FY2015 Annual Report

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FY2015 Annual Report

CRIEPI

CRIEPI
Central Research Institute of Electric Power Industry

Contents

Overview of the FY2015 Annual Report

The road to resumption of nuclear power plant operation is gradually reopening, however electric power utilities continue to face a harsh business environment. Meanwhile, in April 2016 the electric power retail market became fully liberalized, with many new operators entering the industry and electric power utilities diversifying their business strategies or breaking up into separate companies, indicating that the electric power business is on the brink of significant reform.

With a forward-thinking focus on this electric power business reform, CRIEPI has conducted research based on a specific order of priority in our FY2015 activities, produced many accomplishments which contribute to industry and society through ongoing enhancement of safety in the nuclear power generation field, stable operation after resumption of nuclear power generation, rationalization of diagnosis for high-temperature equipment and maintenance/operation of existing plants in the thermal power generation field, rationalization of equipment maintenance and renewal and natural disaster countermeasures in the power distribution field.

In parallel to these initiatives, CRIEPI steadily advanced our measures related to corporate operation, including completing the transition to a general incorporated foundation and upgrading our research bases. We promoted structural reform so that we may continue fulfilling our duty as a research institute which contributes to the further sophistication and rationalization of energy supply and usage, including electric power. In other words, CRIEPI has begun establishing a sustainable business management system. Furthermore, in order to convey our new form to stakeholders and emphasize that CRIEPI will embrace the coming reforms and further lead them, we have replaced our conventional Business Report/Financial Statement with this Annual Report.

The electric power domain is an equipment industry based on technology, and the fact will never change that technical solutions to challenges from all aspects will always be sought and that the approval of society in regards to these technologies is essential. CRIEPI will continue to create and offer research accomplishments based on scientific objectivity as the “central research institute of the electric power industry” and “academic research institute contributing to society through scientific technology research”.

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 engaged in a broad range of R&D activities, produced results able to be utilized in a variety of scenes within the industry and ultimately, contributed to society.

In fiscal 2015, amidst demands for R&D activities which responded to pressing issues, such as securement of a stable power supply and harmony with the environment, specifically, securing safety in accordance with new regulations for nuclear power plants and the large-scale introduction of renewable energy into power systems, while creating new value for consumers relating to the utilization of electric power and energy, CRIEPI has once again produced a wide-range of results and provided these to the electric power industry in order to support its advancement.
Moreover, CRIEPI defined fiscal 2015 as the "*Year to Prepare for Change*" in order to accommodate changes in the business environment of the electric power industry. As part of this, we formulated research strategies by business sector, strengthened communication with electricity providers and shared our R&D roadmap.
Additionally, we continued the renewal of our fundamental technologies based on a mid-to-long term perspective, maximum rationalization of operational tasks and cost minimization. We also proceeded with the reduction of fixed overhead costs, etc. as part of our effort to build sustainable management structures.

■ Created and provided a wide-range of results to solve issues in the electric power industry

・CRIEPI accurately assessed issues in the electric power industry which needed solving, and by allocating our resources in accordance with the order of priority assigned to such issues, ultimately produced and provided results which contributed to solutions.
Examples of our achievements include proposal of a speed evaluation method and protection measure for tornado missiles, as well as an evaluation of radioactive material decontamination performance utilizing a filtered containment venting system for the nuclear power generation field, development of an evaluation technique for creep life in high chromium steel welds for the thermal power generation field, development of evaluation technology for the seismic performance of transmission towers against large earthquakes for the electric power distribution field, and a proposal for design of a system responding to the issues arising with the large-scale introduction of solar photovoltaic for the business management field. ➡ See Fig. 1, p.16 to p.57 [2-2. Major Research Results] (21 in total)
・CRIEPI also played a role in solving urgent issues by responding to accidents at electric power industry worksites, and flexibly and meticulously responding to other requests for consigned research during fiscal 2015. ➡ See Fig. 2
・In regards to consigned research at the request of the Japanese national government, etc., CRIEPI was commissioned by the Ministry of Economy, Trade and Industry, the Secretariat of the Nuclear Regulation Authority and so on to undertake research which would contribute to solving issues faced by the electric power industry, as well as advanced research to enhance and refine our research capabilities.

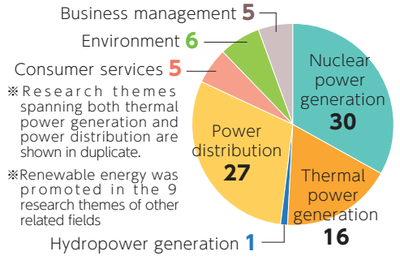


Fig. 1 No. of research themes by field for FY2015

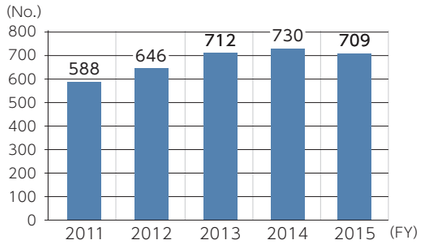


Fig. 2 Transition in no. of consigned research projects from electric power utilities

■ Formed research strategies, etc. in preparation for change

・With an awareness that the advancement of the Electricity System Reform, etc. would impact upon the various business sectors in different ways, CRIEPI formulated mid-to-long term research strategies for each sector specifically.
Moreover, we ensured multilayered communication with electricity providers, shared our mid-to-long term R&D roadmap for the electric power industry, and amidst this, clarified CRIEPI's roles and research projects for attention.
・We used our foresight to pinpoint imminent events predicted to surface in the future, such as the role of the electric power industry regarding mid-to-long term policies on climate change, then promoted research to find solutions for issues that could potentially arise in these areas. CRIEPI also engaged in research based on creative ideas with the potential of leading to breakthroughs for the supply and utilization of energy, including electric power industry.
・With consideration to the changes about to occur in the electric power industry, CRIEPI has continued to strengthen the fundamental technologies expected of an industrial research institute, while at the same time keeping such technologies up-to-date by scaling down those we judged to be of low priority for the future, etc.
・In light of the open innovation trend emerging in industrial research, CRIEPI formed a range of alliances with universities, research institutions, private companies, etc. in areas such as smart meter data utilization and IoT (Internet of Things), with the aim of further harnessing our research capability.
・With consideration to the Electricity System Reform, CRIEPI has amended its bylaws, etc. on the continuous benefits concerned with J-POWER (Electric Power Development Co., Ltd.), the Japan Atomic Power Company and the Okinawa Electric Power Company, so that individual electric utility companies can utilize our institution equally in accordance with their respective licenses.

■ Maintained and improved our research capability and problem-solving ability

・CRIEPI carefully selected large research facilities critical to solving issues in the electric power industry, such as the Experimental Facility for Supply/Demand Regulation in Low-Voltage Distribution Systems, which can recreate various events in low-voltage distribution systems, including consumer-related, on a real-life scale, and the Aberration-Corrected Transmission Electron Microscope (Cs-TEM), which observes the microstructure of high chromium steel pipes in thermal power equipment. Once we made our selection, we introduced and renewed this equipment while reducing costs.
➡ See p.13 [Major New Research Facilities]
・We promoted the development of personnel with highly-specialized knowledge and knowledge on the electric power industry through dispatching our researchers on a long-term basis to research institutions and electric power companies, etc. both in Japan and abroad.
・We strengthened and expanded our networks with research institutions both in Japan and overseas through joint research and human interaction with institutions possessing sophisticated technology in energy-related R&D (EDF in France, EPRI in the U.S., etc.) ➡ See p.67 [Research Network]

■ 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 with the awareness that such results acquire value when utilized by the electric power industry and society at large. Moreover, in regards to our intellectual property such as patents and software, CRIEPI licensed our development programs to various corporations, such as the licensing of CPAT (CRIEPI's Power system Analysis Tool) to the Organization for Cross-regional Coordination of Transmission Operators (OCCTO). ➡ See Fig. 3, p.66 [Research Results / Intellectual Property]

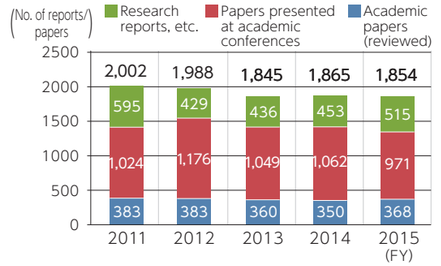


Fig. 3 Transition in no. of research reports and papers

・Through participation in various committees run by government bodies and academia, CRIEPI contributed to the establishment of various standards and technical guidelines relating to energy and the environment, such as the Technical Guidelines on the Earthquake Resistant Design of Nuclear Power Plants.
・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 upon request from electric power companies, manufacturers, etc. at our High Power Testing Laboratory.

■ Steady promotion of research development base and reduction of fixed overhead costs

・CRIEPI continued to steadily promote of a research development base in the Yokosuka area, etc. by creating a research environment for the future and developing measures which contribute to the reduction of fixed management overheads.
・We made a through effort to reduce costs in the aspects of both research and operations, such as promoting competitive ordering in regards to procurement, and internalizing operational tasks. ➡ See p.58, p.59 [3. Organization Management]

■ Overview of financial Statement

・Current revenue for fiscal 2015 was 27,610 million yen, which included 23,560 million yen in benefits received from electric power utilities under the temporary reduction measures ongoing since fiscal 2014, and 3,730 million yen of government-funded consigned research projects. Meanwhile, current expenditure was a total of 28,190 million yen, which included 9,460 million yen in personnel expenditures and 18,720 million yen in overheads. There was an ordinary net decrease of 570 million yen. ➡ See p.60 to p.63 [II. Financial Statement]

After comprehensive appraisal of the whole of the electric power industry, CRIEPI clarified the issues which required solving, promoted research and produced/provided various research results which will contribute to electric power industry.

In order to clarify the benefits our research results offer the electric power industry and society on the whole, we newly established research subjects from 8 areas including nuclear power generation and promoted our research based on these. 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, p.71) are shown in bold. Explanations have been provided for some keywords.

Nuclear Power Generation

Greater advancements in safety of light water reactors

Initiatives aimed at resumption of operations

・CRIEPI supported electric utilities to assess external natural events (earthquakes, tsunamis, tornados, volcanic eruptions, etc.) and to develop countermeasures in preparation for New Regulatory Requirements reviews.
For example, CRIEPI contributed to resumption of operations through assessment of the impact of tornado-borne missile on nuclear power facilities and adoption of a protection net as the countermeasures in actual plants. ➡ See p.16
・To realize an evaluation of the decontamination performance of the Filtered Containment Venting System (FCVS), which allows for the containment over-pressure release through multi-scrubbers, CRIEPI has developed a technique acquiring a systematic database of FCVS decontamination performance for the major radioactive materials. ➡ See p.18

Establishment of probabilistic risk assessment (PRA) technology

・In order to establish a fire hazard analysis method and data for fire PRA, we clarified the relationship between the mass loss rate and heat release rate of the fire source by conducting a lubricant oil combustion test and enhanced the combustion property data used in the fire model (Right figure).
・In order to improve seismically induced flooding PRA method and internal fire PRA, which can impact the progress of severe accidents, we are establishing a PRA method by developing a simulator for internal flooding, and trial quantification of fire frequencies for fire source categories, etc.
・To enhance the human reliability analyses conducted for the Japanese nuclear power stations, we have created a HRA implementation guide which contains a qualitative analysis technique with an innovative concept, “Narrative”, as well as a quantitative analysis method of human error probabilities.

A lubricant oil combustion test using ceiling height as a parameter

Establishment of evaluation techniques for low-frequency phenomena

・We aim to establish a rational and highly-accurate evaluation technique for earthquake ground motions formulated without a hypocenter specified, and near-fault ground motions. We modeled the subsurface velocity structures based on the results of the geophysical surveys at the strong-motion observation sites where the large accelerations were recorded during medium-scale earthquakes. Moreover, we estimated the slip distribution on the fault planes of several earthquakes which showed a significant effect to near-fault ground motions.
・To enhance the evaluation technique of fault activity, we verified the change in geometry of the fault plane and change in fault fracture properties through fracture zone structure evaluation and confirmed the existence of similar changes in the actual fault.
・We used actual components such as the safety valves of nuclear power devices to conduct a vibration test using a strong shake generator, confirmed the dynamic function when vibration had a maximum acceleration of 20G and reflected the result into relevant standards (Japan Electric Association, JEAC4601 by JESC, etc.).

Probabilistic Risk Assessment (PRA)
PRA is a method to quantitatively assess frequency and impact of accidents which could occur in nuclear power facilities and to express the safety level in term of risk, which is the product of frequency and degree of impact.

Human Reliability Analysis
Human reliability analysis is a technique used in PRA to quantitatively or qualitatively assess the likelihood and impact of unsafe human acts.

Narrative
“Narrative” is a narrative and the related background information of context leading up to accidents or human errors which is based on the facts such as situations affecting human failure events in accident sequences, accident analysis results etc.

Earthquake ground motion formulated without a hypocenter specified
Seismic ground motion formulated with consideration to the possibility an active fault may exist within the proximity of a power plant unable to be assessed even in a detailed investigation.

Aging management assessment
A technical assessment focusing on important safety equipment and internals conducted prior to a plant operating for 30 years (and every 10 years thereafter) from commencement of commercial operation. This assessment assumes that the facility being assessed will continue to operate beyond the abovementioned periods.

Surveillance specimen
Test specimens fabricated from the same alloy metal as reactor pressure vessels (RPVs) which are placed inside the RPV upon commencement of operation and removed periodically in order to investigate embrittlement caused by neutron irradiation.

High-level radioactive waste
Highly-radioactive waste liquid and the glass solids thereof remaining after the spent fuel reprocessing process due to being unsuitable for reuse.

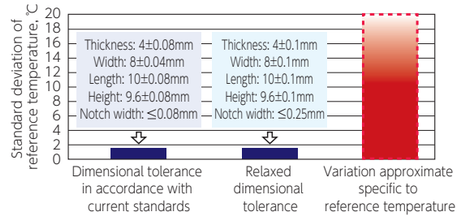
Countermeasures for major incidents

・CRIEPI has developed Japan’s first Fuel Rod/Control Rod Breakage/Melting Test Unit which is able to reproduce the conditions inside a reactor during a severe accident. We also clarified the physical and chemical properties of fuel debris, such as the characteristics of products created by melted fuel reacting with concrete and the seepage of radioactive substances created from the melted fuel. ➡ See p. 20
・As part of an initiative to prevent human error in power plants, we formed an Error Management Process and presented procedures for its gradual introduction and continuous improvement measures. ➡ See p.22

Safe operation of light water reactors

Advances to safety technology for light water reactors

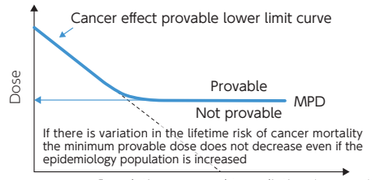
・Regarding the coating of devices, pipes, etc. installed inside nuclear reactor containment vessels, we clarified the specifications for a type of coating that doesn’t peel even during loss-of-coolant accidents or deteriorate the performance of the emergency reactor core cooling system strainer. The results have been utilized to repair coatings in the container vessels. ➡ See p.24
・To achieve low-cost, effective training of the examination personnel who conduct ultrasonic testing in a plant, we developed a virtual UT system that enables examination personnel to simulate damage detection without using actual pipes or detectors. ➡ See p.26
・To establish a fracture toughness evaluation based on the Master Curve method using miniature specimens which enables the effective utilization of surveillance specimens in LWR aging management assessments and special inspections, we clarified the dimensional tolerance for specimens and accuracy of fracture toughness evaluations.
・We demonstrated that even if a realistic dimensional tolerance was used for miniature specimens it would not affect evaluation accuracy, and reflected this finding in the JEAC by JESC (Right figure).



Effect of dimensional tolerance relaxation on the standard deviation of reference temperature

Radiation risk evaluations

・As a new indicator used in radiation risk evaluations, we proposed the minimum provable dose (MPD) using an index of the possibility to prove epidemiological radiation effect, and demonstrated it was possible to quantitatively allocate priority to protection measures for emergency personnel in relation to the effect on cancer (Right figure).



Minimal provable dose (MPD)

Establishment of nuclear fuel cycle technology

・In order to achieve storage of spent fuel in concrete casks, regarding the stress corrosion cracking (SCC), which is a major issue concerning metal canisters stored in casks, we have developed a technique for the prediction of SCC occurrence through inspection of the amount of adhered salt content, etc., an evaluation technique for the speed of crack tip progress, and occurrence prevention technology. ➡ See p.28
・CRIEPI devised a method to determine the Ru species volatilized during the loss of cooling function in a storage tank of concentrated high-level waste, which is one of the severe accidents in a reprocessing plant defined by the New Regulatory Requirements. The reaction mechanism evolving the volatile Ru species was then clarified based on the experimental results.

Support for radioactive waste disposal operations

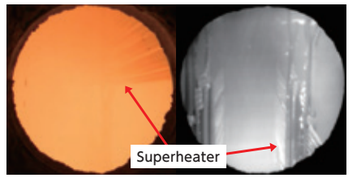
・To establish rational risk assessments of uplift and erosion in the selection of sites for the geological disposal of high-level radioactive waste, we analyzed the amount of erosion over the past 100,000 years for 45 locations across Japan, and demonstrated the maximum amount of erosion due to sea level fall is around 100 meters.

2-1. Outline of Results

Thermal Power Generation

Ensuring reliability of existing thermal power plants

- For the development of visual observation technology in an operational pulverized coal combustion boiler to clarify the factors of clinker formation in the pulverized combustion boiler, CRIEPI discovered that camera technique using a mid-infrared is effective. (Right figure).
- To streamline the timing of chemical cleaning carried out to avoid creep failure in the tubes of boilers for thermal power generation, we clarified the impact of actual operating temperature which affects the failure time by conducting creep tests using actual tubes and tube temperature analyses. Based on this, we proposed an evaluation method for chemical cleaning in line with actual operational statuses.
- In order to improve the accuracy of life assessments for the creep damage which occurs in the welds of high-Cr steel pipes, we utilized actual plant waste to clarify the type of damage and creep strength over a prolonged period of time and developed a life assessment technique for girth welds and repaired welds based on this. See p.30
- To expand the effective utilization of coal ash, we reduced the cost of manufacturing "Neutron Boron Gauge" which rapidly measures the boron content in coal ash, reduced measurement time and gained an outlook for commercialization. These efforts are anticipated to facilitate the speedy selection of coal ash able to secure environmental safety even if used for a prolonged period of time as artificial ground material, etc.



