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-resistant evaluation techniques on ground and structures of nuclear power plants

■ Establishment of probabilistic risk assessment (PRA) technology

- Development of risk assessment methodology for nuclear facilities
- Promotion of Risk Informed Decision Making Process at Nuclear Power Plants

■ Evaluation of impact of major accidents

- Development of evaluation method of radioactive material in environment

■ Promotion and advancement of independent public safety activities

- Development of voluntary safety action programs for nuclear power stations in consideration of human factors

●Safe operation of light water reactors

■ Advances to safety technology for light water reactors

- Development of evaluation techniques for pipe thinning at light water reactors
- Improvement of preventive maintenance technology for LWR components and piping
- Improvement of water chemistry for radiation intensity reduction
- 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 technologies 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

- Development and systematization of long-term safety assessment technologies for radioactive waste 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

- Development of decommissioning and defueling technologies

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 expanding 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

●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 stabilization on large-scale introduction of renewable energy

- ▽Development of next generation power distribution network system
- ▽Development of power system stabilization technology in trunk transmission system assuming high penetration of renewable energy
- ▽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
- ▽Consideration of countermeasures for large-scale introduction of renewable energy

●Expanded introduction of biomass and geothermal power generation

- Development of innovative technologies for promoting the introduction of geothermal power
- ▽Development of technology 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 andreinforcing 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 technology to build power information communications 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
- Verification of washing mechanism and development of practical washing technologies for PCB removal from PCB contaminated transformer
- 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 stabilization on large-scale introduction of renewable energy

- Development of next generation power distribution network system
- Development of power system stabilization technology in trunk transmission system assuming high penetration of renewable energy
- 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
- Development of simulation methods for distribution-system transients based on an electromagnetic transient program

●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
- Establishment of protective measure technologies against wind and snow damage of overhead transmission and 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

Customers services

●Promotion of energy conservation and electrification and enhanced customer satisfaction

- 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 sector
- Development of Customer Satisfaction Measures utilizing Energy Related Information
- Value evaluation for next - generation power demand management

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

●Ensuring consistency of power system reforms and energy measures

- Issues in institutional design of the electricity system reform
- Consideration of countermeasures against large - scale introduction of renewable energy
- Structural analysis of energy and electricity demand

Common cross-cutting field

●Overall optimization through supply/demand coordination

- Optimization of advanced power supply and demand management

●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

● : 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

Thermal-Hydraulics in Reactor Core Under Fuel Uncovering Condition of Rod Bundle

Contributions for improving the safety of nuclear reactor with thermal-hydraulic tests of fuel-simulated rod bundle

Background

In order to quantify safety limit for the critical situations such as reactivity initiated accidents (RIA), whereby the reactor power increases rapidly due to the control rod drop of a boiling water reactor (BWR) or upspring of the one of a pressurized water reactor (PWR), to understand safety margin of a situation where the water level of a nuclear reactor is falling with explosion of fuel due to an accident out of the design standard, it is necessary to clarify the surface temperature of the cladding tube and flow/cooling properties of the coolant under near-accident conditions relevant to pressure and temperature. CRIEPI has developed pulse-type heating technology of fuel-simulated rod bundle for the situation of RIA and measurement techniques at high time/spatial resolution in the test section under high temperature/pressure, in order to clarify thermal dynamics of a nuclear reactor in an accident.

Outline of Results

◇ Clarification of Critical Heat Flux

In order to simulate an RIA, CRIEPI developed a direct electrical heating rod which is able to rapidly heat the fuel-simulated rod bundle and measured the cladding tube surface temperature while gradually changing the heat flux. As a result of a high temperature/high pressure test, it was confirmed that at the condition beyond a certain heat flux, the surface of the heated-cladding tube became dried and the surface temperature rose rapidly, therefore the state of high temperature was maintained even after the stop of the heating (Fig. 1). The minimal heat flux in which this state occurs is defined as critical heat flux (CHF) and it was clarified that the rapidly steam-generated behavior each experimental condition by measuring the CHF from atmospheric to high temperature/pressure condition.

◇ Clarification of the coactive water-level dropping process in a fuel-simulated rod bundle

Regarding the coactive fuel exposure process when the coolant cannot be poured into a reactor core, CRIEPI combined X-ray CT imaging and its transmission image with our original void fraction measurement technology, and devised a predicting equation of void fraction for severe accident analysis to measure the detailed void fraction distribution and the time-depended variation of water level.

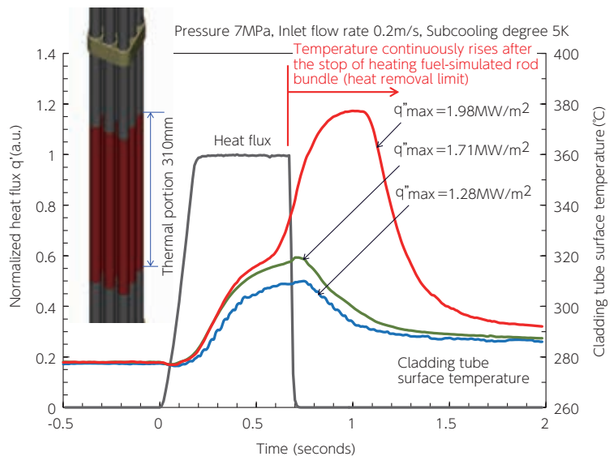


Fig. 1 An example of the change in cladding tube surface temperature over time during an RIA triggered by a control rod falling

Control rod
A rod or plate-shaped device which absorbs the neutrons generated during nuclear fission of a nuclear reactor and reduces the nuclear fission reaction. The control rod is effective in suppressing output.

Reactivity initiated accident (RIA)
Accidents causing the nuclear reactor's output to increase rapidly due to the control rod falling or being projected out and an abrupt reactivity to be initiated within the reactor.

Pulse
An electrical current or electrical wave that flows in an extremely short time interval.

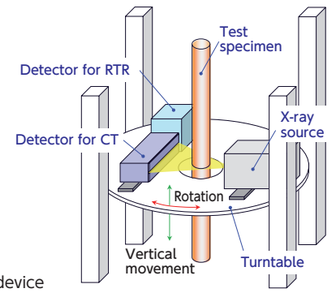
Heat flux
An amount of heat that crosses per unit of area per unit of time.

Void fraction
The ratio of the volume of gas gas-liquid two-phase flow.

Severe accident
An accident which surpasses the assumptions made during the safety design/evaluation process for a nuclear reactor.

Hiroki Takiguchi
Thermal Hydraulics Systems Domain,
Nuclear Technology Research Laboratory

Reactor Internal Flow Visualization Unit X-ray CT/real-time Radiography Device
A device able to visualize the two-phase flow within a mock fuel ssembly in 3D format.



Conceptual diagram of an X-ray CT/real-time radiography device

Application Examples of Research Results

Aim to increase the reliability of safety evaluations and improve nuclear power plant safety by applying the void ratio prediction equation to safety analysis in the critical heat flux and fuel exposure processes during an RIA.

References: T. Arai, M. Furuya et al., Multiphase Sci. Tech., Vol. 27, p. 203 (2015)

Establishment of a Method to Systematically Evaluate the Activity of Faults in Nuclear Power Plants, Identify Active Faults and Help Improve Facility Safety

Nuclear Power Generation

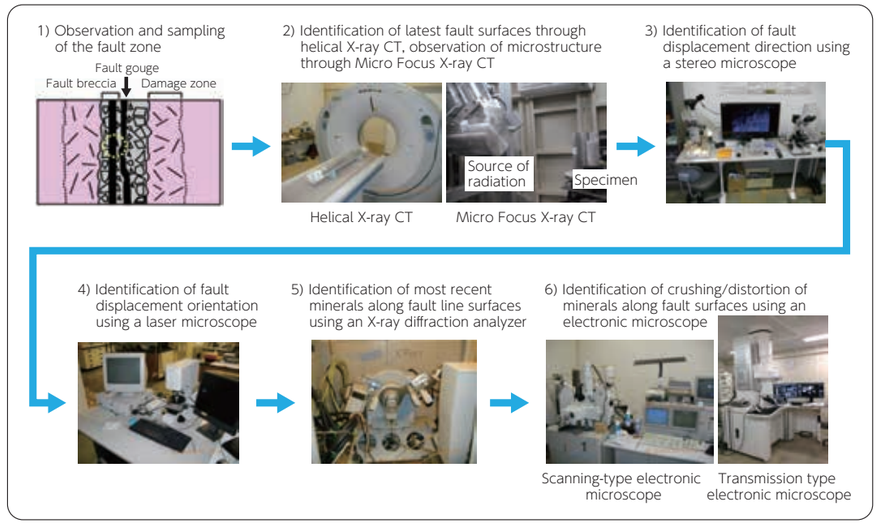
Background

In order to improve the safety of nuclear power plants, it is necessary to appropriately evaluate the activity of faults which exist within the power plant site. Even the new standards established after the Great East Japan Earthquake include a requirement to identify fault lines which may impact the safety of nuclear power facilities and make detailed evaluations of fault activity, such as when the latest activity was, the amount of displacement since the last activity, etc. CRIEPI has established a method to evaluate fault activity based on the crushing properties of faults within bedrock and is working to develop a method to evaluate the activity of faults within nuclear power plant facilities throughout Japan with higher accuracy.

Outline of Results

◇ Establishment of a fault activity analysis flow

Regarding the crushing properties of faults within bedrock, CRIEPI established an analysis flow enabling detailed evaluations, from macroscopic evaluations such as outcrop observation and boring core observations to microscopic evaluations using electronic microscopes, such as identification of mineral damage and distortion along faults. We applied our analysis flow to an actual nuclear power plant and objectively observed that the faults within the plant site could not be considered active faults in regards to earthquake resistance (faults for which activity since the Late Pleistocene period approx. 120/130,000 years ago can't be ruled out).



Fault activity analysis flow

◇ Demonstration of the rationality for conducting fault surveys at nuclear power plants

As a result of conducting a trench survey and fracture zone analysis of the surface fault ruptures that appeared after the 2014 Northern Nagano Earthquake and 2016 Kumamoto Earthquake, CRIEPI confirmed the accumulation of fault displacement and layered makeup of the fault gouge, which is characteristic of active faults, even in those areas where active faults weren't shown in existing literature. From this we clarified it was possible to appropriately evaluate whether a fault was active or not by conducting a fault survey on a nuclear power plant site.

New standards

After the Fukushima Daiichi nuclear disaster, the Nuclear Regulation Authority (NRA) issued these standards under which it is mandatory to implement countermeasures for severe accidents and these regulations specify stringent safety countermeasures assuming earthquakes and tsunamis. These standards must be met in order to operate a nuclear power plant.

Active faults

Faults that have been repeatedly active from the new geological age onwards and have the potential to be active in the future.

Outcrop observation

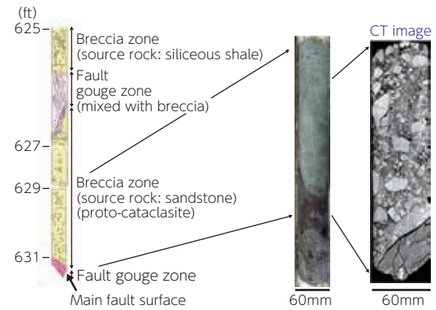
An observation of places outside where strata or rocks are exposed conducted in order to obtain information on the stratigraphic relationship of strata, etc.

Trench survey

A survey involving digging a trench to a depth of several meters to several dozen meters at a location where it is believed fault activity has occurred and closely observing the strata in the trench walls in order to investigate past activity of active faults.

Keiichi Ueta
External Natural Event Research Team, Nuclear Risk Research Center

Helical X-ray CT
A device enabling the detailed, non-destructive, 3-dimensional observation of a specimen by transmitting X rays inside the sample.



Example of results of an observation into the internal structure of a fracture zone
The photo in the middle shows the boring core specimen, while the photo to the right shows the helical X-ray CT photo of the boring specimen.

Application Examples of Research Results

The fault activity evaluation technique proposed by CRIEPI is incorporated and quoted in documentation for reviews to confirm conformity with the new standards for nuclear power plants across Japan. It is also utilized to evaluate the activity of faults on a power plant's site.

References: CRIEPI TOPICS Vol.18 (2014)

Nuclear Power Generation

Development of a Human Reliability Analysis (HRA) Guide for the Utilities

Aiming for the appropriate assessment of human error on nuclear power plants risk evaluation

Human Reliability Analysis (HRA)
HRA quantitatively and qualitatively evaluates the impact of human error probability (HEP) and safety improvement as part of probabilistic risk assessment (PRA).

THERP (Technique for Human Error Rate Prediction)
A quantitative assessment method for human error probability developed and published in 1979 with the support of the U.S.NRC.

Background

In the probabilistic risk assessments (PRA) of nuclear power plants there is a need to quantitatively assess the human error probability (HEP) to ascertain the extent that human errors by operators, etc. impact risk. In recent years, the reliability of nuclear power-related plant equipment is improving, therefore the impact of human error on risk is becoming relatively higher and the importance of Human Reliability Analysis (HRA) is increasing. The HRA quantitative method (THERP) currently being used in Japan is the method of handling the human error at the process of emergency procedure (mainly execution failure). However, in international HRA research trend, the method (Ex. Decision Tree Evaluation Model) that treats contexts of cognition / diagnosis failure in case of emergency situation will be becoming the next generation standard methods. CRIEPI is working to create an HRA Guide in order to introduce these techniques in Japan. And we are also working on the development of new HRA methods which focuses on the decision-making process in terms of response during severe accidents, including situations where there are no clear procedures.

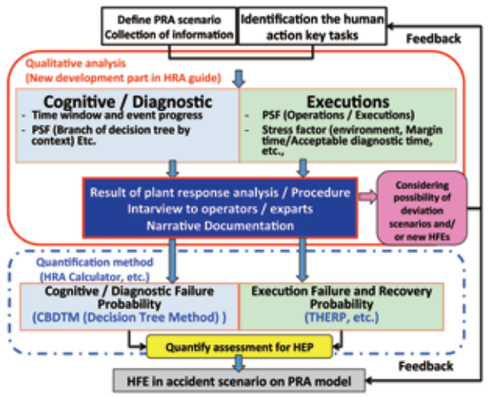
Outline of Results

◇ Developing the HRA Guide

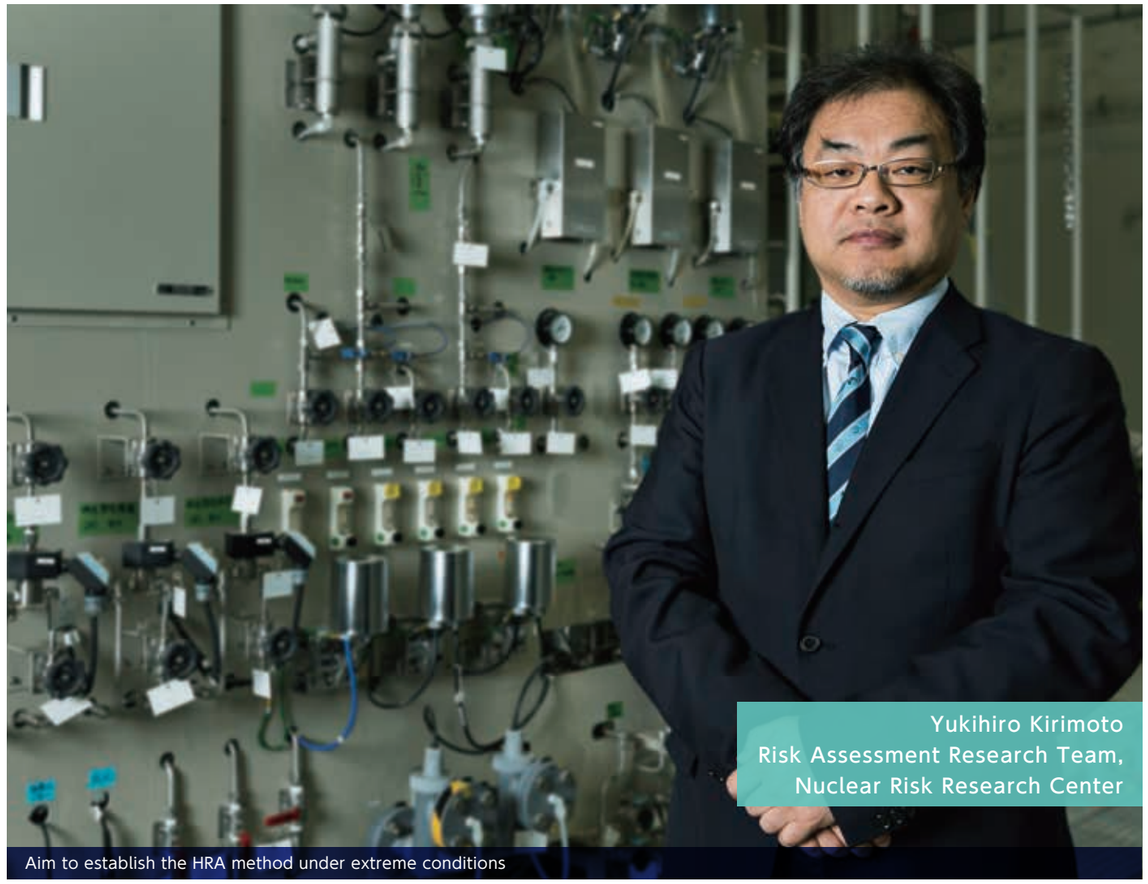
CRIEPI has established a new qualitative analysis ("Narrative developing") method for HRA based on the concept that the occurrence of human error is not random but occurs by the context of cognition and action in the environment in which humans (operators). Moreover, we have developed the HRA Guide, in order to apply this qualitative analysis approach to the quantifying method (a combination of Decision Tree and THERP methods) currently being used as the standard in the U.S., etc. By using this guide, it is possible to conduct HRA based on clear grounds for judgment against the input data from the time of the analysis.

◇ Extraction of problems for development of new HRA method under extreme conditions

CRIEPI applied the HRA guide to the assessment, using the scenario of transporting, installing and supplying fuel to the mobile water injection pump for the emergency alternative core spray, and reviewed problems with current quantification methods. As a result, CRIEPI discovered that THERP, which focuses particularly on human behavior as random failure, has the issue that, if descriptions on the multi-layered nature of operation steps and recovery procedures per individual task step were lacking, the failure probability was extremely high. CRIEPI aim to utilize the knowledge gained from analyzing these types of actual severe accident scenario, develop a new quantifying method to respond to human error context and revised HRA guide under extreme conditions. CRIEPI aim to utilize the knowledge gained from analyzing these types of actual severe accident scenario, develop a new quantifying method to respond to human error context and revised HRA guide under extreme conditions. Configuration of an HRA guide using the concept of cognitive / diagnosis failure.