Visible light image　Mid-infrared image

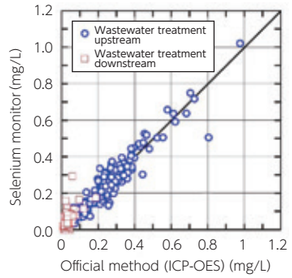
Photographs of boiler interior

Clinker

Clinker is formed when the ash formed from coal combustion adheres to the furnace wall tube, etc. and forms clumps in a coal-fired boiler. Clinker is an obstacle to the boiler operation and must therefore be removed.

Thermal technology to mitigate environmental load

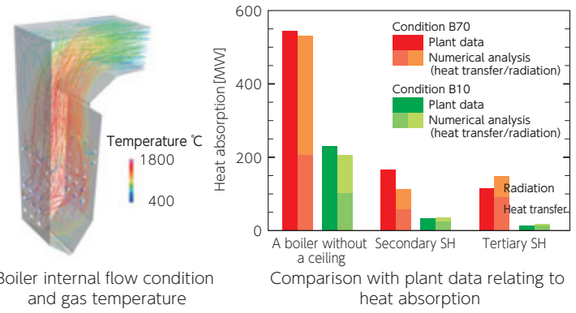
- To reduce the cost of monitoring selenium in desulfurization wastewater, we evaluated the applicability of the CRIEPI-developed selenium monitor on an actual plant and verified that concentration monitoring was possible through simple, monthly maintenance. (Right figure)
- To reduce CO_2 emissions from coal-fired power plants, we proposed high-efficiency oxy-fuel IGCC which recirculate Gas turbine exhaust gas (CO_2) and use mixture of O_2 and recirculated exhaust gas for coal gasification and gas turbine combustion. Through various verifications, we confirmed the feasibility of this system. See p.32



Selenium monitor measurement accuracy

Diversification of fossil fuels

- We verified the effectiveness of our coal operation evaluation system able to predict and evaluate the operation costs of coal-fired power plants at an actual power plant. Moreover, we clarified that it was possible to use our combustion numerical analysis to predict the combustion state inside an actual pulverized coal boiler, where it is difficult to measure the state due to a high temperature. (Right figure)



Boiler internal flow condition and gas temperature

Comparison with plant data relating to heat absorption

Comparison with combustion numerical analysis result and plant data

Seismic performance verification

To confirm whether or not target structures have sufficient seismic performance to withstand earthquake ground motion.

Ascertaining PV output

To predict and ascertain the photovoltaic (PV) output within a specific area from solar irradiance, etc. when the system operator is unable to directly know what the PV generation output is.

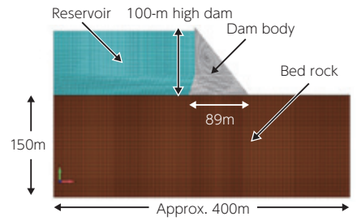
Response to large-scale introduction of renewable energy

- In order to develop a flexibility of thermal units, based on current situation surveys of electric utilities and power plants in Europe, the frontrunner in regards to the large-scale introduction of renewable electricity source, CRIEPI compiled operational improvement methods for coal-fired and natural gas thermal power generation which increase market value and clarified the technical conditions necessary to respond to renewable electricity source fluctuations.

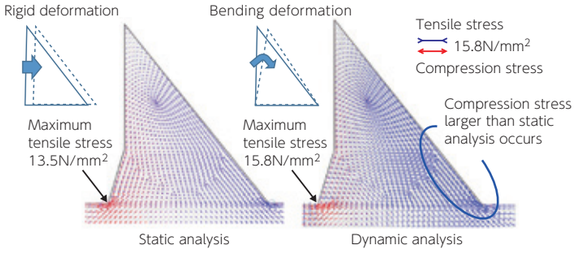
Hydroelectric Power Generation

Disaster prevention and maintenance and management for hydropower facilities

- We established a simple technique using two-dimensional static analysis as an alternative to complicated dynamic analysis in seismic performance verifications of gravity dams in the event of a large-scale earthquake (Below image). This technique can be applied to dams of 50 meters or less in height, which account for 70% of the gravity dams owned by electric power companies, and is anticipated to speed up seismic performance verifications and help reduce costs.



Example of element mesh used in analysis



Principal stress distribution when downstream deformation occurs for a 100-m high dam

Renewable Energy

System stabilization on large-scale introduction of renewable energy

- With the goal of achieving stable power supply/demand operation, CRIEPI devised a technique for levelling irradiance fluctuation by applying the moving average of the irradiation measurement value to establish technology for real-time photovoltaic output assessment in a particular region, and verified this through application at an actual location. See p.34

Expansion of the introduction of biomass and geothermal power generation

- To realize a highly-efficient, highly-economic geothermal power generation system, CRIEPI created a hybrid geothermal-biomass power generation system able to improve power generation efficiency by utilizing renewable energy, etc. to super-heat the steam injected into the turbines in a geothermal power plant. Moreover, we clarified the system configuration, as well as the thermal efficiency and cost of power generation under actual operating conditions assuming a commercial plant. See p.36

2-1. Outline of Results

Electric Power Distribution

Response to the Electricity System Reform

Analysis of root mean square value of power systems

An analysis technology to analyze changes in the root mean square values of voltage and current in the seconds after an accident, for example, then calculate system stability, etc.

・As a response to the enhancement of wide-area power system operation, CRIEPI launched a tool for the analysis of root mean square value of power systems (CPATFree), which can be downloaded for free, in order to standardize power system analysis tools.
In additions, we have developed and maintained the generic simulation models of modular multi-level (MMC) ac/dc converters which are expected to become the main technology for 50/60-Hz frequency conversion and dc transmission. The models have been integrated into the electromagnetic transient analysis program XTAP, and this significantly simplifies the complicated simulation tasks.
・We developed a technique to evaluate how power quality would be affected due to changes to the operation of existing power generation systems expected to occur as a result of separation of power generation and power transmission and the large-scale introduction of renewable energy. We clarified the issues which need to be addressed and presented solution methods thereof. ➡ See p.38

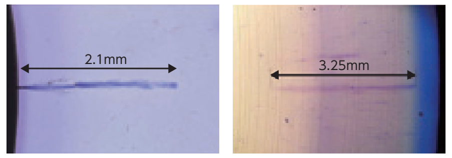
Electromagnetic transient analysis

It simulates the dynamic behavior of a power system based on the waveform-level calculations.

Formation, maintenance and upgrades of substations and transmission lines

Advancing preservation technology for aged facilities

・Main corrosion factors such as airborne salinity was calculated based on meteorological and terrain conditions, aiming at establishing a preventive maintenance for operation of overhead transmission towers. Calculated results were taken over to construct corrosion maps for the overhead transmission towers across the country.
・We succeeded in the artificial formation of a progressed water tree with a long and narrow shape, which is the main cause of aged XLPE cable (22-77 kV) deterioration (right figure). This achievement is expected to advance life evaluation and deterioration diagnosis technology utilizing extremely aged XLPE cable samples.
・To establish a rational replacement plan for oil-immersed power transformers, CRIEPI proposed an evaluation method of the failure probability of transformers from diagnoses of degradation of insulation materials and of, abnormalities of windings.
➡ See p.40



Progressed water trees with a long and narrow shape.

Water tree

A phenomenon whereby an extremely small amount of water penetrates the insulation layer of XLPE cable (cross-linked polyethylene), condensates at localized points where the electric field is high, and the water-condensated volume progresses and forms branches (tree).

Support to streamline facility design and operate facilities

・In order to use a Lightning Location System (LLS) to estimate lightning data such as peak current amplitudes and charge amount, which are necessary for lightning damage risk evaluation and effective lightning protection design, we developed a lightning data evaluation technique which uses numerical electromagnetic field analysis and clarified the level of performance appropriate for devices equipped on the new LLS.
・To achieve practical application of cleaning large equipment contaminated with trace PCB, we shortened cleaning time and expanded the scope of equipment suitable for the heat-clean processing technology certified by the Ministry of the Environment (oil quantity, PCB concentration).

Lightning Location System (LLS)

A system with multiple sensors which detect the electromagnetic field waveforms radiated from lightning strokes to make estimation of lightning location, time, peak current amplitudes, etc. based on data analysis.

Response to changes in supply form and demand-side changes

System stabilization on large-scale introduction of renewable energy

・We conducted a verification test for economic supply/demand operation and system frequency stabilization utilizing storage batteries under the large-scale introduction of renewable energy, and clarified the effect on reducing fuel costs and reducing the capacity of storage batteries, which are necessary to maintain system frequency, by the optimization of supply/demand operation plans.
・To the existing power distribution system integration analysis tool, we added functions enabling the calculation of connectable capacity for dispersed types of power sources such as mega solar and evaluation of the effect on power distribution cable voltage during connection. This activity improved applicability in the field.

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

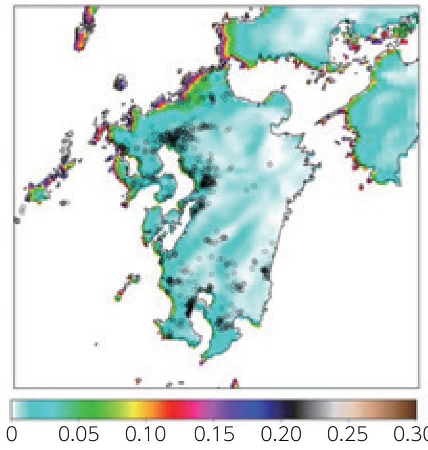
・In order to respond to the large-scale penetration of PV power generation and activation in demand areas due to advancements in storage battery technology, CRIEPI devised a method to evaluate the effect of autonomous operation by groups of consumers (communities) on the voltage, current, load factor, etc. of power distribution systems.

Forming, maintaining and update power distribution facilities

・In order to reduce lightning damage of smart meters, we conducted a lightning performance evaluation test to clarify the lightning failure mechanism of smart meter, and proposed an effective lightning protection measure. ➡ See p.42

Response to disaster and human risks

・To evaluate and countermeasure the risk of damage to power transmission steel towers due to earthquakes, we conducted earthquake response observation and a load resistant capacity test, etc. on actual steel towers and developed an evaluation method for earthquake performance against high-level seismic ground motion by verifying and sophisticating seismic response analysis technology.
➡ See p.44
・To evaluate meteorological disaster risk and take countermeasures, we developed a system to predict rapid contamination of power distribution equipment due to sea salt in association with a typhoon or explosive low-pressure system two to three days in advance (Right figure).
・We built an actual unit environment which simulates an administrative processing system typical of electric utilities and conducting realistic response drills for cyber terrorism. This activity improved technical and organizational response skills against cyber terrorism attacks on electric utilities. ➡ See p.46



Prediction result for sea salt deposition after the onset of an explosive low-pressure system

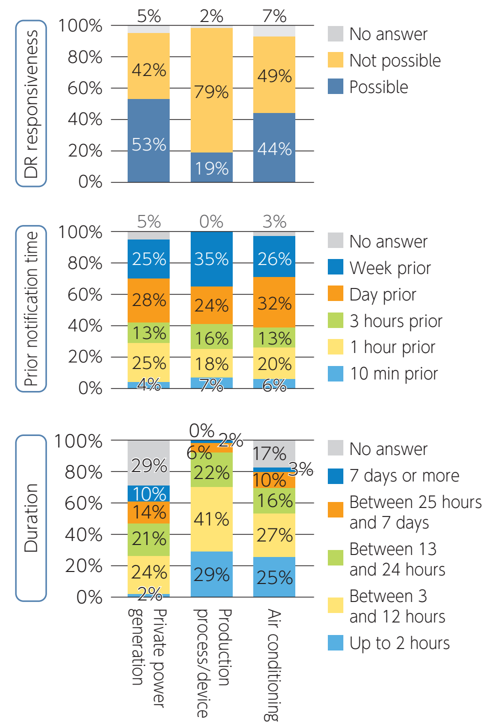
Services for Power Consumers

Promotion of energy conservation and electrification and enhanced customer satisfaction

・We conducted a questionnaire to investigate the ability of the industrial sector to respond to a reserve power supply-type of Demand Response (DR) as a countermeasure for fluctuation in renewable energy output (Right figure).
・We evaluated the steam manufacturing capacity, energy consumption efficiency and controllability, etc. of industrial steam generation heat pumps, and clarified technological measures necessary to further improve energy-saving performance.
・In order to develop a new technique for power supply/demand management which achieves both the rational operation/formation of power distribution equipment and maintenance/enhancement of customer benefits, we developed a technique to estimate power consumption by application and time of day for up to 1,000 households which considers regional differences and consumer diversity. ➡ See p.48
・In order to create new services which enhance customer satisfaction, we have developed a technology using machine learning from demand data obtained through smart meters. This technology estimates with high accuracy the demand data that can be utilized to enhance consumer convenience and incorporated in services such as DR which are effective towards energy conservation.
➡ See p.50

Demand Response (DR)

When the wholesale price has escalated or there is a drop in system reliability, changing the power consumption pattern to suppress power usage by consumers to suit electricity price settings or payment of incentives such as supply/demand adjustment agreements.



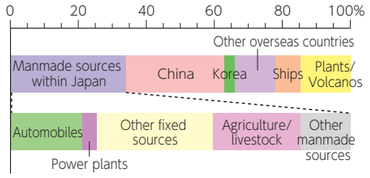
Responsiveness to a reserve power supply-type of DR, acceptable prior notification time and duration

2-1. Outline of Results

Environment

Response to environmental policy and regulations

・Regarding the long-term targets of the world climate policy, CRIEPI addressed the main issues from a scientific perspective after analyzing the relationship between cumulative CO_2 emissions and temperature rise, as well as the difference in relevant results of the Fourth and Fifth Assessment Reports by the IPCC (Intergovernmental Panel on Climate Change).
・We evaluated the impact of manmade sources in Japan on the status of $PM_{2.5}$, the atmospheric particulate matter which has been highlighted as a substance for environmental regulation. (Right figure)



Breakdown of impact of sources in Japan and abroad on $PM_{2.5}$ (top) and impact of manmade sources in Japan

Efficient environmental assessment

・In order to respond to the increasingly complex environmental impact assessments of thermal power plants, CRIEPI developed a numerical model also useful for the prediction of cold water discharge dispersion (in addition to warm water discharge) in the area of LNG thermal power generation.
Moreover, in order to simplify and expedite the environmental impact assessments of geothermal power plants, CRIEPI developed numerical models to predict the dispersion of the hydrogen sulfide discharged from cooling towers. Furthermore, we developed a method to investigate the flight patterns of birds utilizing a transportable camera system which can be used for environmental impact assessments and monitoring of wind farms. ➡ See p.52

Business Management

Evaluation and analysis of energy and environmental systems

・As a response to the debate concerning detailed institutional design of the electricity system reform, CRIEPI carried out an investigation into the issues related to the price regulation during the transitional period following the full liberalization of retail electricity market, as well as regulatory issues concerning Japan's Antimonopoly Act, and presented a course of action for institutional design necessary to create an appropriate business environment. ➡ See p.54
・Through observations relating to the introduction of 'Safety Goals' as an autonomous measure to enhance the safety of nuclear power plants, CRIEPI presented its stance on the issues surrounding establishment of a scheme to secure safety that business operators, society and regulating bodies could all cooperate towards, and the solutions of such issues. (Below figure).
・CRIEPI conducted a quantitative assessment of the problem of uncollected capital for existing power generation facilities stemming from the large-scale introduction of renewable energy. The results will be useful for assessing and proposing capacity mechanisms necessary for stable power supply, ➡ See p.56
・CRIEPI analyzed and evaluated the effectiveness of the Paris Agreement as an international framework for climate policy and presented Japan's issues after its adoption. We also evaluated the cost effectiveness of related projects and initiatives undertaken within the domestic climate policy framework.

The Paris Agreement
An agreement adopted at the 21st United Nations Climate Change Conference (COP21) on December 12, 2015.

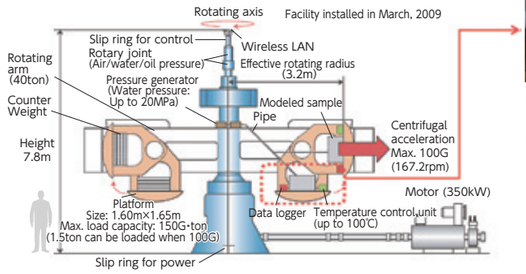
Factors inhibiting utilization of safety goals in the nuclear power domain and future course of action

Major New Research Facilities

Addition of a 3-Dimensional Shaking Table Function on the Dynamic Geotechnical Centrifuge

CRIEPI added a shaking table capable of 3-dimensional excitation to the platform of our dynamic geotechnical centrifuge. This is the world's first case of a 3-dimensional excitation function being added to a dynamic geotechnical centrifuge. This has made it possible to obtain verification data of a seismic design method using 3D chronological nonlinear time history analysis able to evaluate up to the type of ground failure.

Dynamic Geotechnical Centrifuge



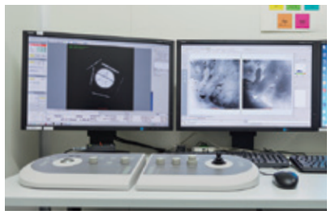
By rotating, the platform (shown in orange) swings upwards and centrifugal force will work on the modeled sample.

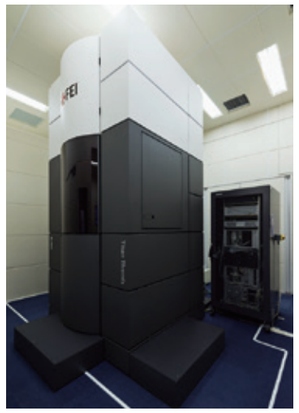
Photo of platform
The shaking table is mounted on top of this.

Shaking table
(3-dimensional excitation)

Aberration-Corrected Transmission Electron Microscope (Cs–TEM)

The Cs-TEM, due to featuring an aberration corrector, is a transmission electron microscope that offers significantly superior analysis spatial resolution and analysis speed compared with conventional electron microscopes, and is capable of performing a detailed analysis of a wide range in a short time. The Cs-TEM enables quantitative and statistical studies of the dispersion of fine precipitates in high chromium steel with differing chemical elements and heat treatment, etc., which were difficult to detect with conventional electron microscopes.
Based on these results, CRIEPI will clarify the correlation between microstructure and material strength, thus contributing to elucidation of the deterioration mechanism of high chromium steel pipes and sophistication of life prediction methods.





Experimental Facility for Supply/Demand Regulation in Low-Voltage Distribution Systems

This facility recreates various event phenomena at full-scale for distribution systems between substations and consumers (6.6kV to 100/200V), in particular low-voltage distribution systems. This facility has an inverter power source (6.6kV, 1MVA) and can simulate the various types of voltage fluctuations, etc. that occur in systems. This experimental facility will be utilized in order to economically maintain electric power quality through voltage management of low-voltage distribution systems and evaluate breakdown of low-voltage equipment such as smart meters in line with the increased introduction of photovoltaic power generation, etc.

List of Research Subjects

Nuclear power generation

●Greater advancements in safety of light water reactors

■ Initiatives aimed at resumption of operations

- Technical Assessment on Nuclear Power Plant Designs against External Natural Events
- Improvement of Internal Fire Protection Methodologies in Nuclear Facilities
- Improvement of Design-Base Event Evaluation in Nuclear Reactors
- Development of Evaluation and Operation Method of the Reactor Containment Failure Prevention Function
- Enhancement of the Severe Accident Analysis Technology and Evaluation of the Effectiveness of Nuclear Facilities Measures

■ Establishment of probabilistic risk assessment (PRA) technology

- Improvement of Internal Fire Mitigation Methodologies in Nuclear Facilities
- Development of Evaluation Method of Phenomena for Enhancement of PRA Technology
- Development of Cross-Cutting Issues Required for Nuclear Risk Management
- Enhancement of PRA Technology and Establishment of Risk Management Methodology

■ Establishment of evaluation techniques for low-frequency phenomena

- Assessment of External Natural Hazards to Nuclear Facilities
- Assessment of Fragility of Nuclear Facilities due to External Natural Events

■ Countermeasures for major incidents

- Improvement of Transient Event Evaluation in Nuclear Reactors
- Evaluation of Fuel Melting Processes in LWR Severe Accidents and its Mitigation Measures
- Development of Voluntary Safety Action Programs in Consideration of Human Factors
- Assessment of Radioactive Material Diffusion and its Impact Evaluation in Environment
- Development for Prevention Technology of Radiation Contamination at Severe Accidents

●Safe operation of light water reactors

■ Advances to safety technology for light water reactors

- Improvement of Pipe Wall Thinning Evaluation and Water Chemistry Control in LWR
- Improvement of Preventive Maintenance Technology for LWR Components and Pipings
- Improvement of Integrity Evaluation Method for Reactor Pressure Vessels
- Improvement of Integrity Evaluation Method for Core Internals, Pipings and Other Components
- Development of Nondestructive Inspection Technologies for Components and Piping in Nuclear Power Plants

■ Radiation risk evaluations

- Quantitative Evaluation of Low-Dose Radiation Risk and Reflection to Radiation Protection Systems

■ Improvements and upgrades to light water reactor technology

- Development of LWR Fuel and Core Management Technologies
- Impact Assessment to Safety and Performance for Operation Extension

●Establishment of nuclear fuel cycle technology

- Development of Long-Term Storage Management Technologies for Spent Fuel
- Technology Development for Safety Improvement and Stable Operation of Reprocessing Plants

●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 Long-Term Use of Nuclear Energy

●Response to Fukushima Daiichi Nuclear Power Station

- Back-Up Studies for Decommissioning and Contaminated Water Issue of Fukushima Daiichi Nuclear Power Station

Thermal power generation

●Ensuring reliability of existing thermal power plants

- Development of Condition Diagnostic and Maintenance Management Technologies of Thermal Power Plants
- Improvement of Remaining Life Assessment, Diagnosis and Maintenance of Thermal Power Plant Components
- Development of Life Assessment Technology for High Temperature Structural Components Made of High Chromium Steels in Thermal Power Plants
- 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
- Development of Technologies to Reduce Environmental Burden from Thermal Power Plants
- Development of Biomass-Derived Power Generation Technology
- Investigation and Analysis of the Trend of Hydrogen Utilization Technologies

●Diversification of fossil fuels

- Development of Advanced Technologies to Apply Unused Fuel Resource to Thermal Power Plants

●Response to large-scale introduction of renewable energy

- Load Following Capability Improvement of Thermal Power Plants
- Development of Flexible Generating Techniques for Backup Power

●Thermal power generation business under the Electricity System Reform

- Clarification of R&D Strategy for Thermal Power Generation Sector

●Response to risk of disasters

- ◇Development of Extreme Weather Forecasting and Hazard Evaluation Methods for Electric Power Facilities
- ◇Evaluation and Measures of Earthquake Disaster Risk on Thermal Power

Hydroelectric power 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 Supply-Demand Operation and Control Technology Using Energy Storage System
- ▽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 Accurate Power Output Estimation and Forecast Techniques of Photovoltaic and Wind Power Generation
- ▽Establishment of the Evaluation Technology of the High-Performance Secondary Battery
- ▽Evaluation of the Long-Term Performance of Photovoltaic Systems for Power Demand and Supply Operation
- ▽Effects of Large Scale Introduction of Renewable Energy

●Expansion of the introduction of biomass and geothermal power generation

- ▽Development of Biomass-Derived Power Generation Technology
- ▽Development of Technologies to Reduce Environmental Burden from Thermal Power Plants

Electric power distribution

●Response to the Electricity System Reform

- Development of Support Technology for Widening System Operation and Reinforcing System Interconnection
- Development of Techniques to Maintain Power System Stability under Steady-State and Emergency Conditions
- Development of ICT Infrastructure Building Techniques Based on General-Purpose Communication 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
- Evaluation and Validation of Washing Treatment for Low-Level PCB Contaminated Transformers
- Development of Countermeasures Against Wildlife Causing Trouble in Electric Transmission Facilities
- Development of Technologies Applied to Maintaining and Renewing Communication Facilities for Electric Power System Operations

■ Next-generation equipment technology anticipating future facility upgrades

- 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 Supply-Demand Operation and Control Technology Using Energy Storage System
- 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 Accurate Power Output Estimation and Forecast Techniques of Photovoltaic and Wind Power Generation
- Establishment of the Evaluation Technology of the High-Performance Secondary Battery
- Evaluation of the Long-Term Performance of Photovoltaic Systems for Power Demand and Supply Operation

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

- Supply/Demand Coordination Technology between Distributed Energy System and Ordinary Power System
- Power Quality Preservation and Enhancement for Distribution Systems with Advanced Customer Devices

●Forming, maintaining and update power distribution facilities

- Development of Evaluation Technology on Lightning Risk Management and Fault Current Countermeasures for Distribution Systems
- Diagnostic Technology for Power Distribution Equipment

●Response to disaster and human risks

- ◇Development of Extreme Weather Forecasting and Hazard Evaluation Methods for Electric Power Facilities
- ◇Evaluation and Measures of Earthquake Disaster Risk on Thermal Power
- Establishment of Protective Measure Technologies against Wind and Snow Damage of Overhead Transmission and Distribution Facilities
- Development of Intrusion Detection Techniques of Cyber Attacks against Supervisory Control System

Services for power consumers

●Promotion of energy conservation and electrification and enhanced customer satisfaction

- Assessment of the Value of Next-Generation Demand Management
- 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 Energy Information Utilization Technology
- ▽Supply/Demand Coordination Technology between Distributed Energy System and Ordinary Power System
- ▽Issues in Institutional Design of the Electricity System Reform

Environment

●Response to environmental policy and regulations

- Scientifically and Economically Rational Scenarios to Reduce CO_2 Emissions
- ▽Evaluation and Analysis of Climate Policy
- Research and Responses to Recent Biodiversity Related Issues in Electric Power Industry
- Characterization and Rational Measures of Environmental Health Risks

●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
- Development of Efficient Impact Assessment Methods for Ecosystems

Business management

●Evaluation and analysis of energy and environmental systems

- Issues in Institutional Design of the Electricity System Reform
- Forecast and Analysis of Japanese Economy, Industrial Structure and Electricity Demand
- Socio-Economic Analysis of Nuclear Power Generation
- Effects of Large Scale Introduction of Renewable Energy
- Evaluation and Analysis of Climate Policy

● : Large segment a grouping of related research subjects in each fields
■ : Intermediate segment a grouping deeply related research subjects within the large segment
・ : Name of Research Subjects
◇ : Name of Research Subjects (promote cross-sectional study across multiple fields (Double Serving))
▽ : Name of Research Subjects (promote research subjects related to other fields (Double Serving))

Nuclear Power Generation

Proposal of a Rational Speed Evaluation Method and Protection Measure for Tornado Missiles

In preparation for the collision of tornado missiles on nuclear power facilities

Background

Nuclear Power plant (NPP) operators are expected by society to protect their facilities against natural disasters to the maximum extent possible, based on the lessons learnt from the Fukushima Daiichi Power Plant disaster in 2011. One foreseeable event is the collision of objects that have become airborne due to tornados (tornado missiles) into nuclear power facilities.
As such, CRIEPI is engaging in R&D to prepare for the collision of tornado missiles into nuclear power facilities.

Outline of Results

◇ Development of a Rational Speed Evaluation Method

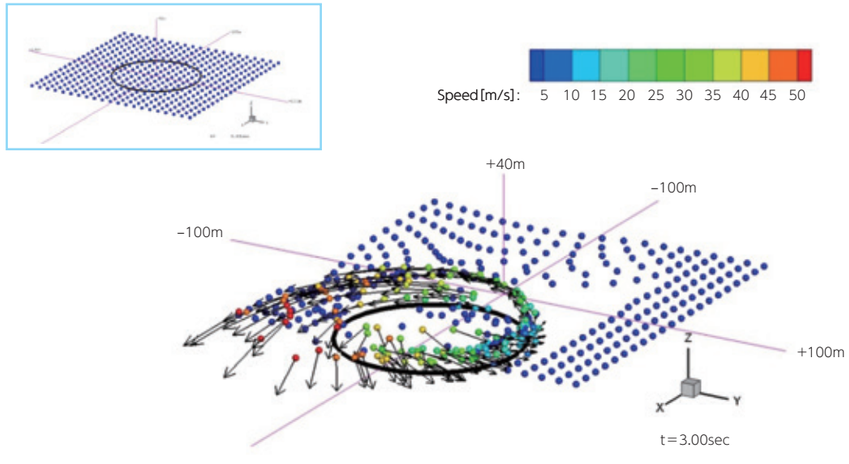
CRIEPI has developed TONBOS, or TOrNado-BOrne miSsile analysis code, as a new method that enables evaluation of how an object will scatter from the actual height located in an NPP as an alternative to the assessment guide for tornado effect on NPPs established by the Nuclear Regulation Authority, etc. The newly developed method has been used in the speed evaluation of tornado missiles by many NPPs and contributed to investigations verifying the conformity of NPPs with new regulatory standards.

◇ A Lightweight, Earthquake-resistant Protection Method against Tornado Missiles

CRIEPI has devised a lightweight protection method with superior earthquake resistance focusing on high-strength wire mesh made by the three-dimensional weaving of high-strength steel wire. In this protection method, a wire rope is used around the entire perimeter of the protection net in order to support loads caused by tornado missiles across a wide area. Moreover, in order to prevent the wire rope breaking, we created a design whereby the deformable steel columns securing the wire could distort flexibly to suit the wire tension. This method has been adopted in many NPPs.

Assessment guide for tornado effect on NPPs
A guideline to confirm in installation approval stages that a nuclear reactor facility is of a design whereby its safety will not be impaired by a tornado.

TOrNado-BOrne miSsile analysis code TONBOS
Analysis software to obtain calculation results for maximum tornado missile speed, etc. by inputting tornado conditions (maximum wind speed, travel speed, radius) and missile data (flight constant, object height). Visualization in the form of moving image is also possible.

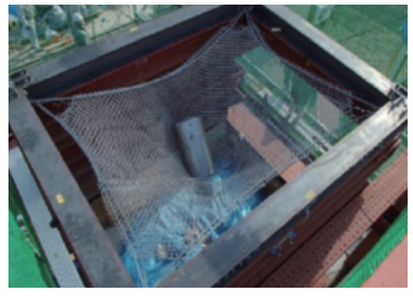


An example of analysis using TONBOS

Visualization of tornado missile movement in the case a tornado (black circle) occurs directly above a group of containers (colored balls) set up on the ground. The top left figure indicates initial conditions, while the bottom right figure indicates the position of the missiles 3 seconds later, horizontal speed (color) and speed vector (arrows).

Koji Shirai/Yuzuru Eguchi
External Natural Event Research Team, Nuclear Risk Research Center

High-speed Loading Experimental Facility Equipment to elucidate dynamic material properties through an impact tensile test of net material



Test to verify penetration resistance against tornado missiles
A test in which a steel weight (1500 kg) is allowed to free fall onto a full-size, high-strength wire mesh protection net (4 m×3 m) from a height of around 15 meters.

Application Examples of Research Results

The calculation results of TONBOS, the TOrNado-BOrne miSsile analysis code developed by CRIEPI, have been included and quoted in investigations into the conformity of NPPs with new regulatory standards. Moreover, the protection method against tornado missiles proposed by CRIEPI has been adopted by many NPPs in Japan, put to practical use and contributed to recommencement of operations.

References: Eguchi et al., Transactions of the JSME, Vol.81, No.823 (2015)
Shirai et al., CRIEPI Research Report N14009 (2015)

Nuclear Power Generation

Evaluation of Radioactive Material Decontamination Performance Utilizing a Filtered Containment Venting System

Suggest the optimal operation method for Japan and contribute to the ongoing enhancement of safety

Background

In order to reduce the release of radioactive material during a severe accident of a nuclear reactor, optimal operation of a Filtered Containment Venting System (FCVS) is necessary however its technical bases is still not sufficient in Japan and we have to rely on the knowledge of European manufacturers. As such, CRIEPI is acquiring a systematic database of FCVS performance, with the goal of suggesting the optimal operation method in Japan.

Filtered Containment Venting System (FCVS)
A facility to reduce pressure inside a nuclear reactor containment and reduce radioactive material release through a multistage filter.

Outline of Results

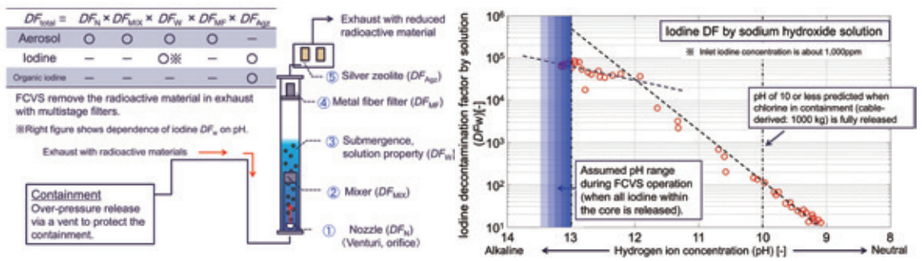
◇ Construction of testing facility to evaluate FCVS performance

The efficiency of decontamination for the main types of radioactive materials (aerosols, iodine, organic iodine), depends on many complex factors, such as thermal-hydraulic and physiochemical factors. Therefore CRIEPI has developed a full-scale test facility that can evaluate complex phenomena with high accuracy. This test facility has real scale test vessel (height: 8 m, inner diameter: 0.5 m), steam boiler, iodine/ aerosol generation system and latest measurement system. It enables evaluation of FCVS performance under various conditions (temperature, pressure, gas-flow rate, water quality).

◇ Detailed decontamination performance evaluation for the major radioactive materials

CRIEPI clarified the detailed property of each filters (venturi scrubber, wet scrubber, metal fiver filter and so on) that make up the FCVS. We performed Japan's first full-scale test for the elemental iodine, and confirmed enough decontamination performance in the high pH range that is assumed during actual operation. Moreover, this results show that pH control (adding NaOH) is valid as a countermeasure for reducing decontamination performance. Moving forward, based on this detailed data, CRIEPI will develop a simulator that enable evaluation of the actual FCVS performance and link this with the sever accident analysis code of nuclear power plant to suggest the optimal management method for FCVSs.

Severe accident analysis code
Integrated analysis codes able to predict and ascertain conditions inside a reactor such as the position of fuel debris during severe accidents. Typical examples of analysis codes are MAAP, MELCOR, etc.



Schematics of FCVS (Left) and dependence of iodine Dependence of iodine DF_W on pH (Right)

The filter portion (left (1) to (5) differs depending on the type of radioactive material. High iodine decontamination factor (DF) is expected in the alkaline solution expressed by (DF_W) in the diagram on the left, and the extent of that effect depends on the solution's pH level. CRIEPI conducted a test regarding the dependence of iodine decontamination performance on the pH level of a solution and obtained the result that iodine can be reduced efficiently in the range of pH>12.

Full-Scale Test Facility for Filtered Containment Venting System Performance Evaluation

Test facility for Filtered Containment Venting System (FCVS) performance evaluation
A full-scale test section and equipment such as steam boilers are also installed.

Application Examples of Research Results

Utilization of a FCVS evaluation tool based on test data obtained with a full-scale test facility has contributed to promotion of activities to improve reliability of impact mitigation measures during severe accidents, and promote safety enhancement activities conducted by electricity providers, as well as helped to reduce the amount of radioactive material released during a severe accident.

References: T. Kanai, M. Furuya, T. Arai, Y. Nishi, "Development of an aerosol decontamination factor evaluation method using an aerosol spectrometer", Nucler Engeering and Design 303, pp58-67 (2016)

Nuclear Power Generation

Clarification of Degraded Fuel Behavior During Severe Accidents

Contributing to the enhancement of nuclear power plant safety through clarification of the core degradation process during severe accidents

Background

Japanese electric power suppliers are promoting the development of countermeasures against light water reactor severe accident (SA) as reflections upon the fact that they could not prevent the Fukushima Daiichi nuclear power plant from SA progression. This research clarifies the damaged fuel behavior in the degradation and relocation processes during SA and physicochemical property of re-solidified fuel debris formed in accident prototypical scenarios, which are necessary to improve SA countermeasures.