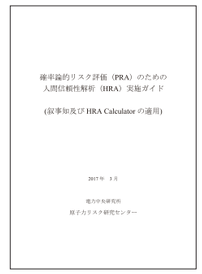


Configuration of an HRA guide using the concept of recognition/diagnosis failure, which is the latest technique



Yukihiro Kirimoto
Risk Assessment Research Team,
Nuclear Risk Research Center

Aim to establish the HRA method under extreme conditions


確率論的リスク評価（PRA）のための
人間信頼性解析（HRA）実施ガイド
(従事知及び HRA Calculator の適用)
2017年 3月
電力中央研究所
原子力リスク研究センター

Human Reliability Analysis Guide
(HRA Guide)

Application Examples of Research Results

Japanese utilities are considering using the quantifying tool for human error rate being used in the U.S. etc in probabilistic risk assessments for reactor core damage that occurs due to causes intrinsic to the facilities/operational management of power plants. The HRA Guide created by CRIEPI is anticipated as a tool for ensuring appropriate data is inputted into this quantifying tool.

References: Y.Kirimoto et al., "Developing an HRA Guide for Japanese Utilities Combining the NRC Narrative Approach with the EPRI HRA Calculator", A-093, PSAM13
Y.Kirimoto et al., "NRRC HRA upgrading, and research plan of HRA method development for extreme condition"SS6-5, PSAM13

Nuclear Power Generation

Development of a Strength Assessment Technique for Nuclear Reactor Pressure Vessel Steel Using Ultra-small Test Specimens

Contribute to the securing of integrity for nuclear reactors through a strength assessment effectively utilizing surveillance specimens

Background

The steel used in nuclear reactor pressure vessels (RPV) are embrittled due to the irradiation of neutrons, therefore it is important to assess whether the steel has sufficient strength (fracture toughness) to confirm the integrity of nuclear reactors after the irraidation. For this reason, every RPV has multiple surveillance specimens installed inside and the specimens are periodically retrieved and subjected to a fracture toughness evaluation. In order to perform a fracture toughness evaluation throughout the entire period of a reactor's operation, a greater number of test specimens are required, therefore there is a need for technology to enhance data, such as re-using surveillance specimens. CRIEPI is developing a fracture toughness evaluation method using an ultra-small C(T) (Mini-C(T)) specimen as small as a person's thumbnail, making it possible to machine additional specimens from the broken halves of the surveillance specimens spent for a Charpy impact test.

Outline of Results

◇ Development of a technique for fracture toughness evaluation utilizing Mini-C(T) test specimen

Several Mini-C(T) specimens can be machined from the broken halves of a surveillance specimen used as a Charpy impact test specimen (10 × 10 × 55 mm) (Fig. 1). CRIEPI confirmed that fracture toughness evaluated by Mini-C(T) specimens and the Mater Curve method is equivalent to that by larger C(T) specimens. As such, it has become possible to obtain additional fracture toughness data coexistent with the Charpy impact test currently being used.

◇ Confirmation of potential for application in weld metal materials

A pressure vessel is made by welding steel plates (base material) together. CRIEPI clarified that Mini-C(T) specimens could also be used to assess the fracture toughness of weld metal, even though the weld metal potentially has material variability due to the heating history during the weld process. We confirmed that the assessment results were consistent among multiple institutions both in Japan and overseas.

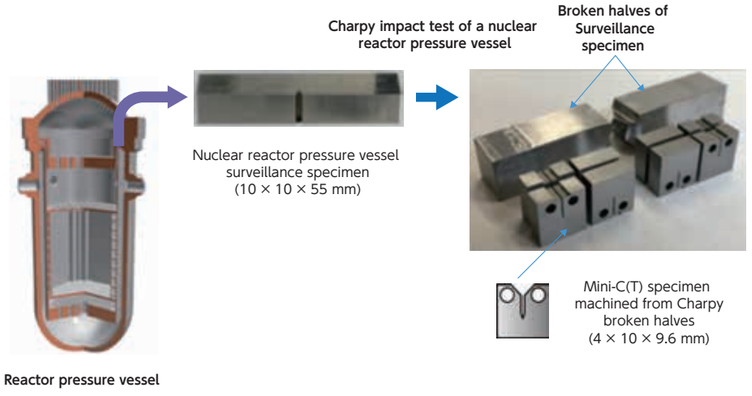


Fig. 1 Concept image of Mini-C(T) specimen retrieval

Charpy impact test
Breaking a square specimen with a notch in it through high-speed impact to assess the specimen's toughness based on the energy needed for the break.

C(T) test (Compact Tension test)
A test which involves pulling (tensing) a square test specimen with a crack to determine the strength when the specimen is broken from the tip of the crack.

The Master Curve Method
A type of fracture toughness evaluation characterized by expressing the dependency of the specimen in a formula.

Masato Yamamoto
Vessels/Reactor Structures Unit,
Nuclear Power Plant Maintenance Research Team

Fracture toughness evaluation device
A device that pulls a specimen with a crack in its center in a vertical direction to assess the strength when the specimen breaks from the crack (fracture toughness).

Photo of the C(T) specimen
From the top: Mini-C(T) specimen, 0.5 inch C(T) specimen, 1 inch C(T) specimen. The rectangular object shown in the bottom left is a surveillance specimen for a nuclear reactor pressure vessel.

Application Examples of Research Results

The fracture toughness test and evaluation method using Mini-C(T) specimens developed by CRIEPI are contributing to securing the integrity of nuclear reactors in various ways, such as being standardized as Japan Electric Association Code JEAC4216-2015 "A test method for the determination of ferritic steel fracture toughness reference temperature (T_0)."

Reference: Masato Yamamoto, Naoki Miura, "Applicability of Miniature-C(T) Specimen for the Master Curve Evaluation of RPV Weld Metal and Heat Affected Zone," ASME 2016 Pressure Vessels and Piping Conference, PVP2016-63762, (2016)

Nuclear Power Generation

Establish a Radiological Protection System with Scientific Rationality

Reflect to the Radiological Protection Standards and Streamline Radiation-related Work

Background

After the Fukushima Daiichi nuclear disaster, different radiation exposure situations, including emergency, existing (post-accident) and planned (normal situation) exposure situations were mixed both geographically and chronologically. Radiological protection standards are separately stipulated corresponding to those exposure situations, however the current standards require adjustment as they do not sufficiently consider the balance between mixed radiation exposure situations. Moreover, there is lively international debate regarding the treatment of non-cancer effects, such as circulatory diseases, since radiation risk has primarily been defined based on cancer-related effects by the ICRP. In response to this situation, CRIEPI is 1) formulating academic standards for the adjustment of the current standards for radiation management of nuclear power operators (standards for transporting goods from radiation controlled area) and 2) establishing a protection system based on the new radiation risk concept of covering non-cancer effects applicable to both planned and emergency situations.

Outline of Results

◇ Formulation of guidelines

CRIEPI has developed a surface contamination dose evaluation model, which can estimate the radiation dose of the members of the public due to the reuse of surface contaminated material, by classifying the three categories of handling objects by hand, handling objects at close proximity and handling objects at a distance (bottom figure on right-hand page). Utilizing this evaluation model, we have prepared a proposal for guidelines on moving out of contaminated goods considering the balance between each exposure situation (emergency, existing and planned). This proposal was adopted into the guideline as quantitative- and scientific-based standards by the Radiological Protection Standardization Committee of the Japan Health Physics Society.

◇ Establishment of a New Radiation Risk Concept

CRIEPI proposed Minimum Provable Risk (MPR) (Fig. 1) as a new indicator able to prove epidemiological detectability in radiation risk evaluation. By using the life table method with Japanese statistical data of population and annual mortality rate for cause of death, we have calculated the lifetime mortality risks and their variations for circulatory diseases and cancer. Then based on these results, we have estimated the MPR for circulatory diseases (MPR_N) and for cancer (MPR_C), respectively. The result quantitatively indicated that, compared to cancer, circulatory diseases had a larger MPR (Fig. 2). This clarified that radiation risks related to circulatory diseases are sufficiently suppressed by the current standards that aim to protect against radiation risks related to cancer.

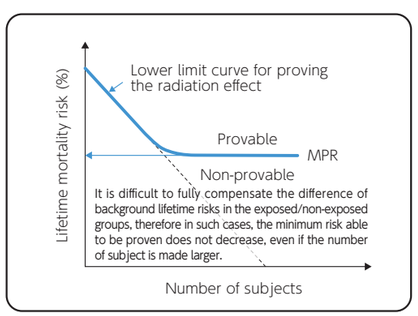


Fig. 1 Definition of Minimum Provable Risk (MPR)

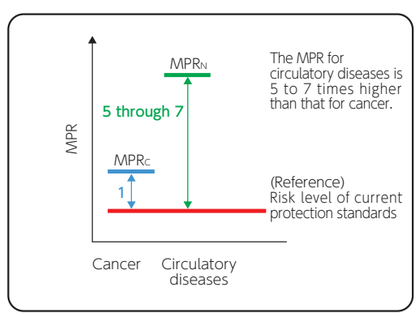


Fig. 2 Comparison of Minimum Provable Risk (MPR)

Emergency exposure situations
Unforeseen situations that may require emergency and long-term protection measures.

Existing exposure situations
Situations in which exposure existed prior to decision on control being conducted.

Planned exposure situations
Situations in which the protection measure was planned in advance and the scale and scope of exposure can be rationally predicted.

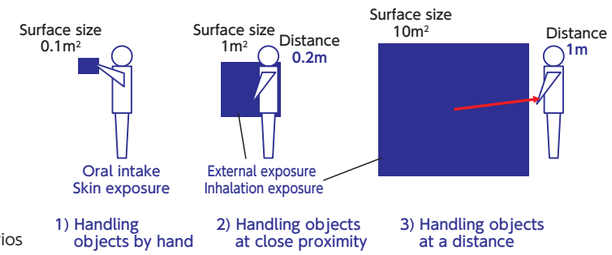
ICRP (International Commission on Radiological Protection)
An independent, international academic organization that provides recommendations on radiological protection from an expert standpoint.

Life table
A table expressing the probability of people of varying ages becoming deceased within one year's time and the average number of years the individual is expected to live, etc. using indicators such as mortality and average life expectancy.

IAEA (International Atomic Energy Agency)
A self-governing body established under the United Nations for the purpose of promoting scientific and technical cooperation regarding the peaceful utilization of nuclear power.

Michiya Sasaki / Takatoshi Hattori
Radiation Safety Research Center, Nuclear Technology Research Laboratory

Engaging in efforts to establish a radiological protection system based on the new concept of "Minimum Provable Risk".



3 types of representative exposure scenarios

Application Examples of Research Results

We will aim for our guidelines to be reflected in the international standards (clearance standards) currently being examined by the IAEA (International Atomic Energy Agency). We will make presentations to stress that the circulatory disease will relatively be difficult to be proven as a effect of radiation exposure in international meetings in order to reflect the results to the next ICRP's main recommendations.

References: Ogino et al., J. Radiol. Prot., Vol. 36, p. 865 (2016)
Sasaki et al., Jpn. J. Health Phys., Vol. 51, p. 167 (2016)
Ogino et al., Appl. Radiat. Isot., Vol. 67, p. 1282 (2009)

2-2. Major Research Results-6

Nuclear Power Generation

Development of a Highly-Reliable Quality Control Technique for an Engineered Barrier Material

Contributing to the construction and operation of low-level radioactive waste disposal facilities

Pit disposal

The disposal method of low-level radioactive waste with a relatively low radioactivity concentration. The waste is disposed in an artificial structure such as a concrete pit in approx. 25 meters underground.

Sub-surface disposal

The disposal method of low-level radioactive waste with a relatively high radioactivity concentration. The waste is disposed in a tunnel or silo-like structure made of concrete at a depth of 50 to 100 meters underground.

Background

The engineered barrier in the pit disposal and the sub-surface disposal facilities for low-level radioactive waste will be constructed by using clay (bentonite) in order to prevent nuclide migration. An important function of the bentonite is low permeability. Low permeability of the bentonite is mainly determined by the montmorillonite content, because the montmorillonite has a characteristic to swell by absorbing water. In order to ensure safety in the disposal, CRIEPI is promoting research to realize the highly-reliable quality control of the engineered barrier material through precise measurement of the montmorillonite content of bentonite.

Outline of Results

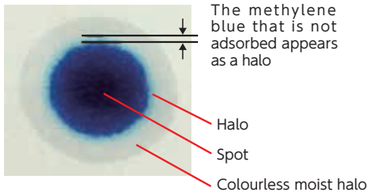
◇ Comparative verification of testing methods for the montmorillonite content

The montmorillonite content is evaluated by the methylene blue (MB) adsorbed on the bentonite, and the simplified method which is so-called “spot method” has been frequently used in practice. The spot method has a possibility of individual error due to visually determination of the amount of MB adsorbed. CRIEPI performed the MB adsorption test by the spot method using unified equipment for testing, then compared the experimental result to that of “the spectrophotometric method*”. This comparison clearly showed that the results of both methods were practically corresponded. Therefore the spot method can provide reliable data with high accuracy if the equipment and procedures were unified.

*A method to quantify the concentration of MB using absorbance. In compared to the spot method, it is not easy to frequently use the spectrophotometric method in construction sites, because of the cost and setting equipment for testing.

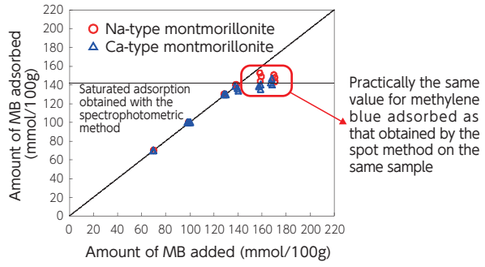
◇ Technique to collect pure montmorillonite from the bentonites

As using a centrifugal separator, etc., CRIEPI established the method to collect the montmorillonite with high purity by removing accessory minerals contained in the bentonite. Measuring the amount of MB adsorbed on both the collected montmorillonite and the bentonite lead to evaluation of the montmorillonite content of the bentonite more accurately.

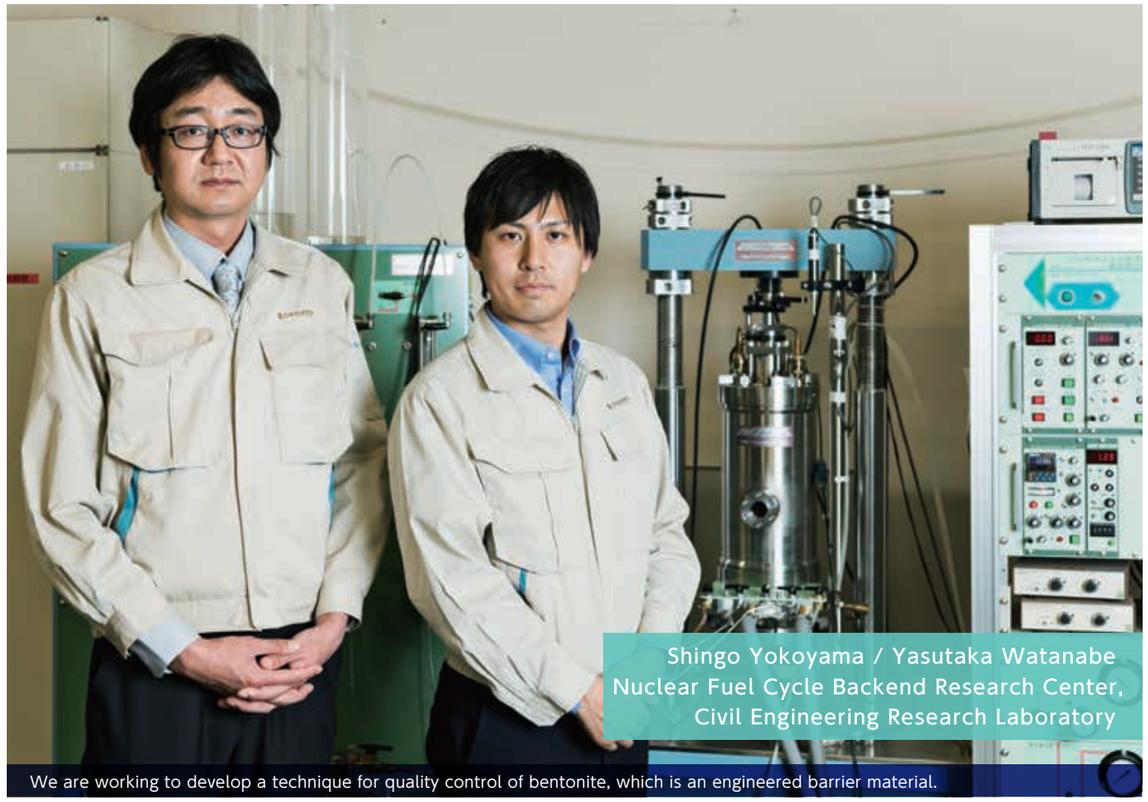


Spot method

(Using a ruler to visually measure the width of the halo formed when methylene blue solution mixed with clay put on a filter paper)

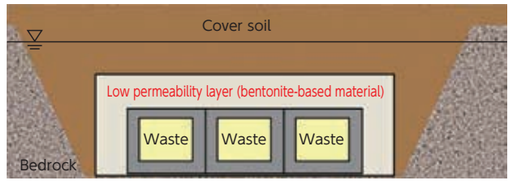


Results of the methylene blue adsorption test by the spectrophotometric method

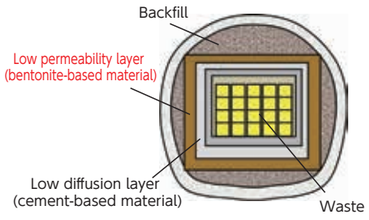


We are working to develop a technique for quality control of bentonite, which is an engineered barrier material.

Shingo Yokoyama / Yasutaka Watanabe
Nuclear Fuel Cycle Backend Research Center, Civil Engineering Research Laboratory



Pit disposal



Sub-surface disposal

Conceptual image of using bentonite in low-level radioactive waste disposal facilities

Application Examples of Research Results

The verified method for the measurement of montmorillonite content contributes to the standardization of the spot method as a testing method that can be utilized in practice. Moreover, the results of this research, including the technique to collect the pure montmorillonite, lead to progress of the quality control of the bentonite in order to keep safety to construct and operate the radioactive waste disposal facilities.

References: Watanabe et al., Goldschmidt Conference 2017 (Paris)

Thermal Power Generation

Proposal of a Life Assessment Method for High Chromium Steel Pipe Considering Individual Material Properties

Contribution to the improvement of pipe maintenance and management in high-efficiency thermal power plants

9Cr steel
A type of high chromium steel which contains 9% chromium and is a ferritic heat-resistant steel. Heat resistance temperature is 600 - 630℃.

Creep failure
A phenomenon whereby stress works constantly on metal causing the distortion to increase over an extended period of time and ultimately break.

Background

With the aim of improving thermal efficiency, thermal power plants built in recent years have had higher steam temperature; therefore 9Cr steel, which has higher strength than the material used to date, is widely used. 9Cr steel is an excellent material, however if used at a high temperature for a long period of time, creep damage gradually progresses in the pipe welds. Thus, the remaining life must be assessed. In response, CRIEPI has performed creep tests on welded pipes and by predicting the life of the pipe based on the statistical analysis of this vast amount of data (99% reliability lower limit), each thermal power plant is operating with sufficient consideration to safety. CRIEPI is developing a higher accuracy life assessment method through conducting various studies into pipes actually used for extended periods of time and the detailed analyses thereof.