Severe accident

When a situation arises which surpasses the assumptions made during the design stage of a nuclear power plant that render it impossible to suitably control with assumed means and results in damage such as core meltdown.

Outline of Results

◇ Development of a core DEGradation and RElocation test Equipment (DEGREE)

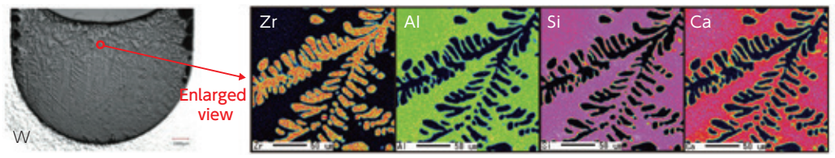
CRIEPI has developed Japan's first out-of-pile fuel bundle experimental facility (DEGREE) capable of simulating the chemical conditions inside a reactor pressure vessel during SA, such as high temperature steam atmosphere with rapid temperature rise of 3 ℃/s or more. DEGREE can heat 9 (3 × 3) simulated fuel or control rods in steam atmosphere up to 2000℃ or more to observe fuel behavior at the early stages of accident progression in accordance with changes in steam flow rate, rate of temperature rises and cooling conditions. By accumulating experimental data on fuel behavior in the processes, it will be possible to clarify the core degradation sequences during SA in detail.

◇ Ascertaining fuel debris properties

In order to clarify the physicochemical properties of products generated through the interaction between molten fuel debris and concrete during SAs, CRIEPI used our simulated fuel debris manufacturing furnace to conduct a meltdown test combining ZrO_2 as a simulant of molten fuel debris $(U,Zr)O_2$ and typical concrete at a temperature up to 2500℃ and then cooled at a possible rate of 0.1 ℃/s. As a result, we clarified that the ZrO_2 and concrete components hardly dissolve into each other at all when they solidify.

Fuel debris

Fuel debris are created when nuclear fuel in a reactor core overheats during a nuclear reactor accident, causing the nuclear fuel and nuclear reactor structure, etc. to fuse together, then cools and solidifies.



Concentration of concrete components of Al, Si and Ca (black) are minimal in ZrO_2 precipitation (high amount of Zr, shown in orange)

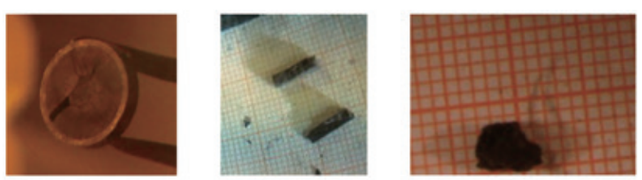
Fig. 1 Microstructure after adding concrete (60 wt.%) to ZrO_2, melting at 2300℃ and then cooling at a rate of 0.1 ℃/s.

Moreover, in order to clarify the leaching property of actinides and fission products (FPs) from fuel debris immersed in boric acid solution which may be used as cooling water to cool a reactor core during SAs, CRIEPI analyzed a segment of spent fuel and TMI-2 fuel debris to identify the substances that had leached into pure water and boric acid solution in collaboration with Europe's Institute for Transuranium Elements (ITU). As a result, we clarified the leaching rate for uranium was not much different between these two.

By identifying the physicochemical properties of once-molten fuel debris in this way, it is possible to elucidate the actinides and FPs behavior of degraded and re-solidified fuel debris under various SA scenarios.

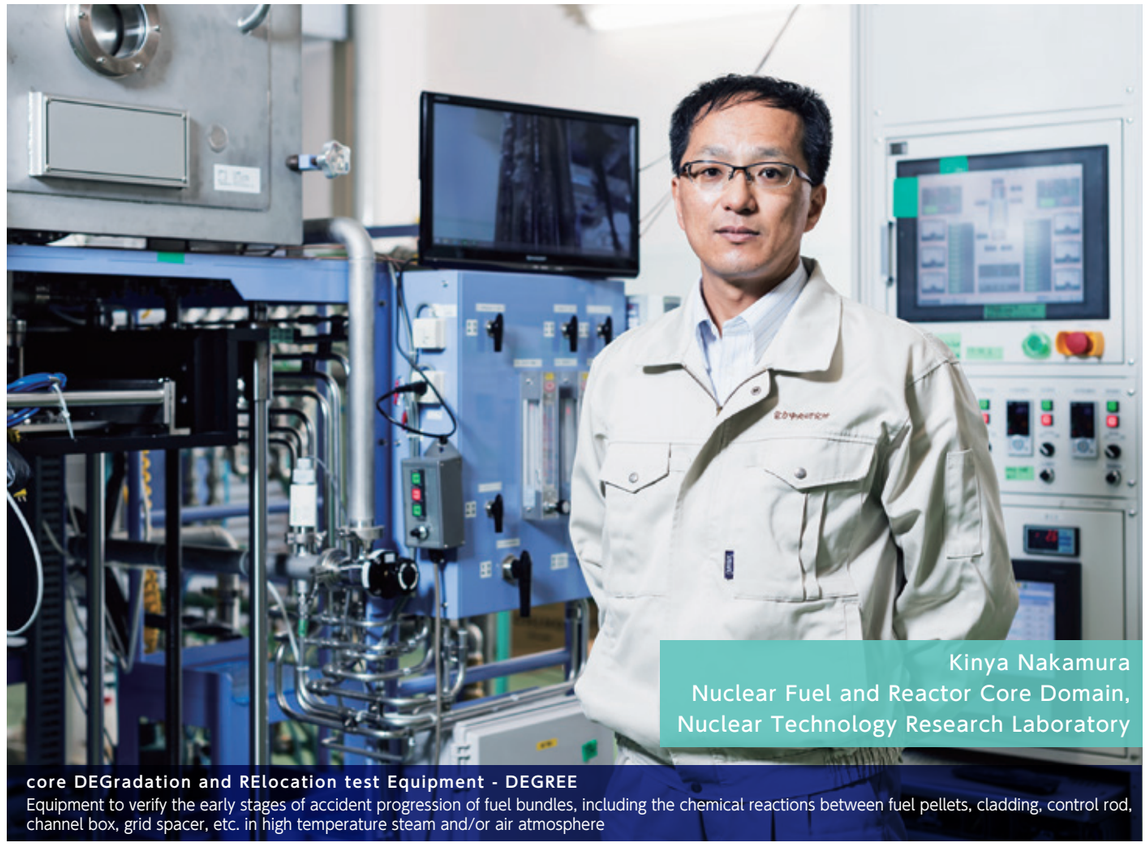
TMI-2

The abbreviation for Three Mile Island-2, one of the reactors of Three Mile Island Nuclear Generating Station in the U.S. where a severe accident resulting in core damage occurred in 1979.



Spent fuel fragment　TMI-2 (Molten pool portion)　TMI-2 (Crust portion)

Fig. 2 Spent fuel fragment and TMI-2 fuel debris sample used in leaching test



Kinya Nakamura
Nuclear Fuel and Reactor Core Domain,
Nuclear Technology Research Laboratory

core DEGradation and RElocation test Equipment - DEGREE
Equipment to verify the early stages of accident progression of fuel bundles, including the chemical reactions between fuel pellets, cladding, control rod, channel box, grid spacer, etc. in high temperature steam and/or air atmosphere

A test fuel bundle after out-of-pile severe fuel damage test in steam-limited atmosphere above 2000℃

Application Examples of Research Results

Through accumulating experimental data on the early stages of accident progression of fuel bundle using DEGREE, it will become possible to elucidate the reactor core damage sequences during SA in detail. Moreover, DEGREE can be used for several fuel damage tests, such as for spent fuel pool in hypothetical SA scenario and for accident tolerant fuel or cladding materials as performance test.

By ascertaining the physicochemical properties of fuel debris, it will be possible to elucidate the release behavior of FPs caused by reaction between molten fuel and concrete as well as contribute to studies into technique for the criticality management and material accountancy for degraded fuel. DEGREE will also be useful in the study of retrieval methods for fuel debris from PCV/RPV at the Fukushima Daiichi nuclear power plant and design of fuel debris storage containers.

References: Nakamura et al., Atomic Energy Society of Japan, 2016 Annual Meeting, 2G05, Mar. 26-28, 2016, Sendai, Japan.
Nakamura et al., Atomic Energy Society of Japan, 2016 Fall Meeting, 3H09, Sep. 7-9, 2016, Kurume, Japan.
Inagaki et al., CRIEPI Research Report, L15006 (2016).
Sonoda et al., Atomic Energy Society of Japan, 2016 Fall Meeting, 3B10, Sep. 7-9, 2016, Kurume, Japan.

Nuclear Power Generation

Establishment of an Error Management Process for Power Stations

Contribute to prevention of events through the systemization of human error prevention measures

Background

In order to prevent events triggered by human error (human factor events), nuclear power stations and other business sites engaged in various measures from the perspective of quality management and safety management however these measures need to be developed into an approach with higher effectiveness. This research aims to develop a method to build a framework for executing the PDCA cycle, which is useful in improving effectiveness, to an entire power station.

Outline of Results

◇ Systemization of error management process

CRIEPI developed the Error Management Process presented in Figure 1 as the vision of what human error prevention measures in power stations should aim for. For the Error Management Process, CRIEPI specified the below four functions of error management, clarified the relationship between measures and developed implementation procedures for each measure.

Function 1:	Systemization of human error prevention activities at worksites	Measures:	Establish annual activity plan, conduct activities, etc.
Function 2:	Identification and reactive prevention of problems based on event information	Measures:	Report human factor events, major event analysis, trend analysis, etc.
Function 3:	Identification of good practices and potential problems aimed at proactive prevention	Measures:	Observe on-site behavior, report near misses. etc.
Function 4:	Prioritization of human error prevention activities at worksites based on problems	Measures:	Comprehensive evaluation, develop comprehensive improvement measures, etc.

◇ Establishment of continuous improvement approach for the error management process

Regarding the functions shown in Figure 1, CRIEPI proposed the gradual introduction consisting of (1) implementation of the major event analysis of Function 2 (utilization of HINT/J-HPES developed by CRIEPI), (2) enhancement of Function 2, (3) addition of Function 1 and Function 4 and (4) addition of Function 3. This makes it possible to continuously improve the error management process while evaluating the actual status of human error prevention measures.

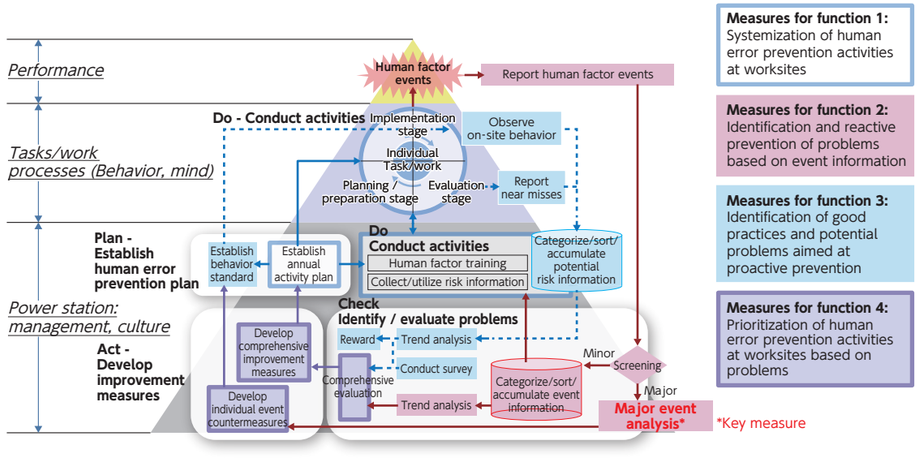
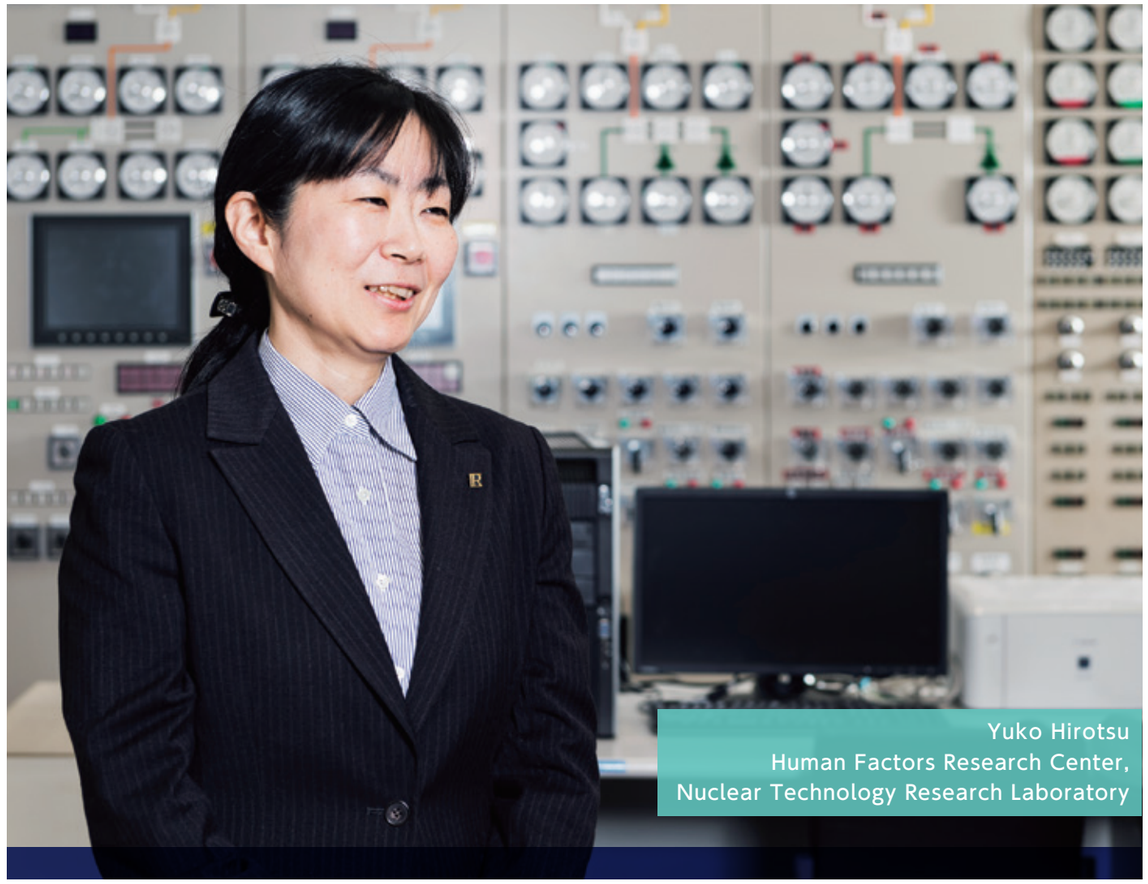


Fig. 1 Outline picture of error management process in power stations

Error management
A comprehensive and systematic approach to preventing human factor events at business sites proposed by James Reason of the University of Manchester.

HINT/J-HPES
A root cause analysis method for major human factor events developed by CRIEPI. Consists of [Understand event], [Gather and classify information about causal factors], [Analyze causal factors] and [Propose countermeasures].



Yuko Hirotsu
Human Factors Research Center,
Nuclear Technology Research Laboratory

Application Examples of Research Results

This method is already adopted at one nuclear power station and utilized as a means of reactive and proactive event prevention. Moreover, HINT/J-HPES, the root cause analysis method for major events developed by CRIEPI, is adopted at six nuclear power stations and utilized as a means of reactive event prevention.
Leveraging the achievements of this research as a guide, it can be anticipated that the systemization and enhancement of human error prevention measures at each power station will lead to greater prevention of events.

Reference: Hirotsu et. al, L08 (2016)
Hirotsu,Y.: "A Management Process for Strategic Error Prevention", In Hollnagel(Eds), "Safer Complex Industrial Environments: A Human Factors Approach", CRC Press, (2010)

2-2. Major Research Results-5

Nuclear Power Generation

Coating Integrity of Nuclear Reactor Containment Vessel and internals

Confirm coating specifications which conform to standards and contribute to nuclear power plant maintenance

Background

The devices and pipes inside the nuclear reactor containments of nuclear power plants are coated to prevent corrosion however if the coating film peels back and falls off during loss-of-coolant accidents, the coolant would leak, which may have an adverse effect on the emergency core cooling system (Fig. 1). For this reason, there is a need to confirm coating specifications which do not peel and fall off through Design Basis Accident simulated testing (DBA testing) which simulates the steam environment during an accident, in accordance with the guideline issued by the Japan Electric Association relating to the coating used inside nuclear reactor containments (JEAG4628-2010). Due to discontinuation of some paints, there is a need to evaluate the integrity of new coating specifications. As such, CRIEPI has conducted DBA testing on the new paint specifications with high priority at electric power companies.

Loss-of-coolant accident
An accident whereby coolant (water) leaks due to pipe failure, etc. in a nuclear reactor resulting in the inability to cool the reactor core.

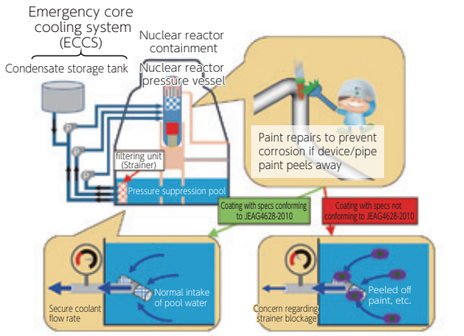


Fig. 1 Schematic of a nuclear reactor containment and an emergency core cooling system

Outline of Results

◇ Confirmation of coating specifications based on DBA testing

Up until FY2015, DBA testing was carried out for 31 types of coating specifications (Fig. 2). CRIEPI conducted an evaluation based on JEAG 4628-2010 and an evaluation of blistering, cracking and peeling based on Japanese Industrial Standards (JIS) quoted in the JEAG 4628-2010 guideline. As a result, of the 31 types of paint specifications tested, it was confirmed that 9 types conformed to the coating guidelines for BWR equation. The results of this research will be provided as a list of coating specifications conforming to JEAG4628 and will be utilized when coating repairs are carried out inside nuclear reactor containments at electric power companies.