Outline of Results

◇ Variation in metal with creep crack and related factors

By analyzing test data of systematic creep in pipes used for extended periods of time, we observed variation of the creep life in the welds of 9Cr steel and identified that this variation depended on the creep life of 9Cr base material. In order to clarify the controlling factors of the base material life, CRIEPI used a state-of-the-art spherical aberration corrected transmission electron microscope to analyze a vast quantity of samples and obtained statistically highly-reliable data of fine precipitates for the first time. As a result, we realized there is correlation between the life of 9Cr base material and the number density of vanadium nitride-based precipitates (Fig. 1).

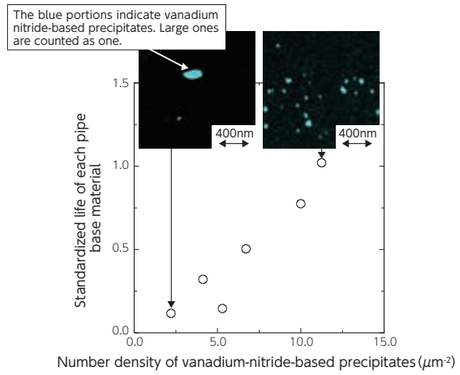


Fig. 1 Controlling factors of creep life in 9Cr base material

The results of microstructural analyses performed on various used 9Cr base materials show a correlation with the creep life only when the various types of precipitates contain vanadium nitride.

◇ Proposal of a creep life assessment method based on a microscopic sample considering the unique material properties of each pipe

CRIEPI proposed collecting a microscopic sample so small there would be no impact on the safety of the pipes, and conducting an analysis of fine precipitates of 9Cr pipe base material as well as a creep experiment. By doing this, it will be possible to assess the life of welds for each specific pipe from the results of a properties assessment of the 9Cr pipe base material using a microscopic sample (Fig. 2).

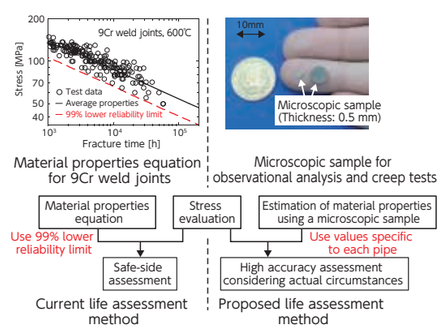


Fig. 2 Comparison of the current vs. proposed life assessment methods

Masatsugu Yaguchi / Susumu Yamada
Structural Materials Sector,
Materials Science Research Laboratory

Spherical Aberration corrected transmission electron microscope
An apparatus is able to quantitatively and statistically investigate the dispersion of fine precipitates in high chromium steel.

Application Examples of Research Results

By applying microscopic sample assessment technology to 9Cr pipe base material, it will be possible to conduct life assessments of each pipe's welds to suit the specific creep properties. By referring to this assessment result, it is anticipated that the maintenance and control of pipes in high-efficiency thermal power plants will be performed with higher validity.

References: Yaguchi et al., ASMEPVP2016-63316 (2016)
Nagai et. al, CRIEPI Report Q14002 (2014)

Thermal Power Generation

Development of a Measurement Device for the Rapid

Measurement of Boron Content in Coal Ash

Coal Ash Mixed Material
A solidified mixture comprising of coal ash mixed with water, cement, soil, etc. It is available in a variety of forms to suit the specification requirements, including sand, gravel or lumps.

Environmental safety
Safety with regards to health impact on humans through soil, groundwater, direct consumption etc. in line with utilization of recycled materials, etc.

Boron
One element stipulated in the Soil Environment Standards. Used in fertilizer, heatproof glass, etc.

Lysimeter
A large tank filled with soil, etc. capable of evaluating the pore water, element mobility, etc. of soil.

Background

Every year, Japan's coal-fired power plants emit approximately 95 million tons of coal ash, of which 60% is used as cement material. However, with no significant increase in demand on the horizon and the limited availability of space for coal ash landfill, there is a need to develop new applications other than as cement material, such as material for artificial ground (Coal Ash Mixed Material, CAMM), etc. As part of efforts to expand the effective utilization of coal ash, CRIEPI is developing a technique to ascertain the content of trace elements in coal ash which pose a risk of environmental impact in order to appropriately evaluate the environmental safety when CAMM is used.

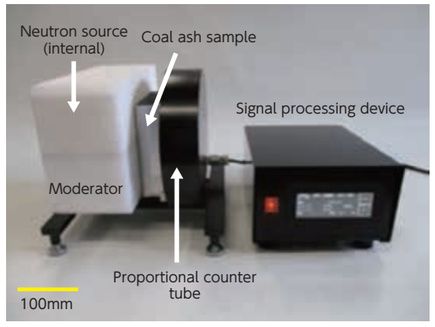
Outline of Results

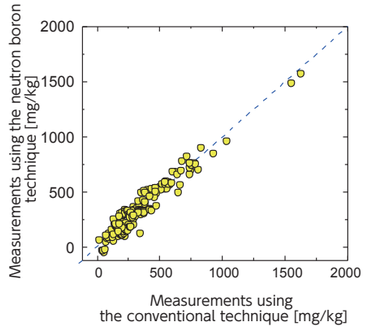
◇ Development of the simple and rapid boron detector for coal ash

CRIEPI developed a neutron boron gauge that measures the boron content in coal ash by utilizing boron's property of specifically capturing thermal neutrons. This device is capable of measurement without pre-treating the sample, therefore it is extremely simple and rapid than the conventional method, which required pre-treatment such as wet digestion method with strong acid, etc. This measurement device has been commercially sold by manufacturers from May 2017.

◇ Establishment of a technique for the evaluation of environmental safety of CAMM

In order to evaluate the environmental safety of using CAMM as subgrade or backfill, CRIEPI has established a full-scale test method utilizing a lysimeter. By applying this test method, it is possible to evaluate the elution of elements from CAMM for a variety of forms and applications in the actual form it is in.



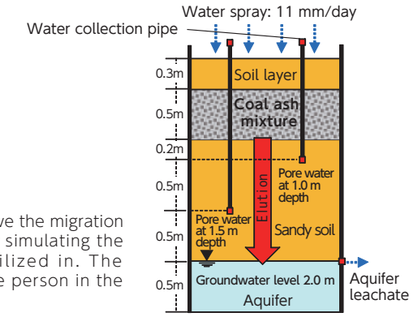


Comparison of the appearance of the neutron boron gauge developed by CRIEPI and the conventional technique

The coal ash sample is irradiated with thermal neutrons and the boron content is calculated from the number of thermal neutrons captured. In measurement of boron in coal ash using our developed detector, because pre-treatment is not required, the measurement time is extremely reduced from two days to five minutes. Moreover, the measurements obtained using the conventional technique and this device are in good agreement, indicating that the neutron boron gauge can replace the conventional technique.

Hiroyuki Masaki / Seiji Inoba
Environmental Science Sector,
Environmental Science Research Laboratory

Lysimeter Testing Unit Utilizing for the full-scale evaluation of coal ash mixture elution properties



Schematic of a lysimeter interior

A lysimeter makes it possible to observe the migration behavior of elements in soil as is by simulating the actual environment CAMM is utilized in. The tank-shaped object to the left of the person in the above photo is the lysimeter.

Application Examples of Research Results

The neutron boron gauge developed by CRIEPI is being utilized for the advance confirmation of coal ash properties by electric power companies. Furthermore, the environmental safety evaluation for CAMM will be utilized in the field and reflected in the design guidelines published by the Japan Society of Civil Engineers.

References: Masaki et al. CRIEPI Report V15008 (2016)
Masaki et al. CRIEPI Report V14003 (2015)

2-2. Major Research Results-9

Thermal Power Generation

Proposal of a Gas Turbine Power Generation Technology Contributing to Maintaining Supply/Demand Balance Upon High Penetration of Variable Renewable Energy

Participating in a national project to promote technological development of next-generation gas turbine combined cycle (GTCC).

Background

The high penetration of variable renewable energy, such as photovoltaic energy, has been proposed as a measure to significantly reduce CO_2 emissions. The output of photovoltaic energy production fluctuates greatly depending on the weather, and the amount of power generated decreases rapidly at sundown, which is precisely when power consumption rapidly increases. One important issue key to achieving stable power grid operation is maintaining the balance between supply and demand, which changes from time to time. NEDO (New Energy and Industrial Technology Development Organization) is promoting a study into higher performance gas turbine combined cycle (GTCC), which has high efficiency and excellent mobility, therefore seen as a promising means to solving this issue. CRIEPI is developing a next-generation GTCC, which is one of NEDO's project.

Gas Turbine Combined Cycle (GTCC)
A power generation method combining gas turbine and steam turbine.

Outline of Results

◇ Clarification of technical issues for next-generation GTCC

CRIEPI has used plant dynamic analysis to clarify fluctuation in temperature and pressure that occurs in a GTCC plant upon rapid start-up and rapid load fluctuation as well as clarify the impact on combustion stability through unsteady numerical analysis. With consideration to these factors which affect GTCC, we has established GTCC target performances (shorter start-up time, improved ramp rate, lower minimum output, improved partial load efficiency) to be achieved by the year 2030 and has identified the concrete technological development issues (Table 1) and issues regarding popularization in order to realize these.

Dynamic analysis
Clarifies changes in properties which vary over time, such as temperature and pressure in gas turbines.

Table 1 The established 2030 GTCC target performances and the main technological development issues concerning their realization

	Start-up time	Ramp rate	Minimum output	50% load efficiency (LHV)	Rated efficiency (LHV)	Example of technological development issues
Target performance (Large-capacity GTCC: 100 MW and above)	10 min	20%/min	10%	56%	63%	①Evaluation during times of heat fatigue and high-durability material technology ②Device control technology able to maintain stable operation even during times of abrupt load variation and dynamic properties evaluation/numerical analysis technology to support such control technology ③High performance cooling/sealing technology to maintain high partial load efficiency
(Reference) Current performance	60 min	5%/min	50%	55%	62%	

◇ Effects of next-generation GTCC introduction

Assuming the future supply/demand status predicted with the high penetration of variable renewable energy, CRIEPI has tentatively calculated the effects of next-generation GTCC with the target performances on supply/demand operation using a supply/demand operation simulator developed by CRIEPI. This confirmed that, if GTCC performance was improved, it would be possible to maintain supply/demand balance upon large-scale introduction of variable renewable energy even with smaller thermal units. This clarified that operation costs of thermal power generation would be reduced (Fig. 1).

Supply/demand simulator
A tool able to simulate supply/demand operation for each power source, storage device, etc. considering the uncertainty of renewable energy output (operation of power plants to balance supply and demand).

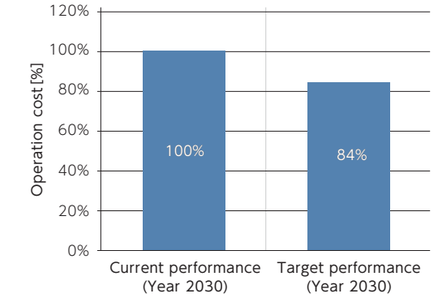


Fig. 1 Example of effects on reducing operation costs of thermal power generation equipment with future power source composition
・Targeting the Kyushu area
・Refer to the right page for the amount of generated power (%) for each power source.
・Transient stability and frequency stability of the power grid are not taken into considered.

Photovoltaic power generation simulation system
A system to analyze the behavior of the power grid when the grid power source is replaced with photovoltaic power generation.

Amount of generated power by each power source for Fig. 1.

Application Examples of Research Results

As we have quantitatively demonstrated that next-generation GTCC is effective towards reducing operation costs and contributing to supply/demand operation, we will aim to reflect our findings in national polycies, etc. as part of efforts to embody technological development. We will also proactively support the popularization of the developed next-generation GTCC so that it may be used by business operators.

References: 2016 NEDO Report "Investigative Research Relating to the Role of Thermal Power Generation in Electric Power Grid Stabilization in the Context of High Renewable Energy Penetration and CO_2 Reduction due to Improved Gas Turbine Load Fluctuation Absorbance Capacity" (2017)
2014-15 NEDO Advanced Research Program for Energy and Environmental Technology Results Report "Research and Development of Advanced Gas Turbine for the Firming Grid in the Renewable Energy Age" (2016)

Hydropower Generation

Development of Efficient Measurement Method for Water Turbine Vane Thickness in Hydroelectric Generators

Reducing labor required for measurement tasks during inspections

Background

The thickness of water turbine vanes in hydroelectric generators can decrease due to the penetration of sand, clay, etc., therefore measuring the thickness of these vanes is important in determining the timing of repairs and renewal. However, the multi-point measurement method using Vernier calipers performed during inspection requires time and effort, and a cross-sectional profile cannot be obtained easily due to this technique being point measurement. In order to overcome these issues, CRIEPI is engaging in the development of a technology enabling efficient measurement of water turbine vanes in a reduced-thickness state during inspections.

Outline of Results

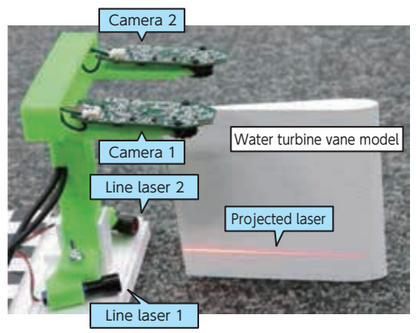
◇ Development of a technique to measure cross-sectional profiles of water turbine vanes combining two lasers and cameras

Line laser
A laser that projects a line rather than a point. The light projected for the vane will curve to reflect the vane cross-sectional profile.

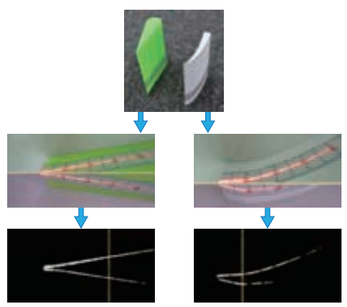
CRIEPI developed the below measurement technique after investigating the shape of the water turbine vane and the current inspection process. By projecting two small line lasers on the vane (one each on the front and back of the vane) and photographing either face using two small cameras, a laser projection image expressing cross-sectional profile is obtained. With image processing using the respective positions and angles of the lasers and cameras, a three-dimensional cross-sectional profile image is obtainable. This has made it possible to conveniently and efficiently measure the cross-section profile of the vane tip, for which measurement had been difficult up until now due to space confinements.

◇ Prototyping a cross-sectional profile measurement device and evaluating accuracy of thickness measurement through experiment

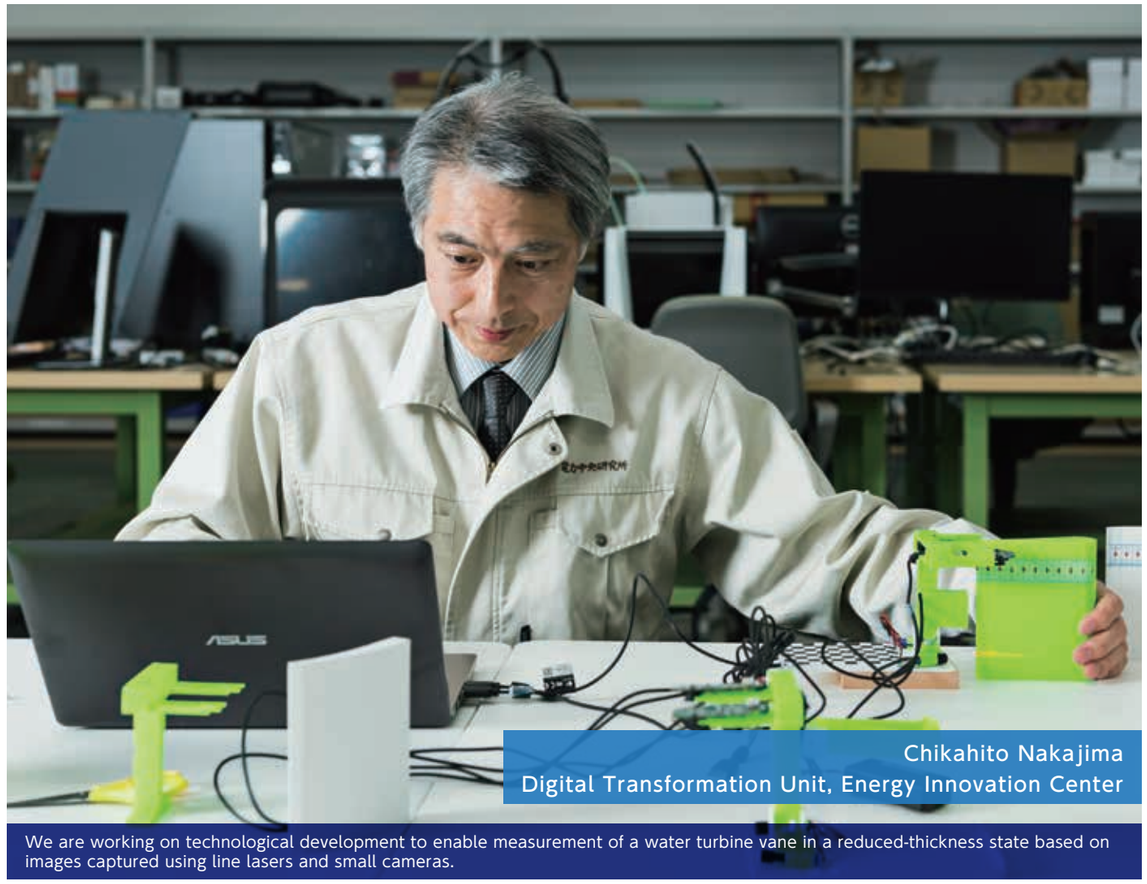
CRIEPI used line lasers and small, high-definition cameras to prototype a measurement device such as that shown in the figure below and evaluated the accuracy of cross-sectional thickness measurement when this measurement technique is actually applied to a water turbine vane, etc. As a result, we noted the potential of this approach for thickness measurement; with the average error for thickness measurement values using a specimen as 0.14 mm (standard error = 0.05 mm) and the average error when measuring the vanes of an actual turbine or vane model also being 0.14 mm.



Measurement device prototype

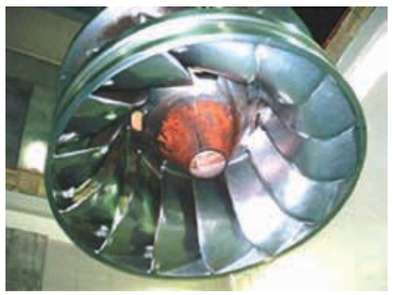


Example of a cross-sectional profile obtained from a vane model



Chikahito Nakajima
Digital Transformation Unit, Energy Innovation Center

We are working on technological development to enable measurement of a water turbine vane in a reduced-thickness state based on images captured using line lasers and small cameras.



Impeller of a Francis turbine (rotating portion)
(Excerpt from Kansai Electric Power's official website)

Application Examples of Research Results

This measurement technique will enable a significant reduction in the cost of inspections of hydropower plant equipment. Moving forward, we will aim for the practical realization of this measurement device and promote its utilization in power plants.

References: Nakajima et al. CRIEPI Report C16007 (2016)

Renewable Energy

Proposal of Evaluation Index of Power System Stability with High Penetration of Renewable Energy

Appropriately evaluating the necessary capacity of the synchronous generator for contributing to power system stability

Background

Many studies of resulting impacts on power system in regard to the extent of photovoltaic (PV) and wind turbines (WT) generation in Japan are focused on the balance of power supply-demand. In overseas, there are examples what the operation to limit synchronous generator and PV/WT generation to a certain ratio is carried out to keep power system stability under a power system fault condition. On the other hand, sometimes transient stability determines the capacity of system operation in Japan, therefore we are working on development for transient stability evaluation method.

Power supply-demand balance

Power supply is balanced with demand to keep the power system frequency. In the situation that power supply-demand is imbalanced, the power system frequency would be changed.

Synchronous generator

Many synchronous generators are interconnected to a power system. AC voltage is generated due to the electromagnet rotation inside the synchronous generator. Furthermore, the power system frequency is derived from rotation speed of the electromagnet. Thus, power system stability is enhanced by controlling magnetic force and rotation speed of the electromagnet .

Transient stability

Transient stability is the ability to recover from unstable state immediately even if a power system fault occurred.

Outline of Results

◇ Proposal of effective evaluation index to keep transient stability

Transient stability is influenced by following factors when PV/WT is introduced to a power system.

・Transient stability is improved with the apparent load reduction due to PV/WT generation.

・Transient stability is declined with decreasing synchronous generator capacity due to reduced inertia and reduced ability to keep power system voltage.

We proposed new evaluation index "α" which means the ratio of decreasing synchronous generator capacity in exchange for non-synchronous generation to keep transient stability. In addition, it was found out that transient stability could be kept by setting the "α" to 50% or less regardless of PV/WT generation using the IEEJ WEST 10-Machine Model.

◇ Analysis of impact on supply-demand operation

Supply-demand operation simulations was conducted to evaluate impacts of ensuring generation capacity for power system stability. A constraint using the index "α" was newly formulated, and the constraint was applied to our simulation tool "Demand and Supply Operation Simulator". The results indicates that a decrease in "α", that is an increase of required capacity, induces increases of operation costs and CO_2 emissions (Fig.2) as well as additional PV/WT output suppression.

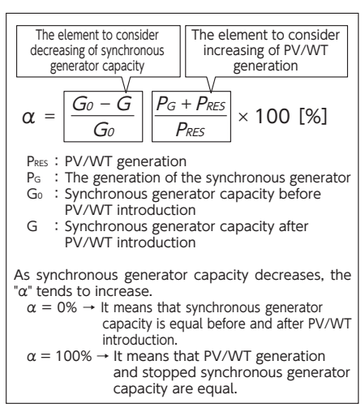


Fig. 1 Definition of the "α"

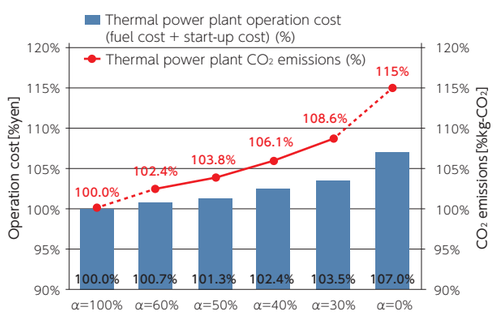


Fig. 2 Results of an analysis simulation of impact on supply-demand operation

A comparison of operation cost and CO_2 emissions in the Kyushu area based on the long-term energy supply-demand outlook in the year 2030. This comparison is based on α = 100%. Ratio of renewable energy (PV, WT) introduction is 33% if α=100% and 31.5% if α = 0%.

Yuji Hanai / Keisuke Shirasaki
Electric Power System Sector,
System Engineering Research Laboratory

Power system simulator
Simulates the devices that configure a power system using a small analog model and reproduces various grid phenomena.

Unlike inverter-besed power generations of renewable energy, all synchronous generators connected to a power grid have synchronizing power which synchronize the rotation speeds of the internal magnets. This feature means that, even if faults in a power system make system frequency fluctuated, the synchronous generators automatically and instantly work to restore their rotation speeds into those of a normal state.

Features of large-capacity synchronous generators
◆Power output control response to frequency variations
◆Synchronizing power which uniformize all rotor speeds
◆Inertia force which keeps robustness of system frequency against faults
◆Synchronous operations continued even during voltage drop by a fault
◆Voltage control capability of bulk power system

Application Examples of Research Results

When power system operations with maintaining synchronous generator capacity were required from the perspective of power system stability, this research result would be useful for electric power companies to consider the necessary synchronous generator capacity and appropriate power system operation method.

References: Shirasaki et al., The National Conference of the Electric Engineers of Japan 2017 Lecture no. 6-086 (2017)
Hanai et al., The National Conference of the Electric Engineers of Japan 2017 Lecture no. 6-148 (2017)
Shirasaki et al., CRIEPI Report R14013 (2015)

Electric Power Transmission and Distribution

Establishment of a Communications Platform Supporting Smart Grid

Mutual Interaction of Applications with Differing Communication Standards to Contribute to Sophisticated Supply/Demand Coordination

Background

With the increasing introduction of smart grids, it is predicted that various applications relating to the coordination of consumers and power grids and consumer services will grow in popularity. However, the standards for communication crucial for power companies to exchange information with consumers and electric equipment differ between applications, making it difficult to achieve interaction with the current situation. In order to solve this problem, CRIEPI is building a communication platform*.
*This research was conducted as joint research with Meidensha Corporation.

Platform
A program for the common use of multiple applications.

Outline of Results

◇ Data coordination through integration of various communications

The various applications that have emerged from a shift towards smart grids, for example power distribution automation, demand response and advanced metering, have communication methods determined by different international standards. In response, CRIEPI has built a communication platform by integrating applications with different communication standards via a common API (Application Program Interface) (Fig. 1). Moreover, the lower level protocol determined by each communication standard adopts XMPP technology which is used for instant messaging, etc. This allows the information of equipment and systems to be used uniformly, request messages generated on the sending side to be directly transferred to the receiving side, and makes the mutual utilization of data easy.

Power distribution automation
Power distribution equipment automatically judges transmission terminal information, etc. with the aim of control, thus achieving automatic control.

XMPP (Extensible Messaging and Presence Protocol)
A protocol with XML-based messages.

◇ Establishment of a Testing System and Performance Evaluation for Communication Platforms

CRIEPI established a testing system for the above mentioned communication platform and evaluated its practical utility. As a result, we have seen the potential for data communication within a practical timeframe even if a low-cost communication line and PC-level device are used.

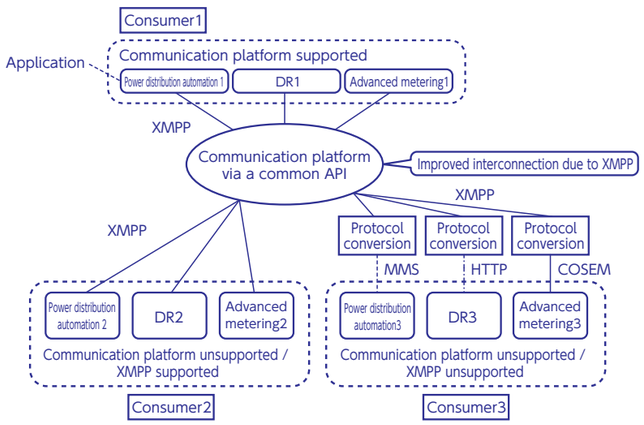


Fig. 1 Conceptual drawing of information coordination through a communication platform

By using a communication platform via a common API, it has become easy to achieve data coordination between various applications (power distribution automation, DR, advanced metering) and consumers. Moreover, if data is communicated in XML format by establishing an XMPP layer in the lower level of each application's protocol, as is the case with Consumer 3, it becomes possible to send and receive data between applications without being concerned about communication protocol.

XML (Extensible Markup Language)
A programming language known for closely resembling natural language able to be written in a text format, making it highly expandable and intuitive.

Hiroyuki Yusa
Communication Systems Sector, System Engineering Research Laboratory

Data Exchange Control Fundamental Tester
Equipped with a communication platform, this tester is utilized for mock communication tests.

Communication standards presumed for application to advanced metering or IoT

	Standard	Communication speed
IEEE	802.15.4g	Max. 100 kbps (920-928 MHz)
	802.11j	54 Mbps (4.9/ 5 GHz)
LTE	Cat.4	150/ 50 Mbps
	Cat.0	1 Mbps
	Cat-M	1 Mbps
	NB-IoT	Around 100 kbps

Application Examples of Research Results

It is predicted that there will be increase in smart grids utilizing IT and IoT in power grids. The results of this research will help with previous day/actual day planning of smart grid consumers, promote utilization of real-time information and is anticipated to make the realization of sophisticated supply/demand forecasting and control easy.

References: Yusa et al. CRIEPI Report R16001 (2017)
Otani et al. CRIEPI Report R13010 (2014)

Electric Power Transmission and Distribution

Development of an Identification System able to Predict Lightning Location and Energy at High Accuracy

Contributing to labor-saving regarding patrols and inspections of substations and transmission lines

Lightning Location System (LLS)
A system with multiple sensors to detect the electromagnetic field waveforms generated from lightning strikes then estimate lightning location, time, peak current amplitudes, etc. based on data analysis.

Background

The spread of lightning protection devices for power transmission has seen a reduction in damage to substations and transmission lines, however it has not yet become possible to eliminate such damage altogether, and patrols and inspections of equipment damaged by lightning require a great deal of labor. In order to ascertain the damage to equipment due to lightning strikes it is necessary to gather information relating to lightning location and lightning energy, however the conventional Lightning Location System (LLS) was unable to identify location with sufficient accuracy, and did not enable estimation of lightning energy. In an effort to save labor entailed in patrols and inspections of equipment damaged due to lightning strikes, CRIEPI is working on the development of the advanced Lightning Location System (advanced LLS) able to identify lightning location at high accuracy and estimate lightning energy.

Outline of Results

◇ Improvement of lightning location identification accuracy

Lightning location is generally obtained by capturing the electromagnetic waves generated when lightning strikes using sensors installed in multiple observation points, then performing data analysis. CRIEPI clarified that the main reason for the error in such analyses is the distortion of electromagnetic waves due to long-distance propagation (Fig. 1). For this reason, we have developed an appropriate sensor arrangement method to offset error caused by waveform distortion and a signal processing method. As a result, the advanced LLS shows potential as being able to identify lightning location with an error of less than 50 meters, whereas this was unable to be reduced below 250 meters with the conventional LLS.

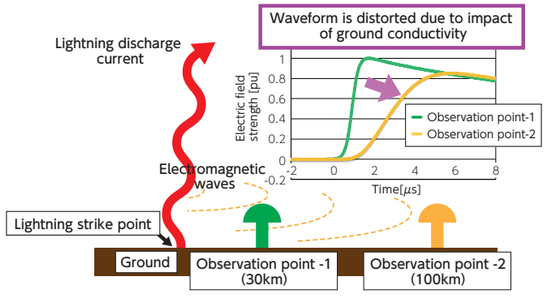


Fig. 1 Image of the electromagnetic waves changing in accordance with long-distance propagation

When lightning strikes, the current of the lightning bolt discharges flows from the ground into the atmosphere. In line with this, electromagnetic waves are generated and propagated around the vicinity. The electric field waveform observed at observation points varies due to the effect of ground conductivity during long-distance propagation.

◇ Estimation of lightning energy

The energy created in a lightning strike (electric charge) is estimated based on electric field observation at ground level and the charge position inside a thundercloud, however there is a certain degree of uncertainty when estimating the position of charge inside a thundercloud. CRIEPI clarified through a calculation that the impact of this uncertainty on estimating electric charge decreased by using electric field observation data taken more than 25 km from the lightning strike point. With the advanced LLS, a distance between sensors of around 50 km is assumed and electric charge can be estimated with high reliability.

Mikihisa Saito
Lightning and Electromagnetic Environment Sector, Electric Power Engineering Research Laboratory

Measurement of magnetic fields in an antenna
Frequency range of 750 Hz to 1MHz range at a 100 ns sampling rate for the purpose of electric field and magnetic field observation.

Lightning strikes Tokyo Skytree

Application Examples of Research Results

This research makes it possible to estimate lightning location and damage to equipment caused by lightning energy, thus helping to identify those substations and transmission lines in need of patrols and inspections. Furthermore, data relating to lightning characteristics such as lightning energy can be accumulated and used as a helpful reference when determining equipment specifications and selecting countermeasure parts, etc. in order to establish effective lightning damage preventative measures.

References: Saito et al., CRIEPI Report H16007 (2017)
Saito, CRIEPI Report H15009 (2016)
Saito et al., CRIEPI Report H14007 (2015)

Development of a Technique to Predict Fusing of Electrical Wires due to High Current Arc Discharge

Utilizing to prevent breaking accidents of electrical wires through the selection of optimal electrical wires considering lightning current, etc.

Electric Power Transmission and Distribution

Overhead Ground Wire/ Optical Ground Wire (OPGW)
An overhead ground wire is a grounded metal wire installed above overhead power transmission lines in order to prevent the lines from being struck by lightning. A composite fiber-optic ground wire (OPGW) is an overhead ground wire with built-in optical fibers for information signal transmission.

Fusing
Melting and breaking of strands of wires due to a high current, such as lightning current or arc current.

Galloping
→ See p.48

Arc
An arc is a form of gas discharge, and arc current refer to the current created upon electrical discharge.

Background

If the overhead ground wires or composite fiber-optic ground wires (OPGW) used in power transmission systems are struck by lightning, a portion of the strands inside them may occasionally fuse due to the electrical current of the lightning strike, causing the overhead ground wire or OPGW to weaken and break due to tensing up from exposure to wind, ice, snow, etc., which could lead on to major short-circuit accidents. In overhead power transmission lines, the same breaking accident may arise due to arc current if the lines short-circuits because of galloping, etc. In order to prevent this kind of breaking accident, ascertaining the characteristics of wire fusing due to high currents such as lightning current and arc current is an important issue. CRIEPI is developing a prediction technique using arc tests and calculation in order to effectively ascertain wire fusing characteristics.

Outline of Results

◇ Development of a calculation technique to predict the number of strands of wires that will fuse due to high energy lightning strikes

CRIEPI has developed a technique to calculate the number of OPGW strands that will fuse by simulating high energy lightning with direct-current high energy arc. In the calculation, the overall heat transferred from the arc to the OPGW as well as the heat transfer area are derived, and the OPGW cross-sectional shape is simplified (Fig. 1, Fig. 2). This has made it possible to predict the number of strands that will fuse due to the arc electric charge that flows through a strand. In order to verify the validity of our calculation method, we performed a direct-current arc test and compared the electric charge at which wires fused. The results of this test were in good agreement with the calculation (Fig. 3). The above technique can also be applied to overhead ground wires, which use practically the same type of strand in their outer most layer. This technique can also be applied to aluminum conductor steel-reinforced (ACSR) used as overhead power transmission lines, making it possible to predict the number of ACSR strands that will be fused due to an alternating-current arc.

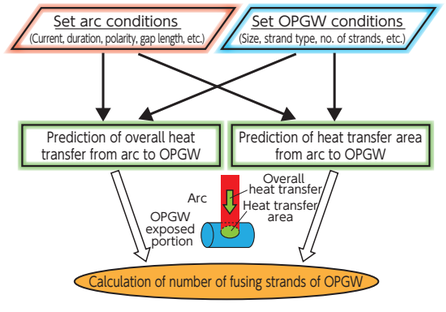


Fig. 1 Calculation technique flow

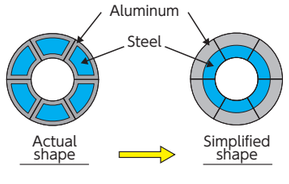


Fig. 2 Simplification of the OPGW cross-sectional shape

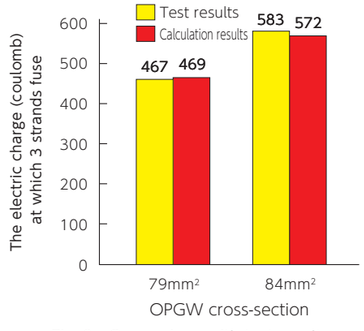
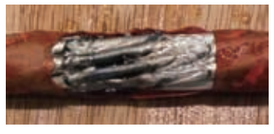


Fig. 3 Comparison with test results

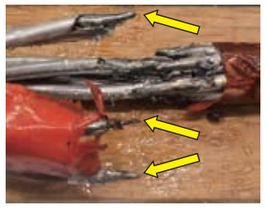
A comparison was made with the results obtained through a test and through a calculation for the electric charge (coulomb) at which three of the total seven strands would fuse when subjected to a 24 kA current.

Mikimasa Iwata
High Energy Sector, Electric Power Engineering Research Laboratory

High Power Testing Laboratory
A laboratory to evaluate the short-circuit performance of power distribution equipment such as circuit breakers, transformers, power transmission cables, etc. applying high current and high voltage.



0 strands fuse
(Electric charge: 491 coulombs)



3 strands fuse
(Electric charge: 583 coulombs)

State of strand fusing on OPGW through a direct-current high energy arc test

Application Examples of Research Results

Prevention of wire breaking accidents by considering lightning current in order to select optimal electrical wires which do not easily fuse for new installation or replacement.

Reference: Iwata et al., 33rd International Conference on Lightning Protection (2016)
Iwata et al., CRIEPI Report H13001 (2013)
Iwata et al., IEEE Transactions on Power Delivery (2013)

Development of Technology for the Removal of Transformers Contaminated with Trace PCB

Promoting safe and efficient detoxification

Electric Power Transmission and Distribution

PCB

A material once widely used in electrical devices due to its excellent insulation performance, but has been prohibited from manufacture or use due to its toxic nature. An Act on Special Measures stipulates that all PCB-affected devices must be treated by March 31, 2027.

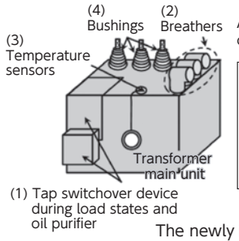
Background

Nationwide estimates indicate that there are several million electrical devices in Japan suspected of being contaminated with trace polychlorinated biphenyl (PCB) and these must be dealt with by the deadline stipulated by law. As washing technology to extract and detoxify PCB, CRIEPI has developed a heated forced circulation washing method for transformers that are no longer in use, and an energized natural circulation washing method for transformers still in use. Currently, both washing methods are publically acknowledged as PCB treatment technologies. CRIEPI is also expanding the application of our washing technologies on various electrical devices and working on development of a more effective detoxification technology.

Outline of Results

◇ Expansion of in-use contaminated transformer treatment through introduction of a portion-specific energized natural circulation washing method

Energized natural circulation washing methods to date dealt with the entire transformer on the whole, and there was a major limitation to the number of transformers to which this method could be applied. As such, CRIEPI proposed a washing method that focuses on separate portions individually based on results of an investigation/analysis into the contamination status of the transformer main unit and its accessories, etc. As a result of this method enabling washing by transformer portion on an individual basis, it seems likely that the majority of transformers containing 2 kL of oil or more used by power companies will be treatable.



A transformer is configured from a main unit and the portions listed (1) through (4). In some cases, the PCB concentration differs between each portion.