BWR equation
Water environment conditions of a BWR (Boiling Water Reactor) such as internal steam and pressure.

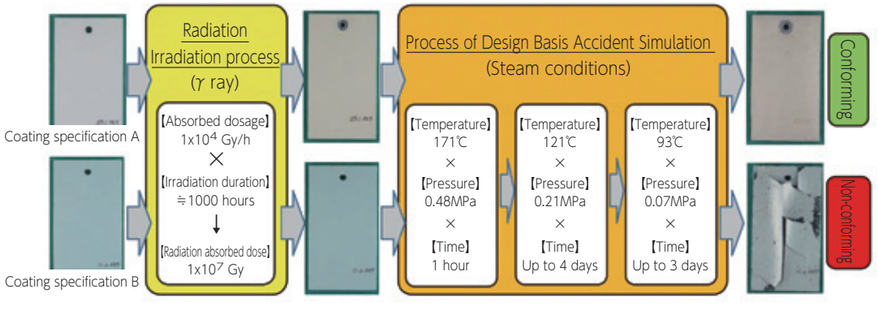


Fig. 2 Flow of DBA testing conducted using BWR equation and judgment of conformity/non-conformity
This experiment involves irradiating test pieces with various coating specifications with radiation then exposing them to a steam environment simulating the inside of a BWR reactor and investigating whether or not the coating films peel off.

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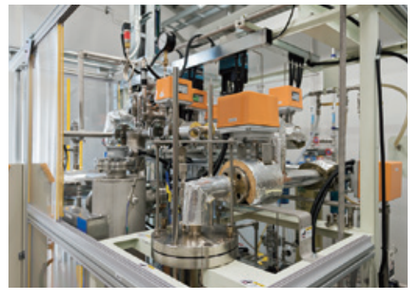
Structural Materials Sector,
Materials Science Research Laboratory



Experimental Facility for DBA Testing
A facility that can simulate a steam environment with various temperature and pressure conditions. Coated test pieces are exposed to steam with controlled temperature and pressure.

Application Examples of Research Results

Coating with appropriate specifications which do not adversely affect the performance of strainers during loss-of-coolant accidents can be used to carry out coating repairs if deemed necessary as the result of periodic inspections in nuclear power plants.

2-2. Major Research Results-6

Nuclear Power Generation

Development of a Virtual Ultrasonic Testing System

Training tool for examination engineers who can detect defects with high reliability, thereby enhancing reliability

Background

Ultrasonic testing (UT) is one of the non-destructive examination techniques used for crack detection in the piping weld joints in power plants, etc. However the skill of the examination engineer (inspection personnel) significantly affects UT results. As such, if high reliability is required, in addition to confirming the inspection personnel's actual level of skill through the Performance Demonstration system (PD), it is important to improve this skill through training, etc. However, one issue preventing the spread in skill level tests and training is the fact that a large number of expensive specimens with realistic defects are required. Therefore, CRIEPI has developed a system to partially substitute testing and training through simulated crack detection not requiring actual specimens.

Ultrasonic Testing (UT)
A non-destructive inspection which transmits an ultrasonic pulse and detects the position and size of damage by receiving echo to suit the nature of the damage, such as internal defects, etc.

Performance Demonstration (PD)
A system to comprehensively prove the defect detection ability of defect testing procedures, equipment and inspection personnel in conditions closely resembling reality.

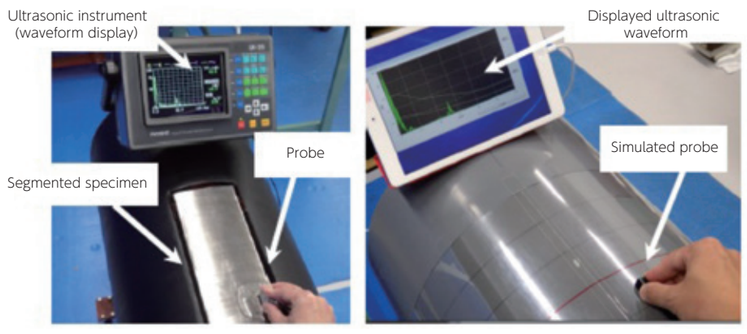
Outline of Results

◇ Virtual Ultrasonic Testing (UT) System prototype

The Virtual UT System displays a waveform depending on the position and skew angle of the dummy probe scanning by the examination engineer. The displayed wave data was recorded by scanning from actual examination data and test specimens in the past. Also, to achieve a real-time response as much as possible, the Virtual UT System pursues conditions as close to the actual task as possible to achieve realistic simulation. Based on these results, CRIEPI prototyped a virtual UT system which adopts a magnetic 3D position sensor capable of detecting the position and angle of the probe with good accuracy and demonstrate high response speed (Figure).

◇ Verification of prototype system performance and fabrication of a first generation model

We confirmed that the prototype system had sufficient accuracy in relation to probe position and skew angle, and that a waveform could be displayed "real-time". We gathered feedback from inspection personnel on how it felt to operate this prototype and received reviews that it did have sufficient functions to partially substitute testing and training. After this, we fabricated a first generation model which reflected these reviews, thus making it possible to train inspection personnel at a low cost.



The figure on the left shows a crack detection test using an actual specimen and the figure on the right shows a virtual UT system

The figures respectively show defect testing using an actual specimen and defect testing using the Virtual UT System fabricated by CRIEPI on this occasion. The displayed waveform data is based on edited data obtained from specimens and defect testing on actual pipe welds, and if defect testing work using a simulated probe on a simulated pipe is performed, the corresponding waveform is displayed.

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PD Center, Materials Science Research Laboratory

Virtual Ultrasonic Testing system
Just as if performing testing on a real specimen with defects, by scanning the simulated probe over a simulated pipe, the corresponding defect waveform is displayed. This eliminates the need to use expensive specimens and creates a virtual experience resembling the actual task of defect testing.

Application Examples of Research Results

The Virtual UT System will be used to train examination engineers, who will perform UT inspections to verify plant soundness, and test their skill level. It will also contribute to enhancing the skill level of personnel performing non-destructive testing who are involved in periodic inspections at power plants, human resource development and increasing the reliability of inspection results.

References: Hajime Shoji et. al., CRIEPI Research Report Q14007 (2015)

Nuclear Power Generation

Development of Countermeasure Technology for Stress Corrosion Cracking in Preparation for the Practical Application of Concrete Casks

Evaluate the long-term safety and soundness of spent fuel storage containers

Background

The amount of spent fuel has increased due to the recommencement of nuclear power plants and decommissioning of reactors, and this has led to the Japanese government calling for the strengthening of storage capability in its action plan for spent fuel, therefore making the establishment of countermeasures to deal with spent fuel an important issue. Considering the increase in dry cask storage, it would be difficult to store spent fuel in metal casks, which are already being utilized, from the perspective of manufacturing capacity, therefore it is necessary to make concrete cask storage possible in Japan, as this is expected to be an economic approach to store large volumes, thus expanding dry cask method options. To put concrete casks to practical use, the long-term soundness of canisters is a key factor, however there is concern that stress corrosion cracking (SCC) caused by airborne salt will cause the canister's sealing performance to deteriorate. As such, CRIEPI engages in the development of SCC countermeasure technology, including SCC evaluation and prevention technique for SCC initiation.

Dry Cask

A method of storing spent fuel in a metal container containing inert gas (helium, etc.). The method of storing spent fuel in a pool is referred to as "wet storage".

Concrete Cask (See p.29)

A cylindrical container for storing spent fuel. Concrete casks comprise of a concrete storage container and canister (made of stainless steel), and its design is such that the heat caused by the spent fuel decaying is released via natural convection through the canister's surface.

Outline of Results

◇ Establishment of a prediction technique for SCC initiation caused by salt deposition

CRIEPI proposed an evaluation method relating to the amount of salt deposition on the surface of stainless steel canisters (accumulated amount) over the passage of time, and clarified the salt amount limit for SCC initiation (Fig. 1). Moreover, we developed infrared measurement technology utilizing a laser to enable measurement in high temperature, high irradiation environments as a technique to inspect the amount of salt deposition during the storage period. This has made it possible to evaluate the potential for SCC initiation during the storage period and secure soundness.

◇ Evaluation of SCC growth rate

Using a specimen fabricated with the same technique as the actual cask, CRIEPI quantified the growth rate in the case of SCC occurring and, based on this result, clarified the crack depth tolerance at which canister soundness could be maintained and storage would continue to be possible (Fig. 2).

◇ Development of SCC prevention measure

As a technique to alleviate the weld residual stress which is a factor causing SCC initiation, CRIEPI used either shot pinning, which involves colliding small steel balls with a metal surface at high speed, or burnishing, a process of pushing small steel balls up against a metal surface, to a canister specimen with the same diameter as an actual canister, and verified the effectiveness of this as a measure to prevent SCC.

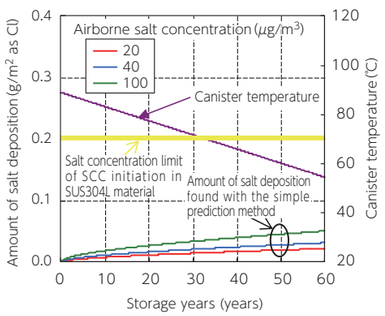

Fig. 1 Evaluation of salt deposition on canister

With the concentration of airborne salt as a parameter, CRIEPI used its simple prediction method to calculate the amount of deposition over time.

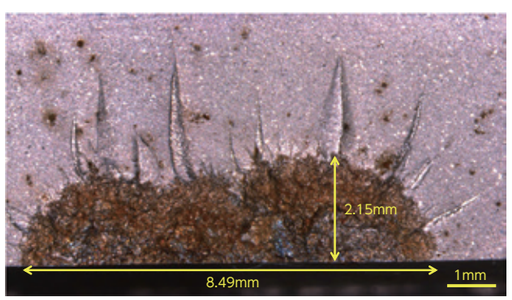

Fig. 2 Example of crack growth test results using SUS304L material

A 4-point bending test was performed on specimens made from SUS304L and 316L to measure the crack growth rate. The specimens were broken after the test to measure the depth and shape of the SCC.

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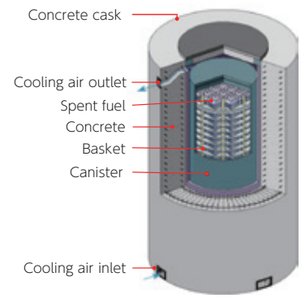
Thermostatic Chamber for Evaluation of Long-term Soundness
A thermostatic chamber providing constant temperature and humidity to perform long-term soundness experiments (corrosion testing, etc.) on full-scale specimens (e.g. diameter: 1.8m, height: 1m, weight: approx. 2ton).

Schematic of a concrete cask and example of concrete cask storage facility in the US

Concrete casks are mainstream in the U.S., primarily for economic reasons, and SCC evaluations are conducted on the canisters of storage facilities which have been in use for 20 years. These canisters are then allowed to continue being used for storage if the approval of the NRC (U.S. Nuclear Regulatory Commission) is granted.



Application Examples of Research Results

CRIEPI plans to reflect the results of this research in revisions to the concrete cask standards of the Japan Society of Mechanical Engineers and the Atomic Energy Society of Japan. In regards to securing soundness through SCC evaluation and SCC prevention technology, a demonstrative experiment at full-scale cask size is necessary to obtain approval. Once this is done, it is anticipated that the practical application of concrete cask storage will be possible, there will be more options regarding dry cask storage methods, storage capability will be stronger and spent fuel countermeasures will have greater flexibility.

References: M.Wataru et al., "CRIEPI's studies on the SCC of the canister for spent nuclear fuel", Proceeding of International Conference on Management of Spent Fuel from Nuclear Power Reactors, IAEA (Vienna), 2015
M.Wataru et al., "SCC Tests of the canister for spent nuclear fuel storage using full scale lid model", Proceeding of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM), Kobe (Japan), 2016

Thermal Power Generation

Development of an Evaluation Technique for Creep Life in High Chromium Steel Welds

Contribute to the safe operation and maintenance of high-efficiency thermal power plants

Background

Steam temperatures of thermal power plants are increasing in order to achieve high-efficiency and, generally-speaking, high chromium steel is adopted to achieve this. In recent years there have been reports of cracks occurring due to creep damage in the welds of large-diameter, high chromium steel pipes, which are used in 600℃-level thermal power plants. CRIEPI has conducted a detailed analysis and study using both actual experimentation and theoretical calculations in regards to creep phenomena in girth welds (circumferential welding of pipes) and repair welds, and developed a new life evaluation technique.

High Chromium Steels
The general term for ferritic heat-resistant steel containing 9 to 12% chromium. These steels have a heat resistance of 600 to 630℃.

Creep Damage
A phenomenon whereby stress works continuously on an object and strain increases over a long-term period to ultimately cause the object to break.

HAZ (Heat Affected Zone)
The area of the base material affected by heat due to directly contacting the weld metal. The strength of the HAZ changes to that of the unaffected base material therefore must be treated differently.

Outline of Results

◇ Observation of damage in specimens of girth joints for large-diameter pipes under bending-internal pressure creep conditions

In actual power plants, pipes are subjected to internal pressure acting on an interior surface of pipes in addition to bending force. Given this, CRIEPI performed a simulated pressurization/load experiment on a large-diameter pipe specimen made of 12 Cr and 9 Cr, which are materials used in power plants, stopped the experiment just before the crack reached the outer surface and, as a result, was the first to successfully observe the girth weld cross-section immediately before breakage. Through this activity, it was discovered that a large, visible crack progressed along the fine grain region of the HAZ within the pipe metal (Fig. 1). The results of this research will contribute to elucidation of high chromium steel breakage as valuable data demonstrating the crack progress in full-scale, large-diameter pipes.

◇ Stress analysis of experiment results and failure life estimation based on these results

Based on the results obtained from our experiment, CRIEPI conducted a stress analysis considering the different deformation properties of the base material, welded metal and the HAZ. We satisfactorily recreated creep deformation behavior by considering that hardening of pipe material would recover slightly if pressurization/load was stopped mid-way through. Based on this knowledge, we developed a method of estimating the life of creep in the girth welds of pipes under arbitrary internal pressure and bending load conditions. We also derived a formula to estimate creep life in the case of repair welds. Consequently, it is now possible to estimate failure life of high chromium steel pipes at a sufficient accuracy by combining the life evaluation formula of small joint specimens (Fig. 2).

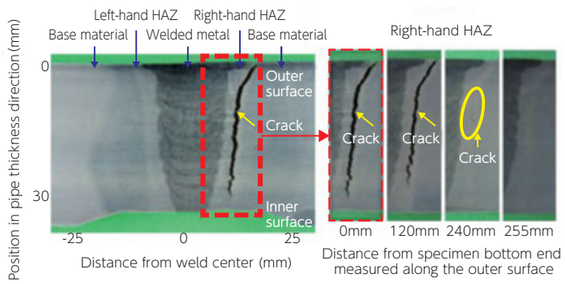


Fig. 1 Crack progress in a 12 Cr steel weld

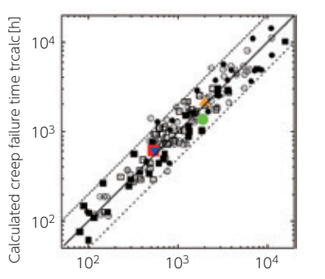


Fig. 2 Accuracy of creep life estimation

Fig. 1 is a photo of a large-diameter specimen cross-section.
By intentionally bending the pipe and stopping just before breakage, it was possible to clearly observe crack progress. The points in Fig. 2 are data obtained from various experiments. The solid line is the result of a calculation using the new life evaluation method. With the solid line as the datum, practically all experiment data was within the range of double and half.

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Structural Materials Domain,
Materials Science Research Laboratory

Actual Pipe Component Test Facility
A facility to perform a bending test on pipes of the actual size used in power plants while adding internal pressure. This facility is installed underground in consideration of size and testing safety, and is capable of long-term testing.

Application Examples of Research Results

The results of this research will be applied to not only 600℃-level thermal power plants but also for the maintenance and management of high chromium pipes used in combined cycle thermal power plants; contributing to significant maintenance cost reductions as well as efficient planned pipe replacement work.

References: Nishinoiri et al., ASME 2015 Pressure Vessels and Piping Conference, PVP2015-45423 (2015)
Takahashi et al., ASME 2015 Pressure Vessels and Piping Conference, PVP2015-45384 (2015)

Thermal Power Generation

Development of high-efficiency oxy-fuel IGCC

Simultaneously achieve highly-efficient coal-fired power generation and significant reduction of CO_2 emissions

Background

The application of CCS (CO_2 capture and storage) is currently being investigated as one mid-to-long term option for reducing the amount of CO_2 emissions from coal-fired power stations. However, regarding conventional CO_2 capture technologies, a large amount of in-house power is required to capture CO_2, and even in the case of IGCC (Integrated Coal Gasification Combined Cycle), it has been tentatively calculated that net thermal efficiency would decrease to the 30% range, therefore an increase in power generation costs has emerged as an issue. In order to make a breakthrough, the New Energy and Industrial Technology Development Organization (NEDO) started project to develop a technology which will enable power generation to be performed with high efficiency in the 40% range even after CO_2 capture is incorporated. CRIEPI is currently engaged in this NEDO project to develop high-efficiency oxy-fuel IGCC System.

IGCC (Integrated coal Gasification Combined Cycle)

A highly-efficient gas turbine combined power generation system which uses gas obtained from coal gasification as fuel. A net thermal efficiency of at least 46% is expected.

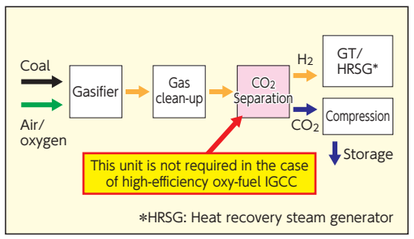
Net thermal efficiency

Ratio of transmitted electricity among overall calorific value of fuel.