With the current system, energized natural circulation washing can be performed only on transformers which have no contamination in (4) and a PCB concentration of 5 ppm or less in the main unit and all portions from (1) through (3).

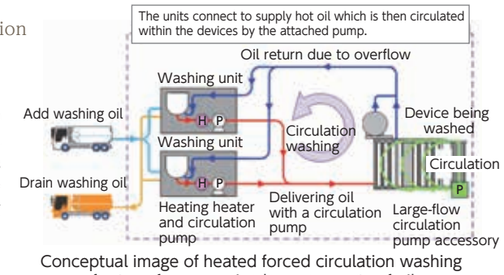
In line with the amendment, regardless of contamination in (4), energized natural circulation washing can be performed on transformers which have a PCB concentration of 5 ppm or less in the main unit and all portions from (1) through (3).

The newly introduced portion-specific energized natural circulation washing method

This method can be applied to portions for which the PCB concentration inside the insulating oil has been measured as 5 mg/kg or less even for those portions that are washable but not yet washed, contaminated portions or unmeasured portions.

◇ Development of a heated forced circulation washing method for transformers using large amounts of oil

CRIEPI has developed a heated forced circulation washing method using two washing units and a transformer pump. We have confirmed effectiveness through a verification test using an 85 kL oil-capacity transformer and enabled efficient treatment of transformers using large amounts of oil.



Conceptual image of heated forced circulation washing for transformers using large amounts of oil

◇ Demonstration of method for collection of residual oil after washing

After washing, the surface of transformers are covered in washing oil containing PCB and this washing oil then travels to the bottom of the transformer as residual oil. CRIEPI has devised and verified a counteracting technology that urges PCB to shift from the washing oil adhered to the surface of transformer parts to the residual oil through depressurization of the transformer, etc. and this has helped to speed up residual oil treatment.

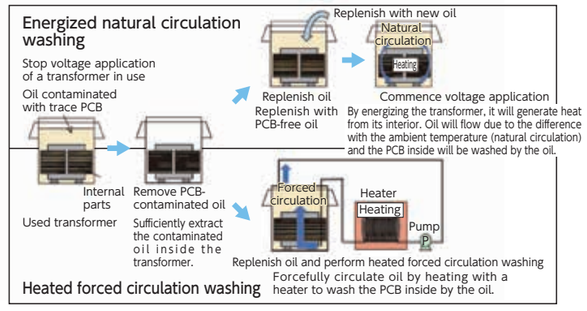
Motoaki Shirai / Naoya Ohmura
Environmental Chemistry Sector, Environmental Science Research Laboratory

Washing treatment site (Yokosuka Area) applying heated forced circulation washing to equipment contaminated with trace PCB
CRIEPI's transformers contaminated with trace PCB are washed by an organization accredited by the Minister of the Environment.

Overview of the energized natural circulation washing method and heated forced circulation washing method

Energized natural circulation washing method: This method applies to devices contaminated with trace PCB which are still in use. First, oil is extracted from the device then uncontaminated washing oil is replenished, and voltage application is recommenced. The electrical charge causes the parts of the transformer to generate heat, which heats up the washing oil, causing it to flow due to the difference with the ambient temperature, which washes away the trace PCB.

Heated forced circulation washing method: This method applies to devices contaminated with trace PCB which are no longer in use. First, oil is extracted from the device then uncontaminated washing oil is replenished, and trace PCB is washed out by heating the oil and causing it to circulate.



Application Examples of Research Results

CRIEPI's portion-specific energized natural circulation washing method was reflected in the Instructions for energized natural circulation washing of Electrical Devices Contaminated with Trace PCB (amended March 2017) published by the Ministry of the Environment and Ministry of Economy, Trade and Industry. Moreover, the method for collection of residual oil after heated forced circulation washing was reflected in the Guidelines for Treatment of Decommissioned Electrical Devices Contaminated with Trace PCB —Washing Treatment Edition— (amended September 2016) published by the Ministry of the Environment and is utilized for detoxification treatment.

Reference: CRIEPI TOPICS Vol.19 (2015)

Electric Power Transmission and Distribution

Establishing a Power Line-Tree Distance Evaluation Method Utilizing Drones

Contributing to simple, low-cost maintenance management of power transmission equipment

Background

In order to achieve stable power supply, it is essential that regular checks are made of the distance between overhead power lines and surrounding trees and tree-felling is carried out where necessary. Distance evaluation had been performed using laser measurement, etc. from aircraft however this is costly and requires special equipment, therefore it takes time to provide data from measurements. As such, there is a demand for technology enabling this distance evaluation for power transmission equipment to be carried out inexpensively and swiftly in regions hard to access by humans, such as mountainous regions, and during emergencies. In recent years, there has been a strong focus on a technology called SfM mapping, which creates 3D shape images the same as that obtainable through laser measurement from aerial photographs using small unmanned aerial vehicles (drones). CRIEPI is developing technology to easily and inexpensively perform maintenance and management of power transmission equipment by applying this SfM mapping to distance assessment for power lines and near-by trees - an application of this technology for which there is few precedents.

SfM
(Structure from Motion)

A technology that finds an identical subject (point correspondences) in multiple still images captured so that been partly overlapped, then estimating the camera capturing position and target shape.

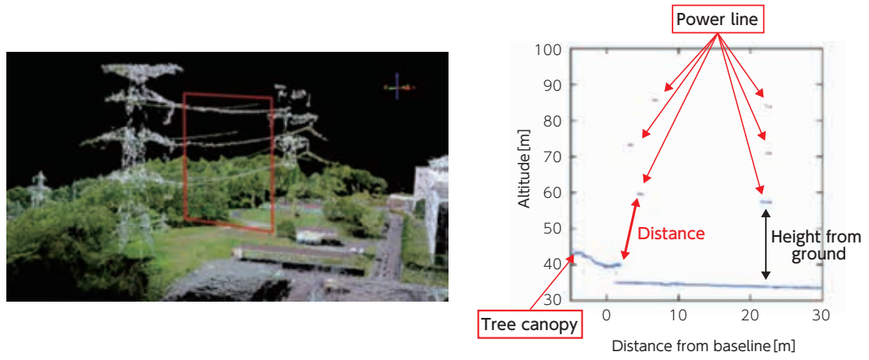
Outline of Results

◇ Reconstructing 3D shapes from drone photography

As a result of carrying out SfM mapping from a series of photographs captured by a drone hovering directly over the locations captured, we clarified that 3D shapes could be reconstructed for the power lines and the surrounding tree canopy by overlapping 80% or more of the visual field between images.

◇ Accuracy of distance evaluation using this technique

By comparing the measurement values of power line heights obtained with the existing ground laser range finder and values analyzed with SfM mapping, we observed that the measurement error ranged between 0.14 and 0.36 m, which is equivalent to the measurement error of 0.20 to 0.30 m obtained using high-accuracy laser measurement from aircraft. This result reveals the potential for drones to enable simple and low-cost evaluation of the distance between power lines and surrounding trees. Moving forward, we will expand utilization of drones to prediction of tree growth, etc. with the aim of establishing a technique to easily identify appropriate tree-felling timing and location.

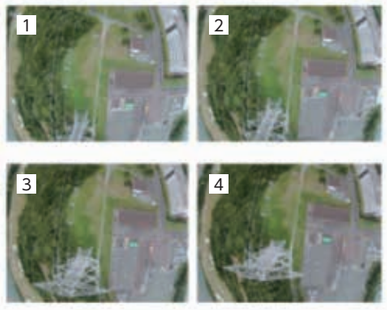


An example of utilizing drones in power line-tree distance evaluation

(Left) A 3D shape image produced from aerial photos captured by a drone (right page) and a cross-sectional diagram circled in red. This shows the distance between the tree canopy and the power lines is approximately 20 meters.

Ko Nakaya
Biological Environment Sector,
Environmental Science Research Laboratory

Developing a technology for the maintenance and management of power transmission equipment utilizing drones.



Aerial photos captured by a drone

The 3D shape image on the left page was reconstructed from these photos. Captured July 2015 at Tohoku Electric Power's Training Center.

Application Examples of Research Results

Some electric power companies have begun using this technique to evaluate the distance between overhead power transmission equipment and surrounding trees. Through application in hard-to-access areas, such as mountainous regions, this technology is anticipated to contribute to the efficient maintenance and management of power transmission equipment.

References: Nakaya et al., CRIEPI Report V15004 (2016)

Electric Power Transmission and Distribution

Proposal of Rational Countermeasures against Snow Damage to Power Transmission Facilities

Contributing to the stable supply of electrical power by reducing damage and halt of facilities due to snow

Background

In December 2005, regions on the Sea-of-Japan side were ravaged by severe snowstorms, leading to massive power outages due to snow damage. In response, the Snow Damage Working Group of the Agency for Natural Resources and Energy requested that electric power companies should conduct centralized field observation and data management of snow damage events, for which there are rare opportunities to observe, in order to further improve research and analysis technology relating to snow damage events. With the cooperation of electric power companies in Japan, CRIEPI has completed a 10-year project launched in 2007 in order to elucidate mechanisms behind snow damage and improve prediction and countermeasure technology.

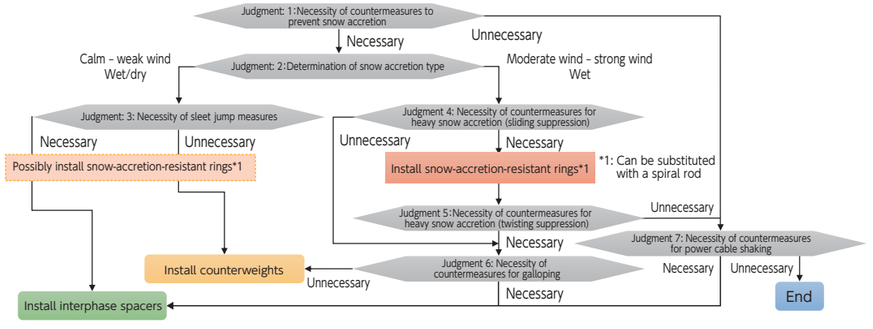
Outline of Results

◇ Establishment of a practical technique for snow damage prediction

CRIEPI has established techniques to easily predict locations susceptible to damage to power transmission facilities from the three major causes of snow damage (heavy snow accretion, galloping, salt snow damage), taking into account the weather patterns of each region. In concrete terms, we have established a technique to estimate the maximum snow accretion on power conductors that should be assumed in snow-resistant design of support structures such as steel pylons, a technique to identify a span at which short-circuits would easily occur due to galloping based on specific features of facilities and weather conditions, as well as a technique to identify regions where there is a concern of salt snow damage to insulators.

◇ Proposing a selection method for appropriate snow-damage countermeasure devices

CRIEPI has analyzed data from long-term field observation and various laboratory tests, verified the effectiveness of snow-damage countermeasure devices and clarified the conditions for effects to occur most easily. We have conducted an analysis of past snow damage events and proposed an effective method for selecting countermeasure devices to suit the weather conditions of each region and specific features of power transmission facilities.



Interphase spacer

These prevent power conductors from getting too close to each other due to galloping and also suppress power conductor twisting.

Counterweight

An eccentric weight makes it difficult for the power conductor to twist, thus preventing excessive cylindrical snow accretion in accompany with power conductor twists.

Snow-resistance ring

Plastic rings preventing accumulated snow from sliding along the twists in a power conductor's surface, thus preventing excessive cylindrical snow accretion.

Example of a flowchart for selecting effective countermeasure devices against snow damage for single conductor lines and types of countermeasure devices

Heavy snow accretion

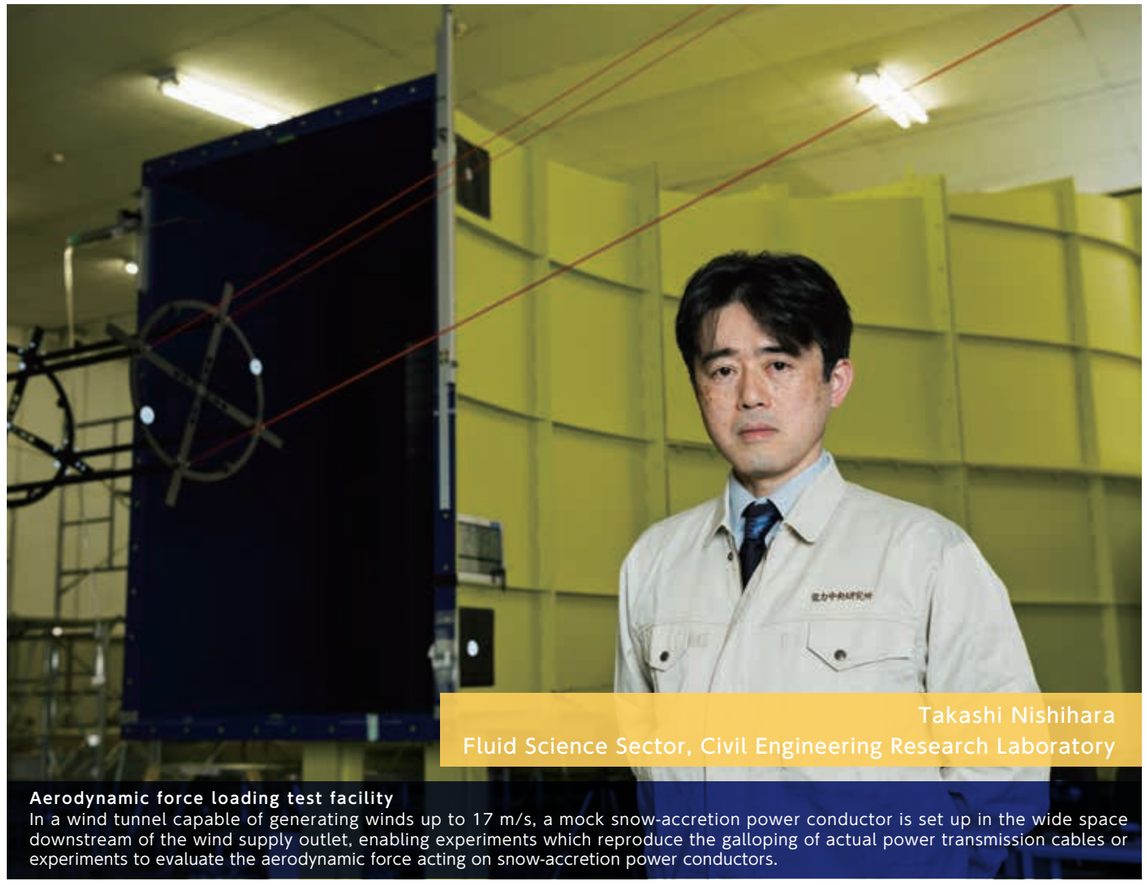
A phenomenon whereby excessive snow that accumulates around a power conductor in a cylindrical form leads to disruption and damage to support structures. In some instances ground faults occur due to conductors drooping under the weight of snow accretion, while in other instances the conductor short-circuits due to jumping upwards as a result of the snow accretion suddenly coming off.

Galloping

A phenomenon whereby a conductor with snow accretion is subjected to wind and oscillates significantly in a vertical direction. If the amplitude is too large, it could lead to the occurrence of short-circuits.

Salt snow damage

A phenomenon whereby wet snow including salt packs closely onto insulators causing them to drastically lose insulation performance, which could lead to the occurrence of electrical breakdown. This is an extremely rare phenomenon but was one of the causes of snow damage in regions on the Sea-of-Japan side in December 2005.



Takashi Nishihara
Fluid Science Sector, Civil Engineering Research Laboratory

Aerodynamic force loading test facility
In a wind tunnel capable of generating winds up to 17 m/s, a mock snow-accretion power conductor is set up in the wide space downstream of the wind supply outlet, enabling experiments which reproduce the galloping of actual power transmission cables or experiments to evaluate the aerodynamic force acting on snow-accretion power conductors.

Full-scale Test Facilities for Snow damage to Overhead Transmission Lines, commonly known as "Kushiro Test line"
A test line constructed in Kushiro, Hokkaido in FY2013 for the purpose of conducting tests, observations and analysis aimed at elucidation of the mechanism of phenomena related to snow damage, verification of countermeasure device effectiveness and improvement of prediction technology.

Application Examples of Research Results

Parts of the above-mentioned research results have already been utilized by power companies to investigate the cause of snow damage and to formulate preventive measures. Furthermore, applying the results of this research to maintenance, operation and snow-damage countermeasures for power transmission facilities allows us to reduce equipment damage and supply hindrance, and to swiftly recover from malfunction even if a snow damage event does occur.

References: Shimuzu et al., CRIEPI Report N16010 (2016)
Honma et al., CRIEPI Report H16004 (2016)
CRIEPI TOPICS Vol. 5 (2011)

Customers Services

Development of a Heat Exchanger with Minimal Frost Accumulation as a part of Achieving Higher Efficiency Heat Pumps

Contributing to energy-saving and comfortable living through high-efficiency dehumidification

Background

When heating or supplying hot water using a heat pump or freezing/refrigerating with a freezer, if the surface temperature of the heat exchanger drops below 0℃, the moisture in the air will condense and freeze, causing frost build up. If a heat exchanger becomes frosted, not only does it lead to decreased heating or cooling performance, it also increases power consumption due to the additional power needed to melt the frost (defrosting). Furthermore, other issues may occur, such as heating or hot water supply being temporarily suspended while the device is defrosting. As part of efforts to increase the efficiency of heating and cooling equipment, CRIEPI is developing a heat exchanger on which frost does not easily accumulate.

Heat exchanger

A device used to transfer heat from hot substances to cold substances. In the case of cooling, a heat exchanger inside the indoor unit transfers the heat in a room to a refrigerant, then the heat exchanger inside the outdoor unit releases the heat of the refrigerant outside.

Outline of Results

◇ Development of a frost-free heat pump water heater and freezer

CRIEPI has developed a heat exchanger coated with desiccant, the Desiccant-Coated Heat Exchanger (DCHE), and solved the issue of frost building up on heat pumps through removing moisture from the air at the heat exchanger inlet in advance (Fig. 1). As a result of conducting tests and trial calculations under various conditions, it was apparent that adoption of the DCHE held the potential to improve efficiency anywhere from 10 to 30% compared to the conventional heat pump water heater system. Furthermore, if DCHE is applied to refrigerators or freezers, a trial calculation of power consumption for an open showcase used in supermarkets, as one example, revealed that COP could be improved by around 40% compared to the conventional approach (Fig. 2).

COP (Coefficient of Performance)

An indication of the power consumption efficiency for cooling equipment, etc., expressed as a ratio of cooling performance against power consumption required for cooling.

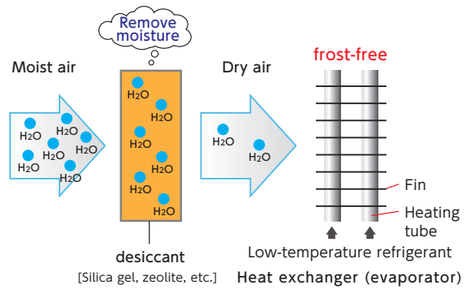


Fig. 1 Frost-free concept

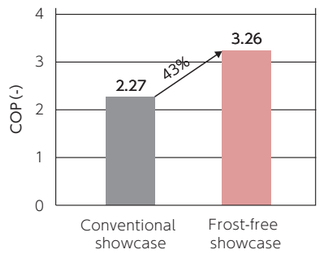


Fig. 2 Open showcase COP trial calculation results

Frost does not build up on the heat exchanger because the desiccant has the effect of removing the moisture from the air, so that it is dry by the time it reaches the heat exchanger. If used on freezer-type/refrigerator-type open showcases, it would result in energy-savings as electricity would no longer be needed to remove frost with an electric heater.

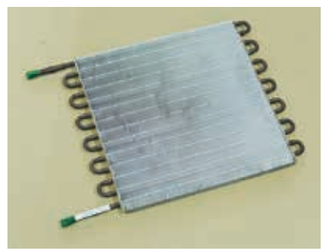
◇ Investigation into desiccant air-conditioning

Desiccant air-conditioning regulates temperature and humidity separately and has attracted attention for some time now as a form of air-conditioning achieving both comfort and energy-saving. However, the popularization of desiccant air-conditioning has been hampered by issues such as large size and high cost. CRIEPI has conducted an investigation into desiccant air-conditioning related products in Japan and ascertained the R&D status. We realized that by using DCHE in desiccant air-conditioning, higher efficiency and smaller installation space could be achieved not only for air-conditioners, but also ventilation with outside air and dehumidification equipment such as that used in food manufacturing plants and school lunch supply centers.

Desiccant air conditioning

An air conditioning system with a function to regulate humidity (humidification / dehumidification) separate to regulation of air temperature. Air conditioning equipment without a desiccant function consumes energy unnecessarily due to performing dehumidification by cooling air excessively then reheating it afterwards.

Heat exchanger test facility
A test facility that measures the heat and mass transfer characteristics of heat exchangers for heat pump applications.



A heat exchanger for frost-free heat pumps

A heat exchanger coated with desiccant (the white portion of the figure to the right) in order to dehumidify the air at the inlet of the heat exchanger.

Application Examples of Research Results

A frost-free heat pump can contribute to higher efficiency of hot water systems in winter, particularly in with regards to hot water heat pump usage in cold regions. A frost-free freezer would help solve various issues such as deterioration of food quality due to frosting, a drop in efficiency due to a defrosting heater, and disposal of water created in the process of defrosting. It is anticipated that the development of desiccant air conditioning using DCHE will lead to realization of air conditioning systems which are compact and offer comfort and energy-saving.

References: Li Zhang, et.al., International Journal of Refrigeration, Vol. 35, pp. 1327-1334 (2012)
Li Zhang, et.al., International Journal of Refrigeration, Vol. 74, pp. 93-102 (2017)

Environment

Investigation and Analysis of Carbon Pricing Policy Implemented in the U.S. and Europe

Supporting policy-making through analysis of Carbon Pricing Policy in the U.S. and European countries and efficient usage of Japan's tax revenue

Background

Paris Agreement
An agreement adopted in December 2015 at the 21st Conference of the Parties of the United Nations Climate Change Conference (COP21). It sets out international frameworks from the year 2020.

Japan's global warming measures are entering a new phase amidst the adoption of the Paris Agreement by the international community and, within Japan, the establishment of the Electric Power Council for a Low Carbon Society (ELCS) and the Japanese government's announcement of the Global Warming Countermeasures Action Plan, etc. In order to achieve long-term, large-scale reduction of CO_2 emissions, there are ongoing studies into "carbon pricing" (emissions trading, heavy carbon tax) and it has been pointed out that this policy entails many issues. Moreover, in FY2016, there was an increase in "tax for global warming countermeasures" and the government is being expected to efficiently utilize tax revenue. CRIEPI conducts investigations and analyses relating to carbon pricing and will continue to investigate potential future policies.

Outline of Results

◇ Investigation and analysis of carbon pricing

CRIEPI has conducted a comparative study into examples of emissions trading schemes adopted in various overseas countries and Tokyo, and extracted issues of debate surrounding scheme design and market transactions. As a result of this study, we observed that, for all schemes, the emissions quota price was low, therefore the schemes are not functioning as a price signal to urge low-carbon investment (Table 1). Furthermore, in addition to the approach of explicitly pricing carbon emission in ways such as carbon tax and emissions trading, there is also the approach of "implicitly" pricing carbon through regulation and various energy taxes, etc. so that carbon price may be compared on a global scale. As such, CRIEPI has reviewed overseas literature to better understand the points of debate surrounding the definition of "implicit carbon price", as well as the various evaluation methods for each policy based on implicit carbon price and limitations of such evaluations. After this review, we raised the point that using a separate indicator such as energy retail price together with implicit carbon price would be desirable.

Table 1 Case study of emissions trading schemes

Scheme name/Applicable region	Current status of scheme operation and issues
EU ETS	Despite of postponing excess emission quotas in 2014-16 and introduction of strategic Market Stability Reserve (MSR), etc. price is sluggish (around €5 to 6/t-CO_2) due to surplus emissions quota.
Californian C&T (California, U.S.A.)	Through promotion of energy-saving and renewable energy, as well as policy for low-carbon vehicle transportation, has achieved a reduction in emissions with the auction price for emission quotas shifting to the lower range ($12.73/t-$CO_2$ in 2016)
RGGI (U.S.'s north-eastern region)	There has been a surplus emissions quota since a drop in demand after the financial crisis, with emissions fetching low prices in auctions until 2012. The price has been around $5 to 7/t-$CO_2$ since the cap was reviewed in 2014.
Total reduction obligation and emissions trading scheme (Tokyo)	Many companies have proactively focused efforts on energy-saving to achieve well over targets, creating surplus credit in the market overall and lowering the credit price to between 1,000 and 2,000 yen/t-CO_2.

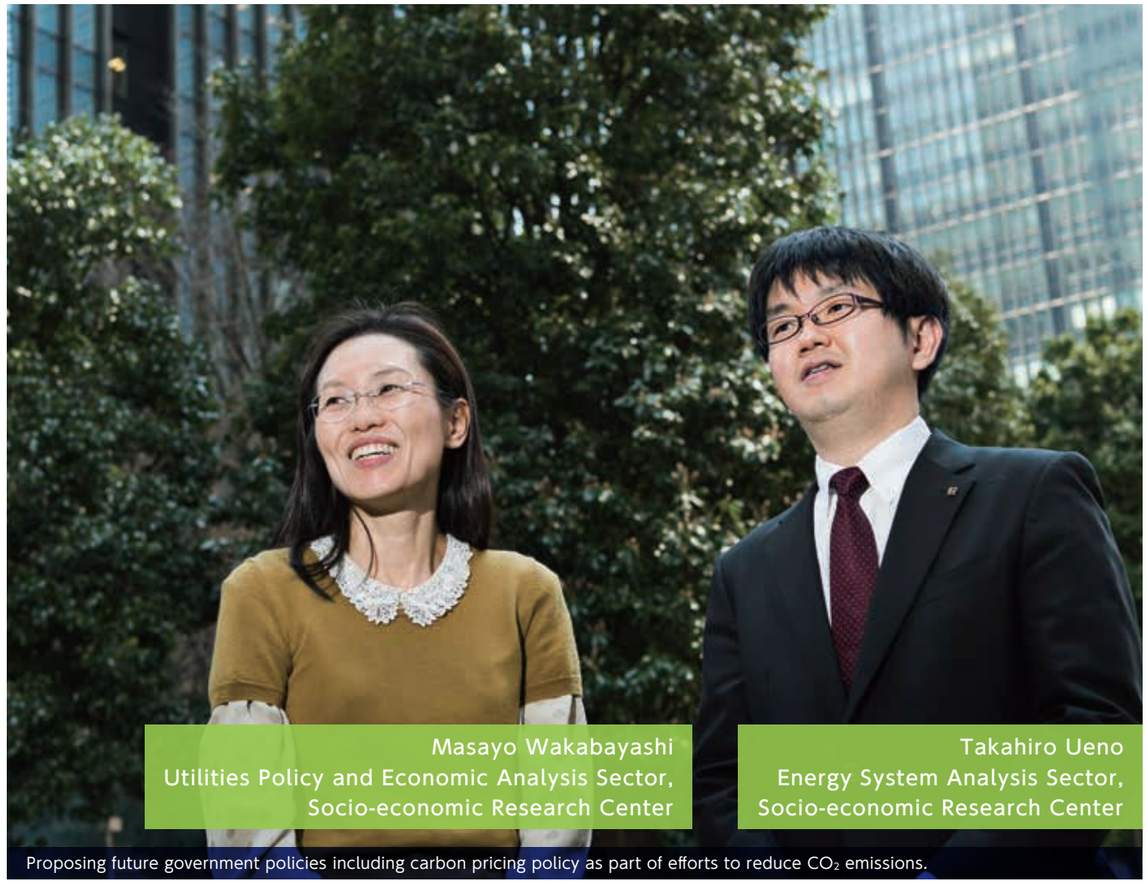
EU ETS (European Union Emission Trading Scheme)
An emissions trading scheme for CO_2 within the EU.

C&T (Cap and Trade)
One form of CO_2 emissions trading, involving setting an upper limit (cap) on emission amount then acknowledging the buying and selling of emissions surplus or shortage between businesses allocated with emission quotas.

RGGI (Regional Greenhouse Gas Initiative)
A regional emissions trading program participated in by nine states in the U.S.'s north-eastern region.

◇ Evaluation of government projects for global warming/energy-saving subsidization

Based on information featured in the Government Project Review Sheet, etc., CRIEPI analyzed the cost effectiveness of each government project to counteract global warming and revealed that the majority of projects were not effective in reducing CO_2 emissions. We also demonstrated that there were many inefficient projects whereby the CO_2 emission reduction unit price was as much as several 100,000 yen per ton, and pointed out that this inefficiency needed to be corrected.



Masayo Wakabayashi
Utilities Policy and Economic Analysis Sector, Socio-economic Research Center

Takahiro Ueno
Energy System Analysis Sector, Socio-economic Research Center

Proposing future government policies including carbon pricing policy as part of efforts to reduce CO_2 emissions.

An award of excellence was received for this research in the "Essay Competition Utilizing the Database Function of the Government Project Review Sheet" run by the Administrative Reform Promotion Council of the Prime Minister of Japan and His Cabinet, which was officially awarded by the Minister for Administration Reforms on September 26th.

Osamu Kimura
Energy System Analysis Sector, Socio-economic Research Center

(http://www.cas.go.jp/jp/seisaku/gyoukaku/H27_review/hyosyo/hyosyo.html)

Application Examples of Research Results

In order to reduce CO_2 emissions in the future to achieve both economic growth and energy security, we will propose desirable government policies including, but not limited to, carbon pricing policy.

References: Kimura et al., CRIEPI Report Y16002 (2017)
Wakabayashi et al., CRIEPI Report Y16001 (2017)

2–2. Major Research Results -20

Utility Management

Detailed Analysis of the Five New Markets in Accordance with Electricity Market Reform

Helping to enhance policy recommendations and mitigate risk through quantitative market analysis and investigation/analysis of overseas case studies

Capacity market

A market that does not trade supply volume (kilowatts per hour: kWh), but rather future supply capability (kilowatts: kW). Two types of capacity market exist: the centralized type whereby a market operator secures capacity, and the decentralized type, whereby electricity retailers secure capacity.

Adequacy

The capacity to supply power demanded by consumers considering unplanned outage of power generation/distribution equipment and operational limitations.

Background

There is action being taken toward detailed system design and revision regarding the various new markets that will be newly introduced with the Electricity Market Reform (Mandatory Auction for Base load Power, capacity market, balancing control power market, cross-regional interconnection lines usage rules, non-fossil value trading market). CRIEPI is helping with the detailed market design reflecting the situation specific to Japan through quantitative analysis using market models and the appropriate presentation of results obtained through evaluation and theoretical analysis of case studies in overseas countries pioneering this area.

Outline of Results

◇ Quantitative analysis using the wholesaler market model

CRIEPI conducted a quantitative analysis regarding the installed capacity of power source required to secure the supply capability (adequacy) necessary for stable supply assuming the high-volume introduction of renewable energy by the year 2030, as raised in the Long-term Energy Supply and Demand Outlook. Through this analysis, we discovered that power source able to cover annual expenditure through income from electric power sales in the wholesale market was only around 40% (Fig. 1). We demonstrated that, in order to achieve both the Long-term Energy Supply and Demand Outlook and stable supply, the creation of a capacity market, etc. as a measure to secure the necessary supply capability was desirable.

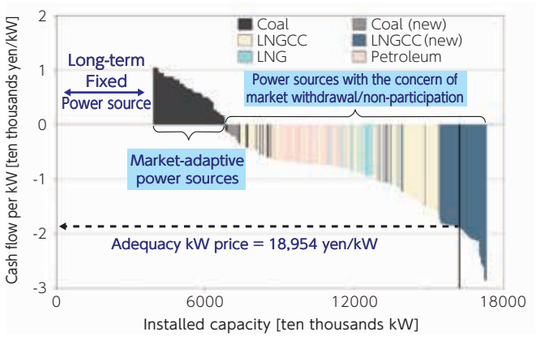


Fig. 1 Cash flow analysis for thermal power source

◇ Analysis of detailed system design for new markets

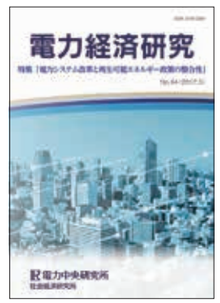
CRIEPI investigated and analyzed the detailed design by overseas countries for new markets in accordance with Electricity Market Reform (Table 1) and proposed a rational approach to system design.

Table 1 Investigation of overseas case studies relating to new market design

New market	Case studies, issue of debate, etc.
Mandatory Auction for Base load Power	Obligatory bidding amount and price setting, France's wholesale power regulations targeting nuclear power
(Centralized) capacity market	Need to differentiate between new and existing generation source, handling of own company's power source and bilateral contracts
Balancing control power market	Europe's Cross Border Electricity Balancing mechanism, relationship with congestion management
Cross-regional interconnection lines usage rules	U.S.'s PJM locational locational marginal pricing, Financial Transmission Rights mechanism
Non-fossil value trading market	Demand for non-fossil certification, Europe's Guarantee of Origin (GO), U.S.'s Zero Emission Credits (ZEC)

Kenji Okada / Yu Nagai / Ken Furusawa
Energy Systems Analysis Sector, Socio-economic Research Center

We have proposed a rational system design for the 5 new markets created in accordance with Electricity Market Reform.



Power Economy Research, Volume 64 (March 2017)
"Consistency of the Electricity System Reform and Renewable Energy Policy"
http://criepi.denken.or.jp/jp/serc/periodicals/index.html

Application Examples of Research Results

CRIEPI published the results of a quantitative analysis for supply adequacy evaluation in general newspapers and industrial journals in order to stress the need for a capacity market to the public at large. In regards to the consistency of the Electricity Market Reform and Renewable Energy Policy, we published our views in Power Economy Research, Volume 64, an academic journal published by the Socio-economic Research Center, and publically raised issues relating to the design of systems for the capacity market, Mandatory Auction for Base load Power, capacity market, non-fossil fuel value trading market, Balancing control power market, etc., therefore, we anticipate that our research results will be utilized to enhance policy recommendations and mitigate risk.

References: Asano et al., Power Economy Research No.64 (2017)

Common Cross-Cutting Field

Development of an Effective Status Monitoring Technology for Power Generation Equipment through the Introduction of IoT Technology

Supporting Labor-saving of Maintenance and Management by Achieving Maintenance-free Status Monitoring

Background

In line with aging of electric power infrastructure and equipment, there is a need to establish rational operation and maintenance technologies. By introducing IoT (Internet of Things), which is attracting attention in recent years, and performing online detection of device breakdowns in power plants, such as temperature and vibration abnormalities or diagnosis of deterioration and damage to structural materials used in devices, it is anticipated that the reliability of equipment operation could be dramatically improved. CRIEPI is developing technologies in order to utilize energy harvesters (environment energy harvesters) which self-produce electric power from the heat, vibration and so on in their installation environment, as power sources for sensors. CRIEPI is simultaneously developing maintenance-free status monitoring technology for power generation equipment using an "autonomous sensor network" configured from an energy harvester, sensors and a wireless communication device.

Outline of Results

◇ Development of vibrational energy harvester using low frequency vibration

When electrolytes are held between electrodes and a voltage is applied, an electric double layer is formed to sustain in the vicinity of the electrodes. By immobilizing these ions while maintaining this electric double layer we succeeded in retaining an electric charge semi-permanently (electret) (Fig. 1). By mechanically modulating contacting area between electrode and electret we were able to obtain a voltage as high as 2V and with 400μW/cm^2 in terms of power generation from low frequency vibration less than 100Hz, which was difficult to generate power using the conventional method. These results suggest that we can obtain electric power from environmental vibration less than 100Hz which is commonly generated from infrastructure or mechanical systems.

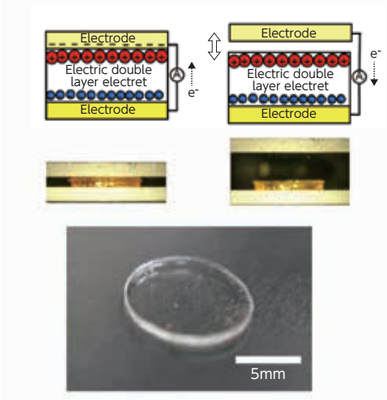


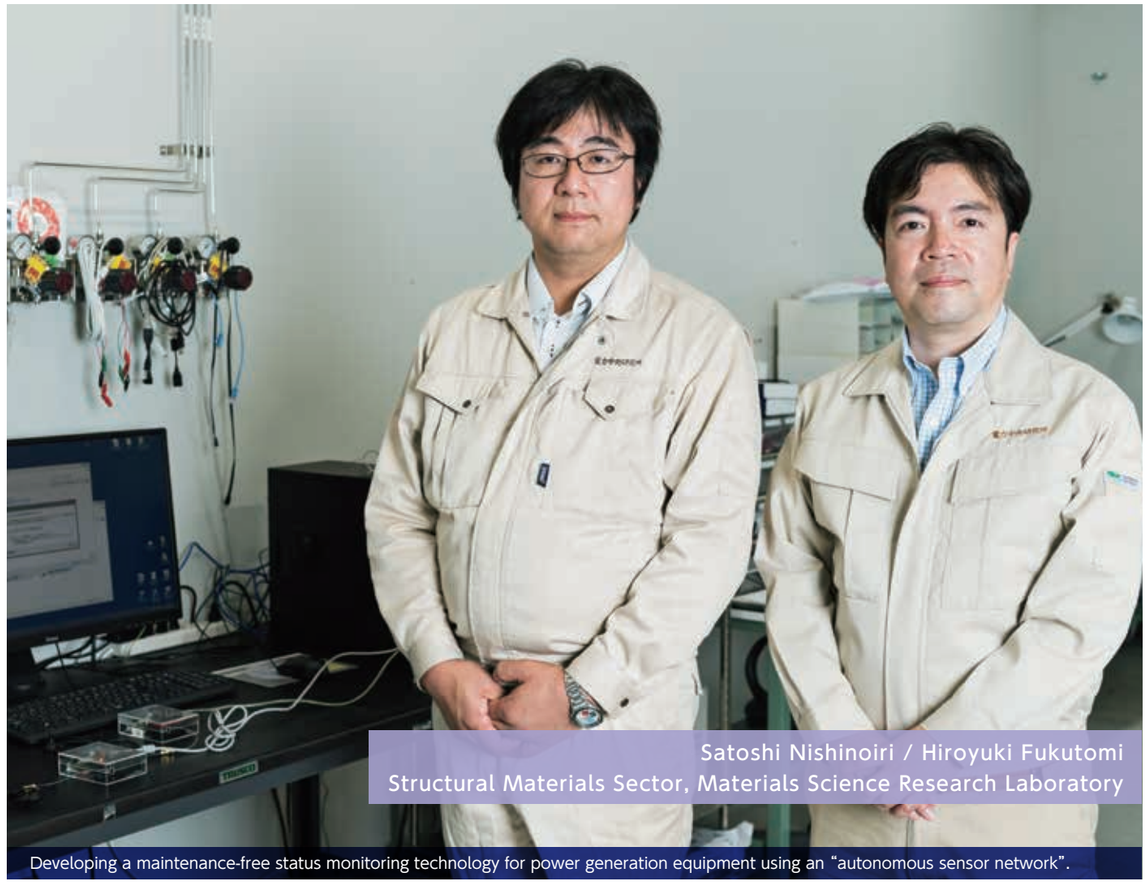
Fig. 1 The power generation mechanism of vibration energy harvesters utilizing electric double layer electrets (top) and the prepared electric double layer electret (bottom)

Electric double layer
A state whereby opposing ions become concentrated in the vicinity of either electrode when a voltage is applied to electrolytes.