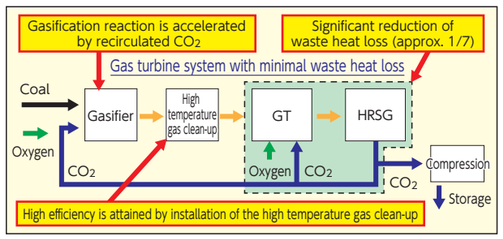
Outline of Results

◇ Concept and performance evaluation of high-efficiency oxy-fuel IGCC System

CRIEPI proposed a high-efficiency oxy-fuel IGCC System which recirculate Gas turbine exhaust gas (CO_2) and use mixture of O_2 and recirculated exhaust gas for coal gasification and gas turbine combustion. This system makes it possible to achieve high net thermal efficiency even after CO_2 capture is incorporated by combining an O_2-CO_2-blown coal gasifier and semi-closed cycle gas turbine system. This is possible due to there no longer being a need for a CO_2 separation/capture unit such as a shift reactor which reformed syngas in the case of the conventional pre-combustion capture method, and the adoption of a gas turbine system instead, which has minimal exhaust heat loss (Fig.). System analysis, using three types of coal with different properties, evaluated that a net thermal efficiency of approx. 43% could be expected in the case of all three coal types.



Conventional pre-combustion capture IGCC



high-efficiency oxy-fuel IGCC

Characteristics of high-efficiency oxy-fuel IGCC

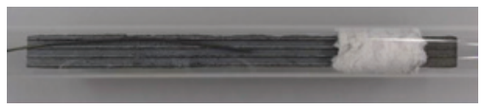
◇ Confirmation of system feasibility by evaluating effect and impact of CO_2 recirculation

In preparation for the implementation of the system, CRIEPI installed a CO_2 supply unit to our existing coal research gasifier, which has a coal processing capacity of 3 ton/day, and evaluated the impact of CO_2 recirculation on gasifier performance. Moreover, numerical simulation clarified that it was possible to evaluate the impact of CO_2 recirculation on performance of a commercial-scale O_2-CO_2-blown gasifier. Through these verifications, we confirmed the feasibility of this system. Anxiety of carbon deposition at the series of equipment through which syngas flows arose from carbon monoxide (CO) that was produced from carbon in coal at the gasifier. The highest anxiety of the carbon deposition at the sulfur removal process was solved by the measure of exhaust gas recirculation and development of durable sorbent.

Yuso Oki
Advanced Thermal Power Technology Sector,
Energy Engineering Research Laboratory

Coal Research Gasifier
To support IGCC demonstration project, we have developed a numerical analysis tool which considers conditions inside a gasifier; specifically, flow pattern, particle trajectory, convection and radiant heat transfer and gasification reaction. In order to verify the analysis results of this tool, we use this research gasifier to measure actual temperature distribution, and to analyze gas composition, and so on, in the gasifier.

Former type desulfurization sorbent



Improved desulfurization sorbent

Comparison of durability to the carbon deposition of the desulfurization sorbents

The former type sorbent (left) was suffered by deteriorative carbon deposition under the severe condition. As alteration of raw material enhanced durability of the improved sorbent (right), the performance of the improved sorbent was maintained properly under the same condition.

Application Examples of Research Results

Through saving fuel consumption thanks to high efficiency and supporting CCS, CRIEPI's research in this area will help to significantly alleviate the burden on the environment as a result of thermal power generation. Moreover, there is expectation that O_2-CO_2-blown gasifier can be put to practical use as high-performance gasifier for industrial use due to the fact that next to no N_2 mixes with the generated gas.

References: Hamada, H., Kidoguchi, K., Kajitani, S., Oki, Y., Umemoto, S., Umetsu, H., "Evaluation of CO_2-Enriched Gasification Characteristics Using Coal Research Gasifier", Proceedings of POWER-GEN International 2013 (2013)
Kobayashi, M., Nakao, Y., Inumaru, J., Hara, S., Oki, Y., "Suitable method to prevent carbon deposition in the IGCC power generation system with exhaust recycling and CO_2 capture", Proceedings of POWER-GEN Europe 2012 (2012)
Oki, Y., Hamada, H., Kobayashi, M., Nakao, Y., Hara, S., "Development of high efficiency Oxy-Fuel IGCC System", Proceedings of ICOPE-15 (2015), Paper ID:ICOPE-15-1174.
Oki, Y.," Development of high efficiency Oxy-Fuel IGCC System", Presentation at Gasification technology conference 2013 (2013), (online), available from <http://www.gasification-syngas.org//uploads/eventLibrary/>, (accessed on 28 September, 2016).

Renewable Energy

Development of Technology to Predict Photovoltaic Power Generation Output in Real-Time

Ensuring stable utility power system operation by predicting the output of grid-connected photovoltaic systems

Background

In the recent years, a large volume of photovoltaic power (PV) has been interconnected with electric power systems. In the interconnected systems, the actual electric power demand is unknown due to the supply of power from PV, and this hinders the ability to secure reserve power, etc. Therefore, in order to ensure stable operation of the utility power system, it is necessary to accurately ascertain in real-time PV output in areas of various scales, from wide areas covering the entire power system, to regional levels corresponding with each distribution substation. The total PV output cannot be directly measured as PV systems are distributed across the regions, therefore CRIEPI has been involved in the development of technology to ascertain PV output from the solar irradiance detected through terrestrial observation and estimated from weather satellite images.

Solar irradiance
Amount of energy radiated from the sun. In addition to the sunlight directly obtained from the sun, PV also uses diffused light for power generation.

Estimation of PV output
Estimating PV output by a method other than directly measuring electrical current or electrical voltage. For example, estimating PV output from the solar irradiance in a place where a PV system is installed.

Outline of Results

◇ Development of an estimation method for solar irradiance using weather satellite data

PV output is most affected by the solar irradiance; thus, it is the most important parameter when estimating PV output. CRIEPI has discovered it was possible to reproduce the incidence of clearness indices through overlapping four normal distributions (modes) roughly corresponding to the weather conditions of clear, fair, slightly cloudy and overcast (Fig. 1). By combining these analysis results with weather satellite image data, CRIEPI has succeeded in estimating the solar irradiance for specific areas.

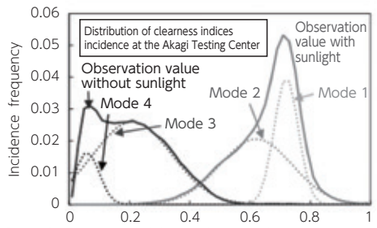


Fig. 1 The 4 weather modes proposed based on the observation results of Akagi Testing Center and corresponding incidences

The peaks were named Modes 1 through 4. The incidence of each mode and the transition probability through modes were analyzed to clarify the properties of the solar irradiance, which is directly connected with the estimation of PV output.

◇ Estimation of PV output for wide areas and its demonstration

In order to ascertain PV output in wide areas, it is necessary to estimate the solar irradiance within the area. We first devised a method to calculate the total PV output of a wide area from observations of solar radiation amounts at a small number of locations. We also developed a method to compensate estimated values for solar radiation amounts in unobserved areas with weather satellite data. Finally, in order to evaluate the validity of field application of these methods, we evaluated the error in the total output calculated from the PV output estimated in the four areas (Fig. 2) against actual PV power generation measured on-site, using the main island of Okinawa as a case study. As a result, we have demonstrated the CRIEPI's estimation methods could be used for actual system operation. These results will be incorporated in the system operation of various regions and contribute to stable system operation.

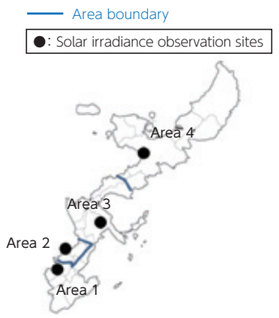


Fig. 2 Solar irradiance observation sites and area divisions on main island of Okinawa

CRIEPI divided the main island of Okinawa up into four areas for each solar irradiance observation site and ascertained PV output.

Akagi Testing Center's outdoor measurement site for PV power generation
This facility has PV panels facing south, west and north and is installed adjacent to a pyrheliometer.

Application Examples of Research Results

CRIEPI's estimation methods can be used to ascertain grid-connected PV output in the utility companies. Consequently, it will become possible to acquire appropriate reserve power and standby power, which will reduce operation costs and improve the stability of utility power system operation.

References: Usami et. al., CRIEPI Research Report Q14012 (2015)
Usami et. al., CRIEPI Research Report Q15014 (2016)

Renewable Energy

Development of a Hybrid Geothermal-Biomass Power Generation System

Realizing high-efficiency power generation through superheating geothermal steam

Background

Japan's Basic Energy Plan has a target of the domestic geothermal power generation capacity being 1.55 million kW by the year 2030, however currently, it stands at around 500,000 kW. Factors preventing the expansion of geothermal power generation include limited land and the fact that the associated thermal efficiency is quite low at around 10%, therefore CRIEPI is engaged in development of a geothermal power generation system with higher efficiency and excellent economic performance in order to promote renewable energy (research under commission by New Energy and Industrial Technology Development Organization (NEDO)).

Outline of Results

◇ Concept of the hybrid heat source geothermal power generation system and economic performance evaluation

CRIEPI devised the concept of a hybrid geothermal-biomass power generation system which could improve thermal efficiency by utilizing an external heat source to superheat the geothermal saturated steam injected into the turbines of a geothermal power plant (Fig. 1). In regards to the external heat source, after considering factors such as heat source performance, legal aspects and equipment investment, we determined that, out of biomass, solar heat and fuel cell exhaust heat, biomass was the most promising.
In order to verify the feasibility of this system, CRIEPI tentatively calculated the cost of power generation for the increased output based on biomass and discovered it would be less than, 40 yen/kWh, which is the FIT cost of biomass power generation. CRIEPI also clarified the relationship between the amount of timber off cuts able to be procured due to specific forest thinning plans in certain locations and the procurement cost including carrying the timber off site, transportation and chipping (Fig. 2). Through applying this technique, it is possible to evaluate equipment capacity and power generation capacity corresponding with potential at development locations.

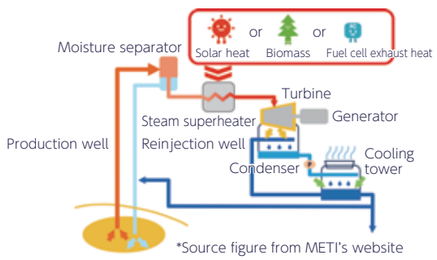


Fig. 1 Schematic of a hybrid heat source geothermal power generation system

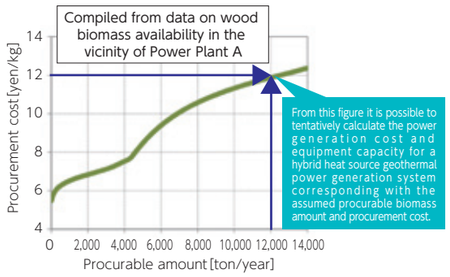


Fig. 2 Relationship between procurable biomass amount and cost (results of tentative calculations at actual locations)

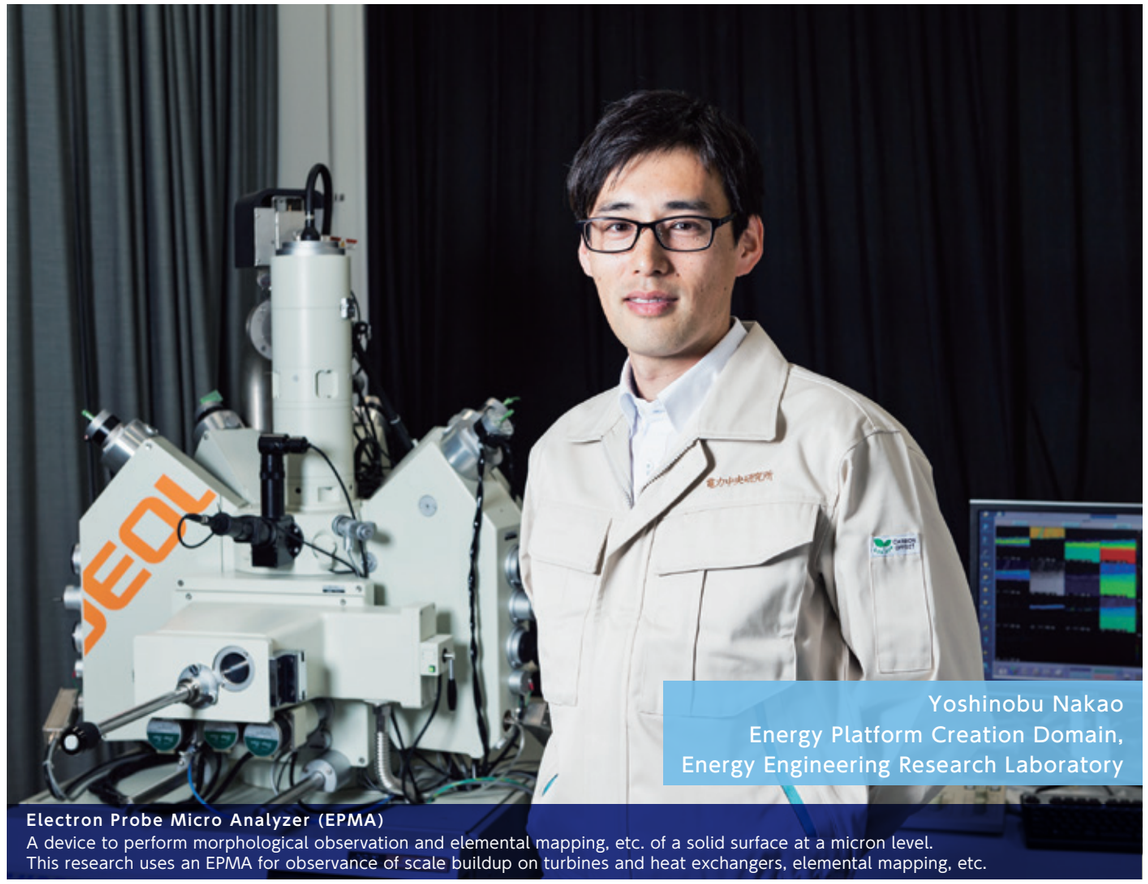
◇ Evaluation of plant performance of a hybrid geothermal-biomass power generation system

By using Energy-Win™ to analyze performance of the hybrid geothermal power generation system, we discovered that power generation output increased by 30% and thermal efficiency was more than 20% in prescribed production well steam conditions and cooling water conditions*.
In the new system, power generation efficiency was 22.7%, where this efficiency can be expressed as the net output increase in relation to the calorific value of the injected biomass chips (geothermal 3 MW-class + biomass 1 MW-class). This means that, compared to the 14%thermal efficiency of a power generation system which exclusively uses biomass as fuel (1 MW-class), the CRIEPI system would lead to effective utilization of biomass chips.

* Production well steam conditions: Saturated gas: 0.5MPaA, condenser water conditions: Condenser vacuum: 700mmHg

Geothermal saturated steam
Steam generated by separating the two-phase fluid of steam/hot water from underground in a moisture separator.

Energy Win
A general-purpose program developed by CRIEPI for analyzing power generation system heat efficiency. This program enables the heat and mass balance analysis of energy systems.



Electron Probe Micro Analyzer (EPMA)
A device to perform morphological observation and elemental mapping, etc. of a solid surface at a micron level.
This research uses an EPMA for observance of scale buildup on turbines and heat exchangers, elemental mapping, etc.

Application Examples of Research Results

Improvement in the efficiency and output of geothermal power generations will lead to recovery of the slump in output due to reduction in steam production volume at existing geothermal power plants and the development of geothermal power generation in new regions.

References: Nakao et al., World Geothermal Congress 2015 (Melbourne)
Nakao, The Geothermal Research Society of Japan Symposium Annual Meeting (2015)

Major Research Results
Renewable Energy

Electric Power Distribution

Assessment of the Impact of Changes in Supply and Demand Situation, etc. on Maintaining Voltage

Indicating the possibility that unbundling and high penetration of renewable energy may impact on power quality during normal condition in power system.

Background

Maintaining voltage, a quality of electric power, within the appropriate range is critical to the stable supply of electric power, and adjustment of reactive power is necessary to achieve this. The conventional large-capacity power stations (thermal, hydro, nuclear) have excellent ability to do this and have contributed for maintaining the appropriate voltage through integrated operation with power transmission facilities (voltage regulators).
In Japan, electricity system reform have been conducted in 2013. In the future, utilities is unbundling into system operation department and generation department. It may become difficult to maintain the appropriate voltage efficiently, therefore there is a need to prepare a framework to substitute integrated operation. Moreover, high penetration of renewable energy (RE) such as photovoltaic (PV), will cause changes in supply and demand condition and power flow. It may result in even greater changes in system voltage operation than ever before experienced. In this way, the operational status of conventional generators and PV, etc. will impact significantly on system voltage, and as such there is a need to quantitatively assess the issues about voltage operation.
Consequently, CRIEPI is currently engaged in the identification of issues relating to system voltage maintenance and development of countermeasure technologies with consideration to future status changes.

Outline of Results

◇ Development of a system model to be used in identifying issues and examining countermeasures relating to system voltage maintenance with consideration to future status changes

With consideration to both the bulk power system, which is subjected to changes in operational status of conventional generators, and the subtransmission systems with high penetration of PV, CRIEPI developed a system model to simulate voltage of each location, power flow including reactive power, and regulation of reactive power using voltage regulators.
Simulations using this system model enabled the quantitative assessment of the reciprocal impact on maintaining voltage in the bulk power system and subtransmission systems (Fig. 1) by inputting the generator operational status and 24-hour fluctuations of the PV output status. These simulations are effective in ascertaining locations where voltage fluctuation becomes obvious.

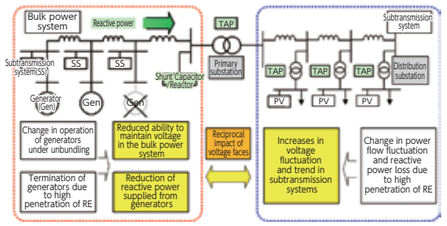


Fig. 1 Issues with maintaining system voltage during normal condition after unbundling

The bulk power system and subtransmission systems are interconnected via a primary substation.
It is assumed that changes in operation or termination of conventional generators in the bulk power system due to unbundling will lead to the reduction of reactive power supply and lead to a decreased ability to maintain voltage.
Furthermore, it is also assumed that voltage fluctuation will increase depending on the RE output status, therefore there is a need to consider the reciprocal impact of voltage faces.