◇ Building a wireless sensor network for status monitoring of power generation equipment

Rather than an approximate 100-meter Wi-Fi communication distance in an unobstructed communication environment, by adopting a wireless communication module with a lower frequency than Wi-Fi communication, it is possible to communicate across a distance of 1 km without multi-hop communication. CRIEPI has built a wireless sensor network supporting multi-hop communication from a wireless sensor device using this module that also supports multi-hop communication and a base station to save measurement data to the cloud via a 3G line. We have seen the potential for this wireless sensor network to be applied to daily maintenance tasks through long-term communication tests.

Multi-hop Communication
A communication method using nodes in a bucket relay system to transmit data.

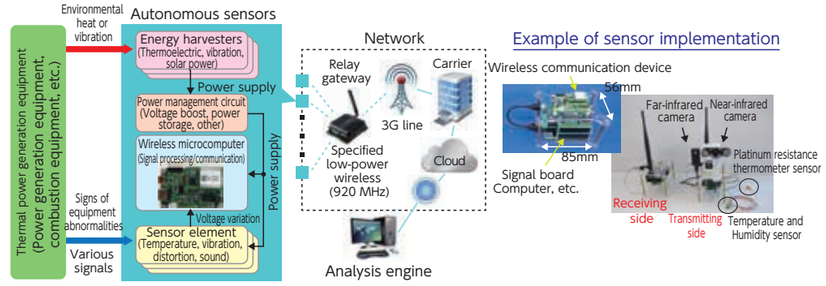


Satoshi Nishinoiri / Hiroyuki Fukutomi
Structural Materials Sector, Materials Science Research Laboratory

Developing a maintenance-free status monitoring technology for power generation equipment using an "autonomous sensor network".

Monitoring thermal power generation equipment status using an autonomous sensor network

It has become possible to communicate across a distance of 1 km in unobstructed communication environments without performing multi-hop communication, therefore data can be stored in the cloud without omissions even when driving devices and base stations on solar power alone.



Application Examples of Research Results

The application of new vibration energy harvesters capable of power generation at frequencies of 100 Hz or less, which was difficult to do using the conventional method, there are expectations regarding saving labor and sophistication of daily maintenance tasks. Through demonstration experiments in thermal power plants, we are verifying the validity of modules adopting a wireless sensor network.

References: Fukutomi et al., CRIEPI Report Q16003 (2016)

2-2. Major Research Results-22

Development of a Technology to Determine OF Cable Abnormalities by Applying AI Technology

Helping improve the accuracy of cable abnormality determination

Common Cross-Cutting Field

OF cable
An electric power cable for high-voltage and ultra-high-voltage that has increased insulation performance due to being filled with insulating oil.

Background

CRIEPI is advancing application of AI techniques in the electric power field and has developed a technology that contributes to the sophistication of work tasks while alleviating the workload of field operators through verification of a method which is simple, but at the same time capable of sophisticated pattern recognition. One successful example of AI field application is determination of OF (oil filled) cable abnormalities. OF cable began being laid around the start of the Showa period (1926), primarily as underground power transmission lines and some on-site connecting line. Currently there is a shift towards CV cable, which is easier to maintain, however some OF cables are deteriorating due to age, therefore accurate detection of abnormalities is important to achieving the appropriate maintenance of OF cable. As part of efforts to detect OF cable abnormalities with higher accuracy, CRIEPI has developed a technology to determine abnormalities by applying an AI technique.

Outline of Results

◇ Proposal of new abnormality determination criteria

Individual power companies used to determine abnormality ranking*1 of OF cable intermediate junctions from two types of data; the amount of acetylene generated due to insulating oil overheating and the total amount of combustible gas. As an alternative, CRIEPI proposed analyzing the gases included in OF cable oil and establishing the determination criteria of individual abnormality ranking as well as abnormal portion*2 for the intermediate joints and terminal joints (Fig. 1) based on the six types of gas included in the oil.

*1 Abnormality ranking determination: Rank A (urgent response required), B (Abnormal insulator), C (some form of abnormality present), D (abnormality-free)
*2 Abnormal portion determination: Targets the reinforced insulating paper and cable insulating paper inside the joint

◇ Establishment of a determination formula

Support Vector Machine (SVM)
A typical AI technique to create high-accuracy determination criteria by identifying/determining examples (support vectors) from trained examples that are close to the borderline between normal and abnormal.

Linear support kernel machine
A technique developed by CRIEPI to create determination critiera with higher accuracy and greater ease than SVM utilizing a linear evaluation formula, by automatically refining the variables effective for determination.

Because people working in the power field prefer tasks that can be performed with ease, CRIEPI established a linear equation using the concentrations of the six gases within oil as the variable as criteria for determining OF cable abnormalities (Fig. 2). In concrete terms, we applied a linear support kernel machine, which is an extended version of the support vector machine typical of AI techniques, and determined the parameters of the linear equation. By doing this, we improved the accuracy rate for unknown data from the approximate 50% capable with the conventional technique to around 80%, thus simultaneously establishing a simple determination formula and improving determination accuracy.

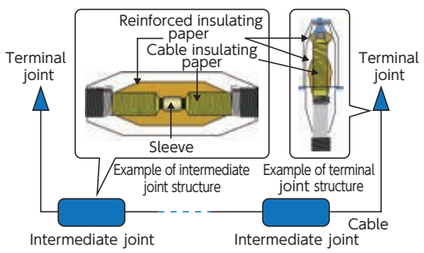


Fig. 1 OF cable equipment

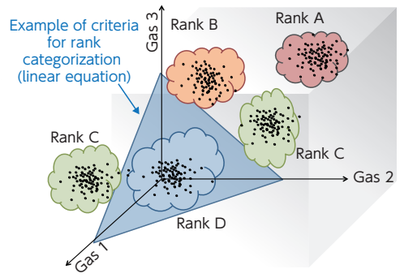
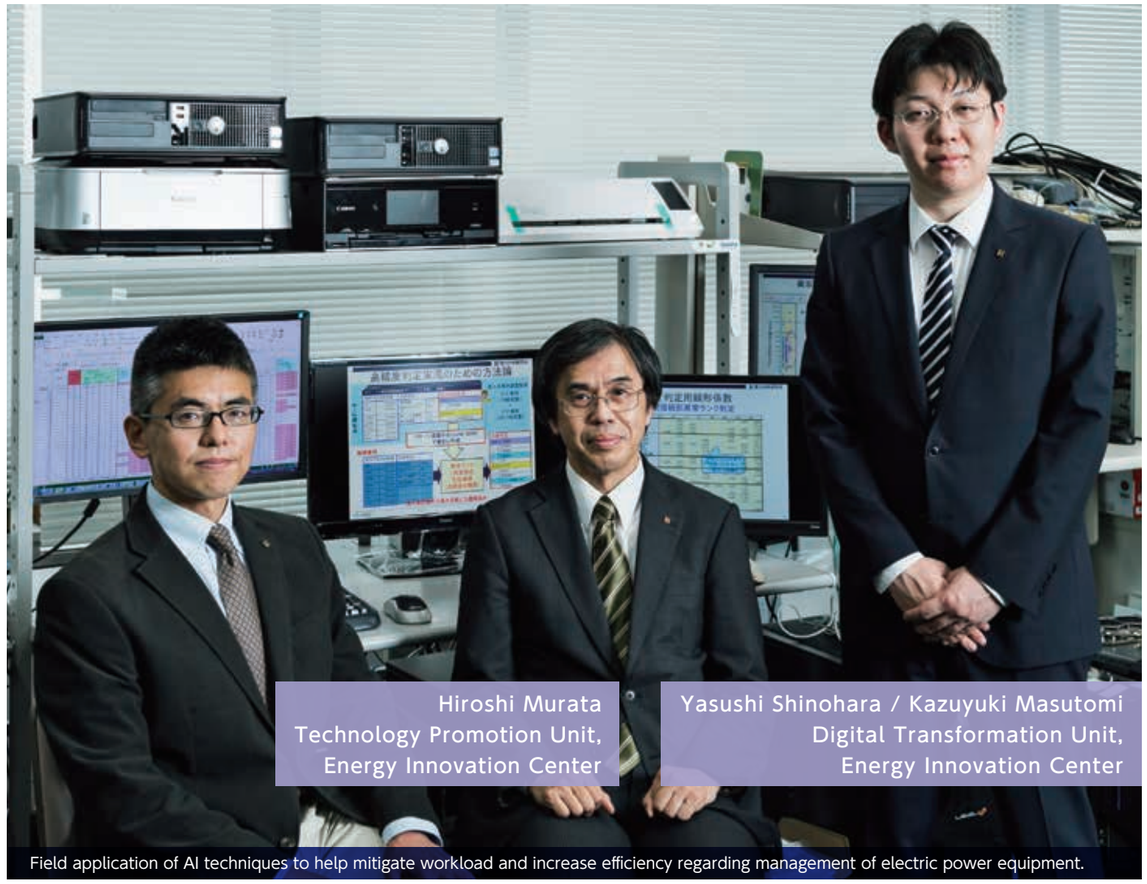


Fig. 2 Concept of the abnormality determination formula

By utilizing data relating to the six gas types, it has become possible to express data collection for abnormality rank and abnormal portion of the intermediate joint and terminal joint in terms of high-order spatial data. Moreover, by applying the linear support kernel machine and finding the parameter of the linear formula that classifies each collection (inclination), categorization can be performed easily even if the positional relationship between each collection is complex.



Field application of AI techniques to help mitigate workload and increase efficiency regarding management of electric power equipment.

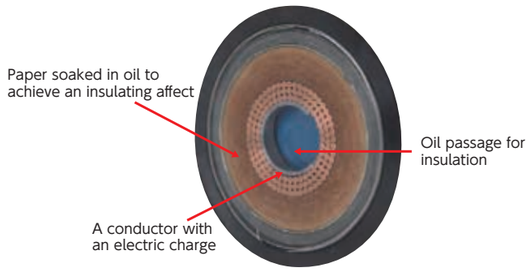


Photo of an OF cable cross-section

Application Examples of Research Results

We published the developed criteria for determining OF cable abnormalities in Appendix 9, Issue 1, Electric Technology Research - Volume 70, which is used by power companies in the maintenance and management of OF cables. Moreover, tools to simplify abnormality determination are being used by the individual power companies.

References: Tsutsumi et al., CRIEPI TOPICS Vol.22 (2016)
Shinohara et al., CRIEPI Report R13002 (2013)

Ordinary profit was higher than previous financial year, however the increases in the ordinary expenses of both general running costs and labor costs were suppressed, therefore the current change in ordinary profit was a positive value.

Net Assets Variation Statement

(Unit: 100 mill yen)

Change in general net assets

	FY2016	FY2015	Difference		FY2016	FY2015	Difference
Ordinary expenses	298.0	283.0	15.0	Ordinary revenue	309.5	276.2	33.3
Labor costs	97.3	94.6	2.6	Ordinary benefit received	252.4	235.6	16.8
General running costs	200.6	188.3	12.3	Operating revenue	54.1	37.3	16.7
				Other revenue	1.0	1.2	△ 0.1
				Transfer from designated net assets	1.8	1.9	△ 0.1
Current ordinary profit	11.5	△ 6.7	18.3				
Current general net assets change	28.4	△ 5.6	34.0				

Change in designated net assets

	FY2016	FY2015	Difference		FY2016	FY2015	Difference
Transfer to general net assets	1.8	1.9	△ 0.1	Subsidy etc. received	0.7	1.0	△ 0.2
Current designated net assets change	△ 1.0	△ 0.9	△ 0.1				
Current net assets change	27.3	△ 6.5	33.8				

Balance Sheet

(Unit: 100 mill yen)

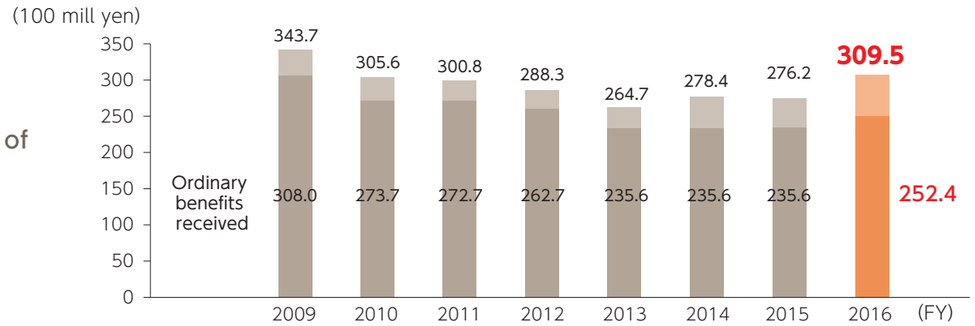
Assets

	FY2016	FY2015	Difference
Current assets	45.4	44.4	1.0
Fixed assets	497.2	472.9	24.3
Total assets	542.7	517.3	25.3

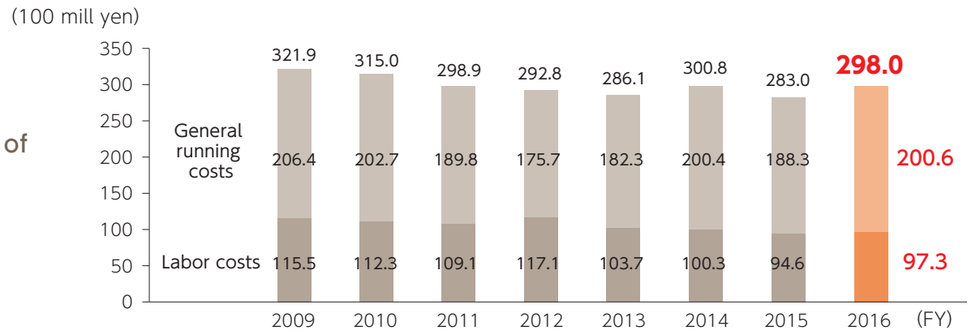
Liabilities

	FY2016	FY2015	Difference
Current liabilities	42.7	42.3	0.3
Fixed liabilities	91.7	94.0	△ 2.3
Total liabilities	134.4	136.4	△ 1.9
Net assets			
Designated net assets	4.0	5.1	△ 1.0
General net assets	404.2	375.8	28.4
Total net assets	408.2	380.9	27.3

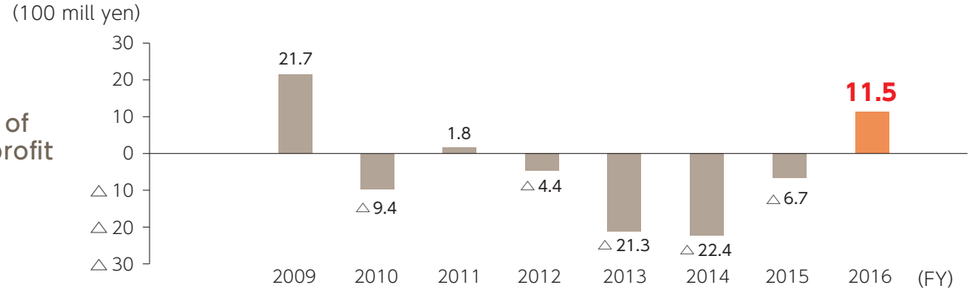
Transition of ordinary revenue



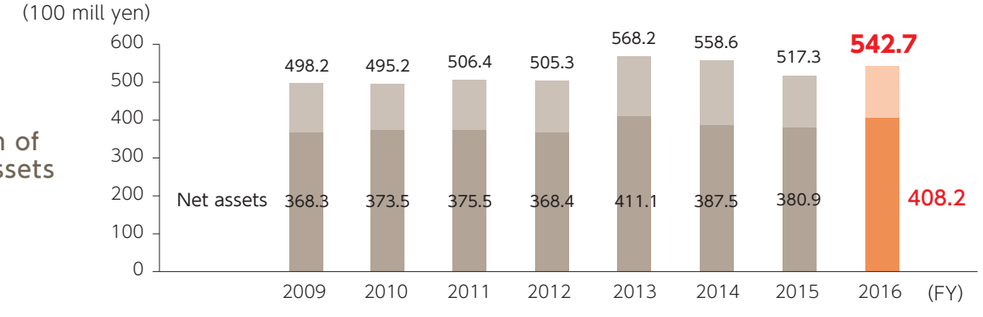
Transition of ordinary expenses



Transition of ordinary profit



Transition of overall assets



* From FY2016, loss on retirement of fixed assets is included in ordinary expenses, therefore figures for the previous financial year have been rearranged accordingly.