◇ Assessing the impact of future status changes on maintaining appropriate system voltage

By simulating voltage fluctuation over 24 hours using the developed system model, we assessed the impact on maintaining appropriate system voltage when a part of conventional generator were partially terminated. The simulation results showed that the impact had on maintaining voltage in subtransmission systems differed between locations. We indicated that, in the area with decreasing conventional generators, the ability to regulate reactive power in the nearby location decreased, therefore there is an increased need to adjust voltage with the operation of a voltage regulator, hence the burden on these regulator is increased (Fig. 2).

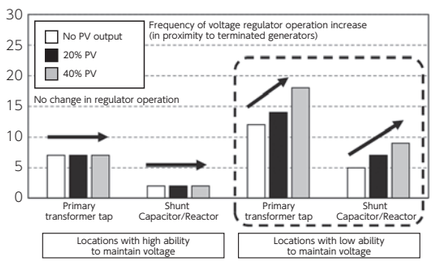


Fig. 2 Change in frequency of voltage regulator operation due to termination of conventional generators

In the area with decreasing conventional generators, the ability to regulate reactive power decreased, therefore there is an increased need to adjust voltage with the operation of a voltage regulator, hence the burden on these regulator is increased (Fig. 2).

Reactive power
Power necessary to maintain voltage. Reactive power is adjusted with a generator and a voltage regulator.

Voltage regulator
Shunt Capacitor and Reactor or transformer tap to regulate reactive power with the aim of maintaining appropriate voltage

Bulk power system
The framework of power system. Mainly comprises of between 500 kV and 154 kV facilities.

Subtransmission system
The power system responsible for supplying electricity. Mainly comprises of between 154 kV and 6 kV.

Hideo Koseki
Electric Power Systems Sector,
System Engineering Research Laboratory

Application Examples of Research Results

As a way of accommodating the Electricity System Reform and advancement of high penetration of RE in Japan, it is anticipated that the appropriate voltage can be effectively maintained even with future changes in status by developing a voltage control system based on the results of this research. This research may also contribute to the design of a framework whereby generation operators and system operators collaborate to maintain the appropriate voltage.

Reference: CRIEPI Research Report R15019 (2016), Koseki et al.

Electric Power Distribution

Proposal of a Failure-Probability Evaluation Method Considering the Structural Abnormality of Transformer Windings

Contribution to the establishment of a rational repair/replacement plan for aged transformers

Background

In Japan, many power transmission and power distribution facilities were introduced during the period of high economic growth and have been operated more than 30 or 40 years. Appropriate operations of such aged facilities while maintaining high supply reliability and rational repair/replacement planning are important issues. Evaluation of equipment life as failure probability is important to achieve rational repairs and replacement. Regarding oil-immersed transformers, winding structural abnormalities*1 can occur, for example, due to the internal electromagnetic force due to short-circuit. In addition, the thermal degradation of insulation materials, such as oil-immersed insulation paper and press board, progresses due to aging and there is a possibility of winding structural abnormalities occurring due to the loosening in clamping strength of the windings. Therefore, CRIEPI has developed diagnosis methods for thermal degradation of the insulation materials and abnormalities of winding such as winding displacement.

*1: For the purposes of this report, "structural abnormalities" shall refer to winding abnormalities such as winding displacement due to spacers falling off and changes in the physical layout and size of windings.

Outline of Results

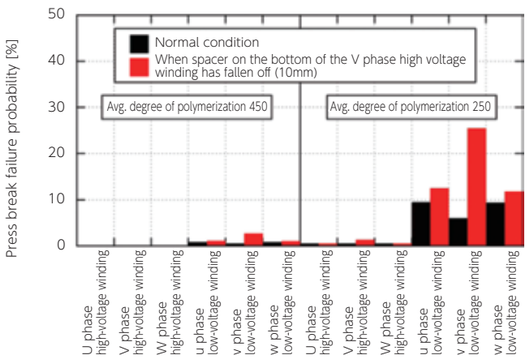
◇ Development of a diagnosis methods for transformer degradation and abnormalities

CRIEPI developed a method to estimate the degree of degradation of the insulation materials by calculating the variation of the temperature of the windings, and so from the variation of the load during transformer operation, and evaluating the thermal stress of the insulation materials. This has made it possible to evaluate mechanical strength based on the thermal degradation of the insulation materials. CRIEPI also developed a method to judge the existence of a winding structural abnormality using Frequency Response Analysis (FRA).

◇ Establishment of a failure probability evaluation method considering structural abnormality of windings

CRIEPI established a method to evaluate the probability of transformer failure which considers the degradation of the insulation materials in mechanical strength due to thermal aging and increase in the electromagnetic force due to winding structural abnormalities*2. Using the 60 kV-class transformer model as an example, we evaluated the failure probability for the transformer winding in normal condition and for winding having some structural abnormality. We discovered that the failure probability becomes higher due to thermal degradation. Furthermore, it becomes even higher when the winding has a structural abnormality. Through this, CRIEPI confirmed that it is possible to evaluate transformer life quantitatively as failure probability by using the developed diagnosis method for degradation of the insulation materials and winding structural abnormality discussed above (Fig.).

*2: Quantitative evaluation of structural abnormality is believed to be possible by increasing the accuracy of FRA-based diagnosis method.



Example of an evaluation result for transformer failure probability (press board failure probability) with a structural abnormality on the transformer winding

Transformer failure probability: This was established as the spacer (press board) break probability by a high current due to short circuit of low-voltage terminals, which is determined only by the short-circuit impedance of the transformer. Here, the probability of external short-circuit occurrence is not considered.

Avg. degree of polymerization of insulation paper and press board: Used as an indicator of the degree of degradation. There is strong correlation between them. According to the Japan Electrical Manufacturers' Association's standard, JEM-1463, an average degree of polymerization of 450 for insulation paper indicates life level, while 250 indicates danger level.

Frequency Response Analysis (FRA)

FRA is a method for diagnosing winding abnormalities. In FRA, transfer functions, such as the ratio of electric input/output signal on a transformer (e.g. voltage ratio) from several tens of Hz to several MHz, are measured. The abnormalities are detected by comparing them with reference data measured when the transformer was in normal condition.

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High-voltage and Insulation,
Electric Power Engineering Research Laboratory

Diagnosis of abnormalities of transformer winding by FRA

Application Examples of Research Results

In order to apply the developed method to transformers in actual use, the accuracy of evaluations for thermal degradation of the insulation materials and winding structural abnormalities must be improved, however it is expected that by applying this method, it will be possible to evaluate the life of aged transformers based on failure probability and to establish rational repair/replacement plans for transformers.

References: Miyazaki et al., CRIEPI Research Report H15002 (2016)
Mizutani et al., CRIEPI Research Report H11026 (2012)
Miyazaki et al., CRIEPI Research Report H14010 (2015)

Electric Power Distribution

Ascertaining the Lightning Failure Mechanism of Smart Meter and Proposing Countermeasures

Help reduce lightning damage of smart meter through effective measures

Background

In recent years, the introduction of smart meters is being promoted in power distribution systems and there is a demand to secure even higher reliability than previously due to the fact that smart meters are being used not only to measure electrical power, but also for communication and as switches, etc. Meanwhile, since smart meters have internal electronic circuits which operate at low voltage, the same as conventional electronic power meters, and, there is concern they are vulnerable to disturbance such as lightning surges. Hence, ascertaining the lightning failure mechanism of smart meter and developing appropriate designs and countermeasures are key issues to be addressed.

Lightning surge
A phenomenon in which a high voltage (overvoltage) occurs in a power line or communication cable, etc. due to lightning, generating a large current (overcurrent).

Outline of Results

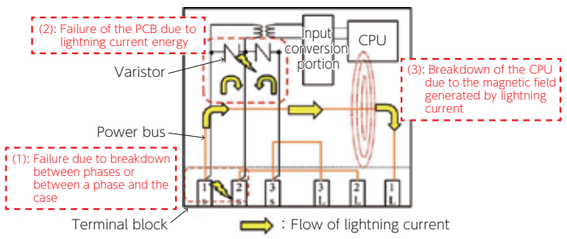
◇ Ascertaining the lightning failure mechanism smart meter and proposing countermeasures

From a lightning performance evaluation test using lightning impulse current (max. current value t: 18.7 kA), CRIEPI clarified that the causes of electronic watt-hour meter failure could be broadly categorized into (1) breakdown between the main circuit and case, etc., (2) fusing of cables on the PCB due to lightning current and (3) breakdown of the CPU due to the magnetic field generated by the lightning current that flows through the main circuit. Regarding (1) and (2), CRIEPI demonstrated that rearranging varistor layout was an effective countermeasure. In regards to (3), we clarified that rearranging or shielding the CPU inside the electronic watt-hour meter were effective approaches to reducing the magnetic field affecting this portion.

Lightning impulse
Voltage/current generated by simulating a lightning surge in a high voltage testing unit.
The standard waveforms stipulated in industrial standards are used in voltage resistance tests, etc.

◇ Establishment of a technique to estimate the failure rate of smart meter

CRIEPI established a technique to estimate failure rate caused by transient magnetic field by comparing the failure threshold value and the analysis result of the lightning current flowing into the smart meter when distribution lines are directly struck by lightning. By evaluating the failure rate due to lightning, it has become possible to clarify the lightning performance demanded of smart meters and verify the effect of countermeasures implemented on power lines.



【Measures to reduce lightning damage to smart meters】
(1) & (2): Prevent cables on PCB from melting by rearranging varistor layout
(3) Reducing magnetic field on CPU through rearranging/shielding the CPU


Interior of a smart meter with the CPU and other electric circuits removed


External appearance

Causes of smart meter failure due to lightning and countermeasures thereof


Kazuyuki Ishimoto
Lightning and Electromagnetic Environment, Electric Power Engineering Research Laboratory

Lightning Impulse Generator
An apparatus which generates and applies lightning impulse voltage or current in order to verify the voltage resistance of devices. This research used the 12 MV impulse generator (below) located at CRIEPI's Shiobara Testing Yard which has the same function and can perform full-scale tests of distribution systems.


12 MV impulse generator (Shiobara Testing Yard)

Application Examples of Research Results

By utilizing this research, it can be anticipated that new smart meters will be given an optimal design to withstand lightning. Moreover, it will be possible to reduce the smart meter failure rate to suit the distribution line equipment conditions and verify the effect of countermeasures. This is expected to help reduce damage to smart meters caused by lightning.

References: Ishimoto et. al., CRIEPI Research Report H14009 (2015)
Ishimoto et. al., CRIEPI Research Report H15003 (2016)

Electric Power Distribution

Development of Evaluation Technology for the Seismic Performance of Transmission Towers against Large Earthquakes

Contribute to evaluation of performance against large earthquakes and establishment of effective countermeasures

High level seismic motion (Level 2 seismic motion)
Seismic motion that extremely rarely occurs while transmission towers are in service.
In principle, the requirement is to ensure no notable (long-term and widespread) interference to power supply.

Design seismic motion (Level 1 seismic motion)
Seismic motion with a probability of occurring once or twice while transmission towers are in service.
In principle, the requirement is that structures would not be damaged if subjected to design seismic motion.

Background

As a result of the 2011 Tohoku Earthquake, evaluation of transmission tower seismic performance against high level seismic motion and the countermeasures thereof have become key issues. To confirm that power supply would not be notably interrupted in the case of high level seismic motion, it is necessary to conduct a detailed evaluation of the degree of damage to structures. Moreover, regarding the JEC-127, the Japanese Electrotechnical Committee's (JEC) standard for Design Standards on Structures for Transmission, revision work is being carried out to newly incorporate seismic load in design standards and there is a pressing need to establish a practical seismic design load. For these reasons, CRIEPI is developing a sophisticated seismic response analysis technology in preparation for the evaluation of complex-structured, large-scale transmission towers.

Outline of Results

◇ Observation of transmission tower seismic response

CRIEPI conducted an observation of the seismic response of an actual transmission tower (Iwaki city, Fukushima prefecture – completed FY2015), and simultaneously observed the seismic ground motion in relation to the 2011 Tohoku Earthquake and the response of the transmission tower in accordance with the earthquake. This was Japan's first simultaneous observation against high level seismic motion.

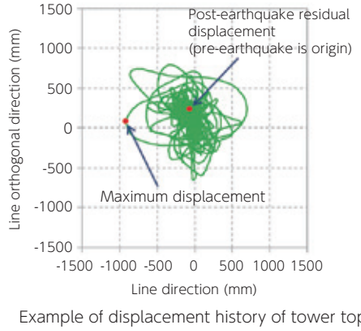
◇ Evaluation of seismic performance against high level seismic motion

CRIEPI performed a steel tower load resistant capacity test using a scaled-down model as well as a sliding element test of the bolt joint portion and through this established the optimal transmission tower model for seismic response analysis. We also developed an analysis method to evaluate the dynamic behavior in the plastic zone and verified the validity of non-linear seismic response analysis using the results of the abovementioned seismic response observation. These initiatives have made it possible to evaluate seismic performance against high level seismic motion (Fig.).

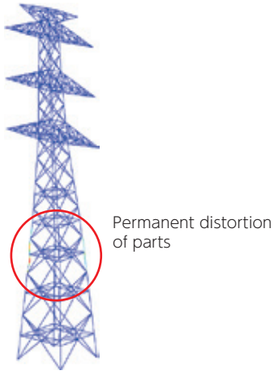
◇ Evaluation of earthquake-resistant design against design seismic motion

By developing a modal analysis program for towers and strung wires coupled system and studying equivalent static seismic design load using the program, CRIEPI has made it possible to create a practical earthquake-resistant design.

CRIEPI performed a seismic response analysis on a 275 kV transmission tower against the seismic motion assuming the Nankai Trough Mega-Earthquake. The result confirmed that, while there was partial damage and residual displacement, the functions of the tower were maintained.



Example of displacement history of tower top

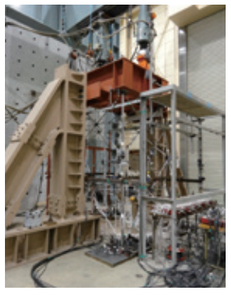


Post-earthquake state

Example of seismic response analysis results against the seismic motion assuming the Nankai Trough Mega-Earthquake

Yusuke Sato/Tomomi Ishikawa
Structural Engineering Sector,
Civil Engineering Research Laboratory

Tower Model after Load Resistant Capacity Test – Buckling deformation of the main leg member of the model.



Load resistant capacity test using a scaled-down tower model
In order to ascertain the collapse behavior of transmission towers, CRIEPI created a test model (1/7th of actual size) representing a portion of an 80-meter transmission tower and used a static load application testing unit able to accommodate loads of up to 2000 kN to clarify the load-displacement relationship of the model against cyclic load, which represents seismic load.

Application Examples of Research Results

By utilizing evaluation technology for the seismic performance of transmission towers against high level seismic motion, it will become possible to evaluate the seismic performance of transmission towers against future large earthquakes, such as the Nankai Trough Mega-Earthquake, and there are expectations that this will result in establishment of effective countermeasures. There are plans to incorporate the seismic design load relating to design seismic motion on revision work of the JEC standard.

References: Sato et al. Japan Society of Civil Engineers, 69th Annual Meeting (2014)
Sato et al., 15th World Conference on Earthquake Engineering (2012)

Electric Power Distribution

Strengthening Response Capability against Cyber-attacks on the Electric Power Sector

Acquire and enhance incident response capability through security exercises

Background

Due to the sophistication of cyber-attacks, it has become impossible to completely prevent cyber-intrusion of ICT systems. In the electric power sector in Japan, as a critical infrastructure sector, it is necessary to not only establish prevention measures against cyber-attacks, but also develop countermeasures for cyber-intrusion. To respond to incidents, not only is early discovery critical, but so too is establishing a framework to enable swift incident response and sufficient incident response capability. Training through security exercises is effective in accomplishing this.

Incident response

Post-occurrence response to mitigate damage when an undesirable event arises compromising the information security relating to information control or system operations (incident).

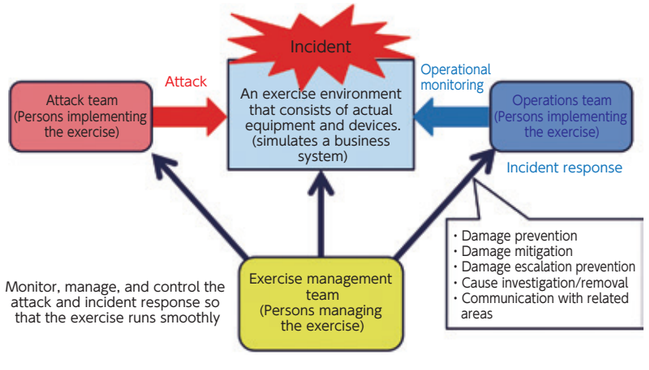
Outline of Results

◇ Providing security exercises able to respond to the latest cyber-attacks

In order to ensure security in the electric power sector, CRIEPI utilizes the knowledge it has acquired through investigations and research into related technologies such as ICT (latest attack techniques and countermeasure deployment), to provide security exercises targeting business systems for electric power companies. For security exercise, we have developed a simulated operational environment that consists of actual equipments and devices. The system for exercises is a dedicated system isolated from the internet, and therefore it enables unrestricted simulations of cyber attacks which are difficult to experience in actually operated systems. Furthermore, cyber-attacks techniques are advancing at a fast pace. Therefore, CRIEPI is continuously adding new scenarios based on investigations of the latest attack techniques.
Through these exercises, the following benefits can be gained (Fig.).

- Raise awareness of the need for security through experiencing realistic attacks.
- Gain knowledge related to the latest techniques through exercises responding to the latest attacks
- Acquire, strengthen and maintain incident response capability through experiencing and responding to rapidly changing situations under cyber attacks

By analyzing incident responses in exercises against the latest attack techniques, the results are incorporated in the development of countermeasures suited to operators of ICT systems for the electric power industry and risk assessment techniques, then the outcomes of this development are reflected in electric power companies. Through these exercises, CRIEPI also ascertains the specific needs of techniques supporting intrusion detection and countermeasure deployment and reflects these in countermeasure evaluations and simulation system design.