2. Financial Statement

Balance Sheet

As of March 31, 2017

(Unit: 1,000yen)

Account	Current fiscal year	Previous fiscal year	Change
Ⅰ Assets			
1. Current assets			
Cash and deposit	1,630,185	1,912,295	△ 282,110
Accounts receivable	2,770,263	2,292,810	477,453
Suspense payments	130,400	216,594	△ 86,194
Advance payments	15,911	23,743	△ 7,831
Total current assets	4,546,760	4,445,444	101,316
2. Fixed assets			
(1) Special assets			
Buildings	164,985	182,014	△ 17,029
Facilities attached to buildings	0	0	-
Structures	1,045	1,254	△ 209
Machine and equipment	234,063	364,016	△ 129,952
Tools and furniture	43,822	42,055	1,766
Lump-sum depreciable assets	2,805	1,494	1,311
Intangible fixed assets	9,317	5,552	3,764
Special assets for retirement lump sum grants benefits package allowance	3,435,900	3,435,900	-
Specific assets for depreciation allowance	2,800,000	-	2,800,000
Special assets for acquisition of research facilities reserves	2,192,500	3,050,000	△ 857,500
Special assets for special project reserves	510,000	510,000	-
Specific assets for base establishment allowance	2,695,127	3,995,408	△ 1,300,280
Total special assets	12,089,566	11,587,696	501,870
(2) Other fixed assets			
Land	9,137,685	8,505,971	631,713
Buildings	11,988,630	10,252,627	1,736,003
Facilities attached to buildings	4,482,670	3,150,034	1,332,636
Structures	1,476,562	1,260,143	216,419
Machine and equipment	6,571,926	7,278,748	△ 706,822
Tools and furniture	1,600,935	1,776,705	△ 175,770
Rolling stock and vehicles	23,680	34,574	△ 10,893
Lump-sum depreciable assets	79,122	49,573	29,548
Intangible fixed assets	695,241	698,615	△ 3,373
Construction in progress accounts	1,580,180	2,699,182	△ 1,119,001
Total other fixed assets	37,636,636	35,706,176	1,930,459
Total fixed assets	49,726,202	47,293,873	2,432,329
Total assets	54,272,963	51,739,317	2,533,645
Ⅱ Liabilities			
1. Current liabilities			
Accounts payable	3,519,784	3,914,547	△ 394,762
Deposits received	86,607	80,410	6,197
Advances received	407,614	2,763	404,851
Accrued bonus	260,000	240,000	20,000
Total current liabilities	4,274,006	4,237,720	36,285
2. Fixed liabilities			
Allowance for retirement benefits for directors	435,000	483,000	△ 48,000
Accrued retirement benefits for employees	8,735,000	8,922,000	△ 187,000
Total fixed liabilities	9,170,000	9,405,000	△ 235,000
Total liabilities	13,444,006	13,642,720	△ 198,714
Ⅲ Net assets			
1. Designated net assets			
Special benefits	261,776	311,069	△ 49,293
Subsidies	67,841	120,262	△ 52,420
Donations, etc.	74,024	82,153	△ 8,129
Total designated net assets	403,642	513,486	△ 109,843
(including appropriation to special assets)	(403,642)	(513,486)	(△ 109,843)
2. General net assets	40,425,314	37,583,109	2,842,204
(including appropriation to special assets)	(8,250,023)	(7,638,310)	(611,713)
Total net assets	40,828,956	38,096,596	2,732,360
Total of liabilities and net assets	54,272,963	51,739,317	2,533,645

Statement of Changes in Net Assets

From April 1, 2016 to March 31, 2017

(Unit: 1,000yen)

Account	Current fiscal year	Previous fiscal year	Change
Ⅰ General net assets change			
1.Ordinary profit			
(1)Ordinary revenue			
[1] Benefit received			
Ordinary benefit received	25,249,026	23,565,000	1,684,026
[2] Operating revenue	(5,415,715)	(3,736,470)	(1,679,244)
Consigned research operating revenue	4,952,427	2,774,762	2,177,665
Other operating revenue	463,287	961,707	△ 498,420
[3] Other revenue	103,580	120,808	△ 17,228
[4] Transfer from designated net assets	188,272	199,208	△ 10,935
Total ordinary revenue	30,956,593	27,621,487	3,335,106
(2)Ordinary expenses			
[1] Operating expenses			
Labor	(8,807,813)	(8,598,452)	(209,361)
Salary and benefit	6,724,773	6,984,078	△ 259,305
Retirement benefit	1,083,562	592,824	490,738
Welfare	999,478	1,021,549	△ 22,071
General expenses	(19,359,482)	(18,133,117)	(1,226,365)
Supplies and printed materials	3,373,500	2,278,604	1,094,895
Utilities	722,813	855,463	△ 132,649
Outsourcing costs	6,110,377	5,742,133	368,243
Joint research contribution	288,292	647,060	△ 358,767
Repair expenses	1,502,004	1,443,438	58,565
Rent	300,050	317,241	△ 17,191
Taxes and dues	578,216	493,542	84,673
Travel and transport	728,498	677,465	51,032
Depreciation	4,824,098	4,891,901	△ 67,802
Loss on retirement of fixed assets	116,078	100,468	15,609
Other	815,552	685,797	129,755
Subtotal of operating expenses	28,167,296	26,731,569	1,435,727
[2] Administrative expenses			
Labor	(927,387)	(870,199)	(57,187)
Director remuneration	141,110	158,070	△ 16,960
Salary and benefits	576,722	540,360	36,362
Retirement benefit	76,568	41,891	34,677
Welfare	75,945	71,358	4,587
Transfer of allowance for director retirement benefits	57,040	58,520	△ 1,480
General expenses	(708,824)	(698,674)	(10,150)
Supplies and printed materials	50,609	48,622	1,987
Utilities	5,650	6,073	△ 422
Outsourcing costs	117,169	110,451	6,718
Repair expenses	17,104	11,368	5,736
Rent	338,839	338,806	32
Taxes and dues	45,915	41,315	4,600
Travel and transport	20,171	22,438	△ 2,267
Depreciation	26,327	31,867	△ 5,539
Loss on retirement of fixed assets	110	4,723	△ 4,613
Other	86,925	83,008	3,917
Subtotal of administrative expenses	1,636,211	1,568,873	67,337
Total Ordinary expenses	29,803,508	28,300,443	1,503,064
Current ordinary profit	1,153,085	△ 678,955	1,832,041
2.Non-recurring change			
(1)Non-recurring profit			
[1] Gain on sale of fixed assets	2,441,665	107,777	2,333,887
[2] Gain on donation of fixed assets	12,525	10,380	2,145
Total non-recurring profit	2,454,190	118,157	2,336,032
(2)Non-recurring expenses			
[1] Business structural reform cost	266,382	-	266,382
[2] Fixed asset impairment loss	498,690	-	498,690
Total non-recurring expenses	765,072	-	765,072
Current non-recurring change	1,689,118	118,157	1,570,960
Current general net assets change	2,842,204	△ 560,798	3,403,002
General net assets beginning balance	37,583,109	38,143,907	△ 560,798
General net assets final balance	40,425,314	37,583,109	2,842,204
Ⅱ Designated net assets change			
[1] Subsidies received	38,674	63,997	△ 25,323
[2] Gain on donation of fixed assets	39,754	40,316	△ 561
[3] Transfer to general net assets	188,272	199,208	△ 10,935
Current designated net assets change	△ 109,843	△ 94,894	△ 14,949
Designated net assets beginning balance	513,486	608,380	△ 94,894
Designated net assets final balance	403,642	513,486	△ 109,843
Ⅲ Net assets final balance	40,828,956	38,096,596	2,732,360

Facts & Figures

Research Reports / Research Papers / Intellectual Property

This section introduces key data on CRIEPI's FY2016 activities, including the number of report publications, number of paper presentations and number of patent applications.

Fig. 1 Transition in number of reports published

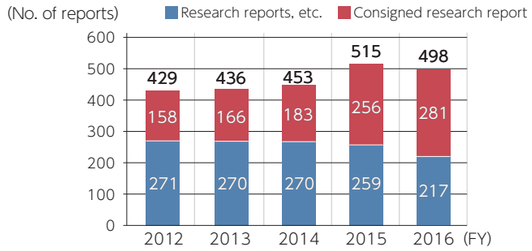


Fig. 2 Breakdown of no. of FY2016 reports by subject field

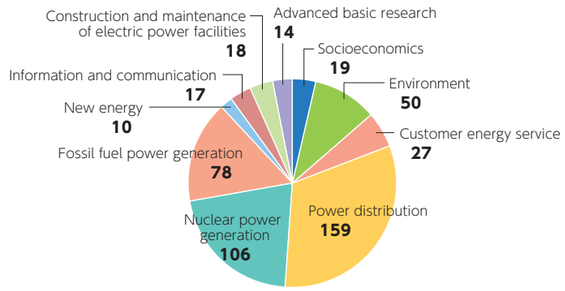


Fig. 3 Transition in no. of papers presented

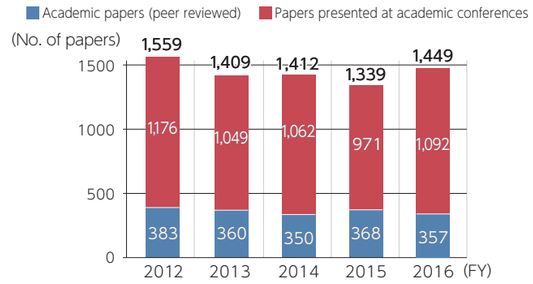


Fig. 4 Breakdown of no. of FY2016 papers by subject field

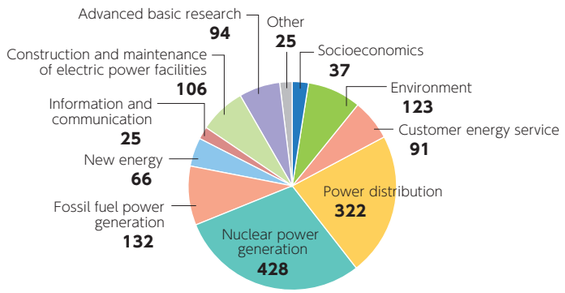


Fig. 5 Breakdown of no. of FY2016 patent applications by subject field

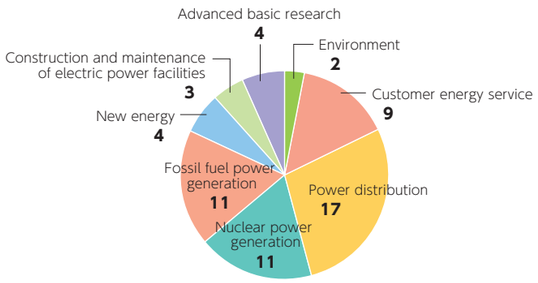


Fig. 6 Breakdown of no. of FY2016 patent registrations by subject field

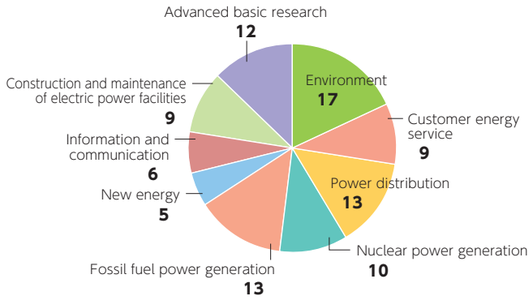
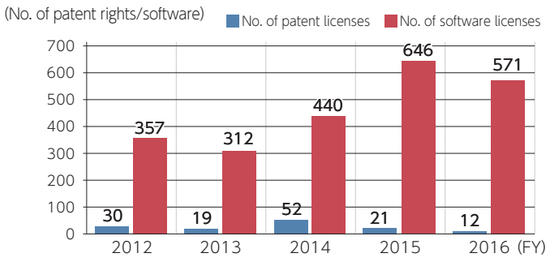
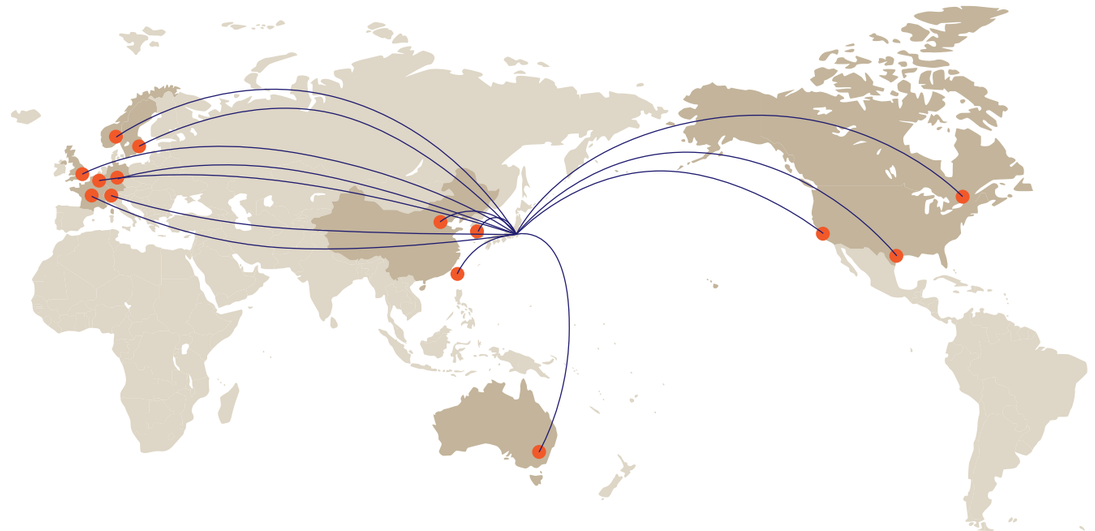


Fig. 7 Transition of patent /software licenses



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 possessing high technical standards.



Main Partners for Research Cooperation Agreements and Joint Research

Asia

China Electric Power Research Institute (CEPRI)
Korea Electrotechnology Research Institute (KERI)
Korea Electric Power Research Institute (KEPRI)
Korea Hydro and Nuclear Power Company Central Research Institute (KHNP-CRI)
Korea Atomic Energy Research Institute (KAERI)
Taiwan Power Company (TPC)

North America (including neighboring countries)

Electric Power Research Institute (EPRI)
Southwest Research Institute (SwRI)
National Center for Atmospheric Research (NCAR)
University of California, Los Angeles (UCLA), University of California, Santa Barbara (UCSB)
Texas Tech University
United States Department of Energy (DOE)
United States Nuclear Regulatory Commission (USNRC)
Atomic Energy Canada Limited (AECL)
Battelle Memorial Institute (BMI)

Europe

French Atomic Energy Commission (CEA)
Électricité de France (EDF)
National Agency for Radioactive Waste Management (ANDRA)
L'Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France
Gesellschaft für Nuklear-Service mbH (GNS), Germany
Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS), Germany
Fortum Power and Heat (Finland)
European Technology Development Ltd. (ETD), UK
Swedish Nuclear Fuel and Waste Management Company (SKB)
Studsvik Nuclear AB (Sweden)
Institute for Energy Technology (IFE), Norway
Studiecentrum voor Kernenergies - Centre d'etude de l'Energie Nucleaire (SCK・CEN)
National Cooperative for the Disposal of Radioactive Waste (NAGRA)
European Atomic Energy Community (EAEC/EURATOM)
Organization for Economic Co-operation and Development / Nuclear Energy Agency (OECD/NEA)

Australia

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Other International Projects

Mont Terri Consortium
Halden Reactor Project

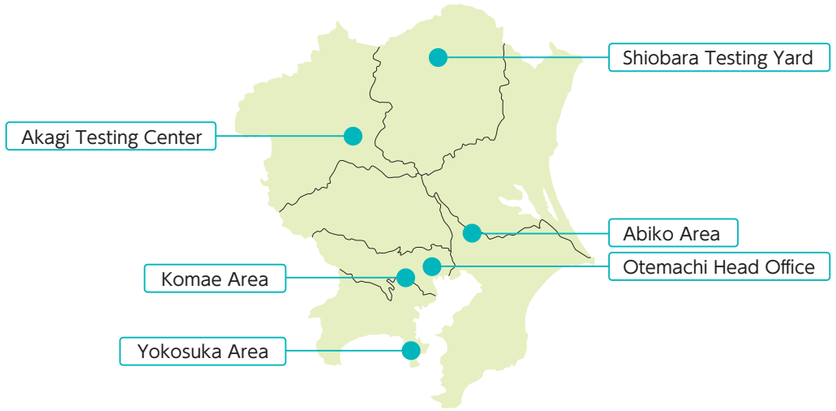
Participation in International Organizations

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

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.
Currently, CRIEPI is developing its facilities with a focus on the Yokosuka Area and Abiko Area, and aims to make Yokosuka a base for research into energy and industrial technologies and Abiko a base for research into 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

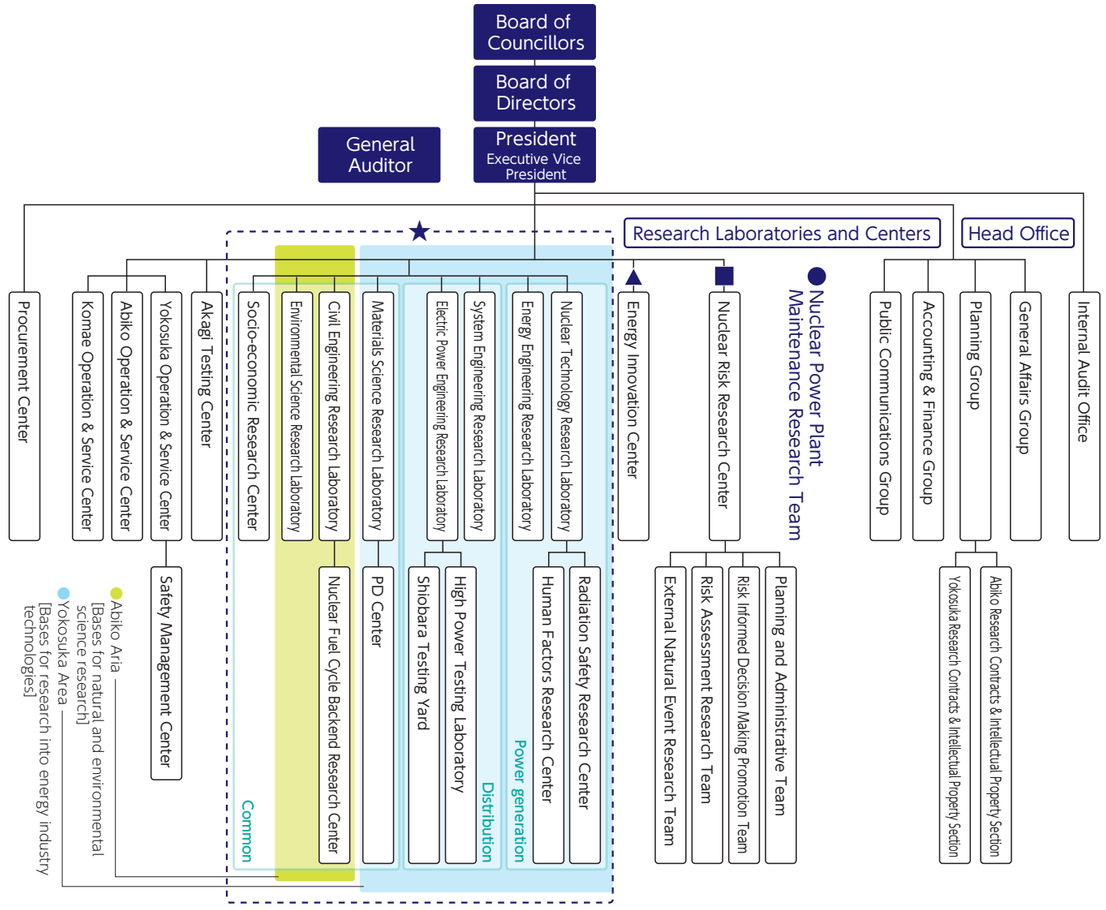
Akagi Testing Center

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



★ 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.

Keyword Index

This Annual Report features the key words listed in I-2. Research Reports. Explanations for each term are provided on the relevant pages.

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.