Outline of exercises

Exercises involve 3 teams, an attack team, operations team and exercise management team, who monitors, manages and controls exercise activities to provide the operations team with effective exercises.

Takehiro Shimada
Communication Systems,
System Engineering Research Laboratory

Engaged in incident response

Application Examples of Research Results

These exercises began in 2004, before any other sector of critical infrastructure in Japan, and were completed by a total of 860 personnel by FY2015 (just under 90 participants/year). The exercises are utilized for skill development of persons involved in cyber security at electric power companies and affiliate companies.

Services for Power Consumers

Development of a Power Consumption Estimation Method by Region Capable of Incorporating Consumer Characteristics

Estimation of demand by application and time of day for a residential area of 1000 households

Method of power supply and demand management
A control method to maintain electric power quality through collaboration between consumer equipment such as energy storage devices installed within a consumer's household and power distribution equipment.

Background

The full liberalization of retail power has created a need to equalize the overall consumer load in order to further reduce costs on the supply side. Moreover, it can be assumed that demand will become increasingly complex due to the introduction of photovoltaic generation (PV) and storage batteries, etc. to residences. Considering this situation, in order to maintain and enhance individual consumers' benefits such as comfort, etc., one approach believed to be effective is a new method of power supply and demand management in which power distribution equipment and consumer facilities can collaborate within regions with common power distribution lines. To achieve this, it will be necessary to incorporate regional differences and consumer type differences when estimating demand for a particular region for specific times of day and applications.

Outline of Results

◇ Development of a power consumption estimation method for a residential area of 1000 households

CRIEPI developed a method to estimate power consumption by application (e.g. lights) and in units of 0.1 hours for residential areas in specific regions which takes consumer diversity into consideration. This method makes it possible to estimate the power consumption for an entire residential area within a region by application and time of day by inputting residence type (detached, complex, floor area) and residence type-specific information (no. of households, family composition), as well as utilizing statistical data on the inhabitants' daily routine (wake time, sleep time) and device (refrigerator, etc.) power consumption in addition to results of software developed by CRIEPI which calculates power consumption for air conditioning purposes to calculate the power consumption by application and time of day for each individual household. As a result of applying this method to a small region within a city on Tokyo's outer fringes (detached house region, housing complex region), we confirmed it was possible to estimate the changes in power consumption between morning and evening corresponding with each residence type in a region (Fig. 1), and that estimated values per application (Fig. 2) had an accuracy in the same order as documented values.

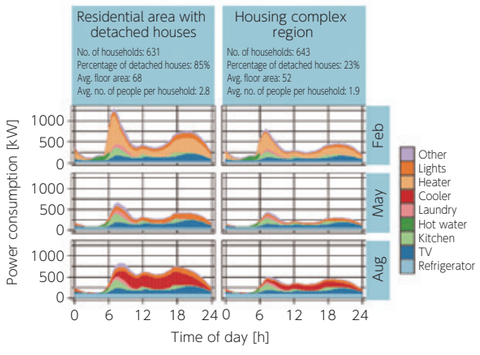


Fig. 1 Results of a power consumption estimation according to season and application to suit a specific region

This is an example of estimation results for monthly-average daily power consumption by season targeting two regions with differing characteristics. It is possible to estimate power consumption by time of day and confirm that the increase in power consumption at morning and night within a residence is expressed.

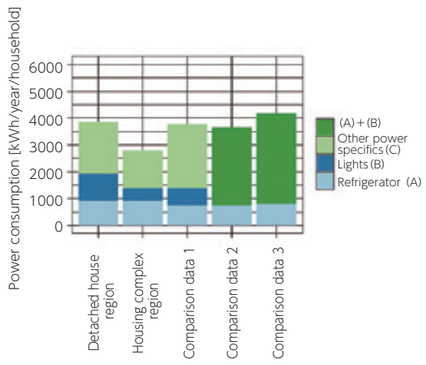


Fig. 2 Comparison of estimated values versus documented values of annual power consumption by application

Indicates the annual power consumption per household specific to refrigerators, lights and other power usage. It is clear from the figure that the estimated values obtained using the method developed by CRIEPI are in the same order as actual measured data used in documentation (Energy Efficiency and Conservation Subcommittee, Advisory Committee for Natural Resources and Energy (Comparison data 1), actual measurement by Tsuji et al. from Osaka University, part 1 (Comparison data 2) and part 2 (Comparison data 3).

Ayako Yasuoka/Tsuyoshi Ueno
Research Team for Advanced Management of Power Supply & Demand

Customer Test Facility (Akagi District)

Application Examples of Research Results

By applying this method in regions where photovoltaic power generation and storage batteries have been introduced to common households, there are expectations that it will become possible to estimate residential power consumption within a region with several hundred to a thousand households, and maximize both energy efficiency and economic efficiency, as well as utilize supply/demand collaboration in the power distribution sector for rational equipment operation.

References: Ueno et al., CRIEPI Research Report R15006 (2016)
Yasuoka et al., CRIEPI Research Report R14010 (2015)

Services for Power Consumers

Development of Component Technology to Utilize Smart Meter Data

Approximating actual demand from recorded data in units of 100 Wh

Route A

A communication route that sends the automatic readings taken by smart meters to electric power companies. Through Route A, demand data is rounded off to the nearest 100Wh every 30 minutes and sent. The portion that is rounded off is carried forward to the next 30-minute period. Meanwhile, the communication route within a household is referred to as "Route B".

Background

In recent times, an increasing number of common households are being fitted with smart meters. There is a movement to utilize the electric power demand data measured by smart meters (smart meter data), then collected and recorded every 30 minutes through Route A, for the purpose of enhancing services offered to electric power company customers. However, smart meter data is collected in units of 100Wh, therefore changes in electric power demand cannot be analyzed in detail, and there is concern that this limits the data's potential as a means of enhancing customer service. In order to remove such limitations, CRIEPI is engaged in the development of component technology to utilize smart meter data with good accuracy.

Outline of Results

◇ Development of a method to estimate actual demand from smart meter data

CRIEPI developed a technology to estimate actual demand with good accuracy based on smart meter data alone. Smart meter data is collected in units of 100Wh, therefore, in the case of a household which uses practically no electricity at all, a measurement of 0Wh would be continuously recorded and collected, however when the cumulative consumption reaches 100Wh, 100Wh would be recorded and collected, giving the impression that demand is sporadic. In this way, smart meter data and actual demand fluctuate differently (Fig. 1). As such, CRIEPI developed a method to estimate actual demand from smart meter data based on the hypothesis that significant changes in demand occur infrequently. With the developed method, data accuracy is improved as the curve approaches the changes in cumulative demand values. By applying the developed method to public data (data taken from 5 Swiss households over a 6-month period), and drawing comparisons with actual data in 1Wh units, we assessed that the new method was effective in improving data accuracy. We then used the 3 households with the lowest actual demand (average of 200Wh or less) to compare the data obtained using the developed method as opposed to the data obtained using the smart meter data directly, and discovered that with the former, it was possible to reduce the error of the measured demand with the actual demand (absolute value average) between 20 and 60%, therefore proving that the developed method made it possible to get closer to actual demand. This method makes it possible to ascertain the operational status of home electrical appliances, etc. with higher accuracy.

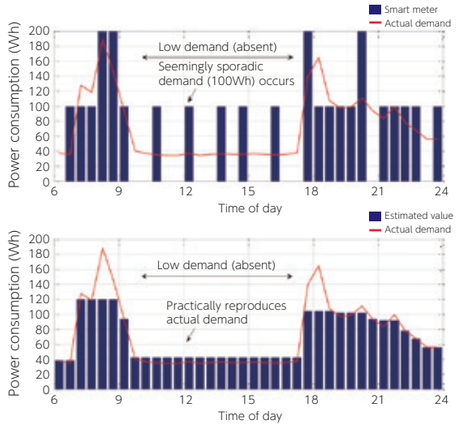


Fig. 1 Example of smart meter data

Smart meter data is measured in units of 100Wh and the rounded off portion is carried forward to the next 30-minute period. Demand is measured as 0Wh until the cumulative demand reaches 100Wh, therefore the fluctuation differs to actual demand.

Household	Avg. Wh of actual demand [Wh]	Error Wh with actual demand (absolute value average)[Wh]	
		Smart meter data	Estimated demand data
No.1	107	43	17
No.2	142	41	27
No.3	177	36	28
No.4	408	33	36
No.5	436	33	35

Fig. 2 Smart meter data and estimated demand data

In the households with relatively low average demand (No. 1 – 3), the error between the demand estimated using the developed method and actual demand was significantly less than the error between smart meter data and actual demand. However, the respective error values did not change significantly in the case of households with large average demand (No. 4 and 5).

Yasushi Shinohara/Shunichi Hattori
Research Team for Advanced Management of Power Supply & Demand

Application Examples of Research Results

Using the developed method, it is possible to better ascertain actual demand, and through combined use with AI and big data analysis technology, such a method has the potential of being used for the sake of new, high-quality services aimed at consumers such as care services for the elderly and energy-saving advice.

References: Hattori & Shinohara, CRIEPI Research Report R15004 (2016)

Environment

Development of New Evaluation Methods for the Environmental Impact Assessment of Power Plants

● **Efficient environmental impact assessments**

Warm/cold water discharge
Warm water discharge is the seawater discharged after being used as cooling water in the condenser of the power plant. Cold water discharge is cold water discharged after being cooled during LNG regasification in LNG power plant.

Environmental impact assessment
A process that aims to create better business plans from the perspective of environmental conservation. Business operators perform investigations, predictions and evaluations of the environmental impact of large-scale development projects before implementation.

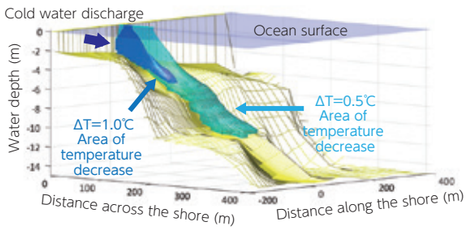
Background

In recent years, electric power companies require performing the environmental impact assessments for the power plants under the complex conditions, because the new power plants constructed near the existing power plants or cities is increasing in the coastal zone. CRIEPI is developing the numerical model to evaluate the dispersion of warm/cold water discharged into the sea amidst such complex conditions as preparation for the construction of power plants, which consider environmental conservation. Moreover, in regards to renewable energy, which is also becoming increasingly popular, CRIEPI is conducting R&D aimed at the simplification and acceleration of environment impact assessments concerning geothermal power generation and wind power generation in order to reduce development lead-time.

Outline of Results

◇ Developing a 3D model for the prediction of cold water dispersion

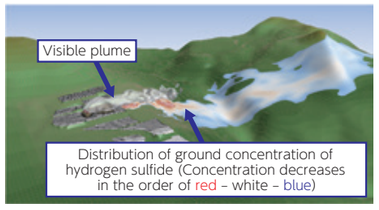
Cold water discharge is heavier than the ambient water and disperses as it sinks to the seabed. CRIEPI has developed a numerical model considering the effects of three-dimensional factors, such as sea bottom topography. Using this model as an alternative to the scaled hydraulic experiments, efficient evaluation of cold water dispersion is possible with high accuracy.



The dispersion of cold water discharge calculated by using CRIEPI's 3D model

◇ Development of an impact prediction method to increase efficiency of environment impact assessments related to renewable energy

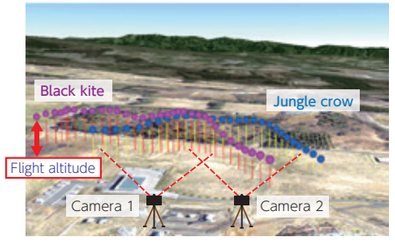
A wind tunnel experiment is essential to predict the dispersion of hydrogen sulfide, which is discharged from the cooling towers of geothermal power plants, and this requires exorbitant costs and time. To solve this issue, CRIEPI has developed a 3D, detailed numerical model capable of making predictions with around the same accuracy as wind tunnel experiments and a PC-compatible simple tool which also conforms to the Ministry for Environment's Guidelines for Rationalization of Replacement Assessments. By substituting conventional wind tunnel experiments, it will be possible to achieve more efficient assessments.



Example of a visualization of visible plume and the distribution of ground concentration calculated using a prediction model for dispersion of hydrogen sulfide

* Joint research with New Energy and Industrial Technology Development Organization (NEDO)

In assessments and post-event monitoring targeting birds in line with wind farm construction, quantitative data relating to birds colliding into turbine blades or changing their flight path to avoid such collisions is required. For this reason, CRIEPI has developed a system that comprehensively and efficiently detects bird flight and quantifies (converts to 3D coordinates) flight paths from long videos taken on two commercially-available cameras. This contributes to better efficiency of bird surveys related to wind power assessments.



Transportable bird observation system

Toru Takeuchi/Hiroki Ono/Yasuo Niida
Biological Environment/Atmospheric and Marine Environment/
River and Coastal Environment Sectors, Environmental Science Research Laboratory

Large-scale Parallel Computer
Utilized for predicting dispersion of warm/cold water discharge into the sea and dispersion of hydrogen sulfide into the atmosphere. This device is utilized in various fields other than those mentioned and is producing many research results.

Application Examples of Research Results

In the evaluation of discharged cold water dispersion in the environmental impact assessment for LNG power plants, the numerical model developed by CRIEPI can provide an alternative to the scaled hydraulic experiments and is anticipated to be beneficial in reducing both cost and time required to perform such evaluations. By using the numerical model to make predictions on the dispersion of hydrogen sulfide in geothermal power assessments, it is possible to reduce the time and cost required for assessments by more than half of the conventional wind tunnel experiments. This method is expected to be incorporated in environment impact assessments of geothermal power plants planned for construction during FY2016. To facilitate the application of this method to bird surveys for wind power assessment or monitoring, CRIEPI is currently collaborating with wind power operators to verify effectiveness through demonstration experiments at operational wind farms.

References: Niida et al., EMECS 11-Sea Coasts XXVI (2016)
Ono et al., The 13th International Conference on the Atmospheric Sciences and Application to Air Quality (2015)
CRIEPI TOPICS Vol.16 (2014)

2–2. Major Research Results -20

Business Management

Proposals for Fair Competition after Full Liberalization of the Retail Electricity Market

Advocate a fair institutional design for price regulation and Antimonopoly Act issues such as product bundling.

Background

The recent full liberalization of the retail electricity market will enable electricity retailers to be creative and offer their customers a diversity of rate plans, and competition is expected to progress. However, there is also a possibility that such progress will be hampered by the continuation of transitional measures such as price regulation and over-regulation by the Antimonopoly Act.
This research has referred to case studies in leading overseas markets to propose a fair institutional design which promotes the progress of market competition in line with the full liberalization of the retail electricity market.

Outline of Results

As a result of focusing our study on judgment concerning the abolishment of price regulation and Antimonopoly Act issues such as price bundling, CRIEPI has put forward the following main proposals.

◇ Evaluation of competition considering price setting by retailers and the switching behavior of consumers

It is difficult to pass judgment regarding the progress of competition and abolishment of price regulations based on market share and the shift in electricity prices alone, and CRIEPI raised the point that, in the case of Europe, a variety of indicators have also been proposed concerning the behavior of business operators and consumers. (Table)

Table An example of indicators used to judge the progress of competition in Europe

Indicators proposed in Japan	Indicators adopted in Europe	Comparison of Japan and Europe Points to note
Share of new entrant retailers, mutual competition between incumbent retailers, share of consumers utilizing market-based price	market share, market concentration index (HHI: Herfindahl-Hirschman Index, CR3: Total of the 3 companies with the top market share, etc.) Percentage of consumers utilizing electricity with regulated prices	In Europe, new entrant retailers are not often distinguished to monitor market share if there are several incumbent retailers.
Shift in electricity prices	Avg. and breakdown of electricity prices, Wholesale electric power price - retail electricity price interrelationship and retail margin	Care must be taken regarding whether it is appropriate to make evaluations amidst continuation of price regulation
Consumer awareness of liberalization	Retailer behavior: Price distribution, type, etc. Consumer behavior: Awareness of liberalization and role of power distribution companies, level of trust towards the energy market, status of price comparison websites, percentage of consumers switching electricity retailers, renegotiation with retailers the consumer is currently under contract with, considering changing electricity retailer, etc.	This serves as material to verify consumer price sensitivity. This is also important for factor analysis of market share and electricity prices and improvement measures. However, suitable indicators must be selected.
Status of smart meter popularization	(not considered much before now)	In Europe, rather than the actual introduction of smart meters, there is a movement to evaluate innovation such as added-value services which utilize smart meters and demand response.

◇ Judgment on abolishing regulations with consideration to the adverse effects of price regulation

When passing judgment on whether or not to abolish price regulation, it is necessary to consider the adverse effects of price regulation in addition to evaluating the status of competition. Particularly in the case of Japan, an understanding of the adverse effects created by the three-block IBT used for price regulation is essential. Three-block IBT is set up so that households with high power consumption are charged a higher rate, however CRIEPI raised the point that if the switching to market-based prices happens without abolishing the three-block IBT element of price regulation it may result in a deterioration of balance of revenue and expenditure for incumbent utilities and create disadvantageous competition conditions.

◇ Reduction of risk concerning over-regulation in accordance with the Antimonopoly Act

In order to demonstrate how the Antimonopoly Act should be applied to the bundled discounts after full liberalization of retail electricity, CRIEPI investigated the discussions concerning similar issues in the United States Antitrust Law. As a result, in order not to curb price competition, CRIEPI showed that regulations should not only be restricted in cases where there are obvious adverse effects, as there is a risk that the Guidelines for Proper Electric Power Trade, which states that the illegality of price bundling discount should be judged in the same way as predatory pricing, could be over-regulation.

Three-block IBT (increasing block tariff)
A system whereby electricity prices are low for households with minimal electricity consumption, middle-of-the-range for households with average electricity consumption and high for households with high consumption. This system is applied to the regulated electricity prices for households.

Guidelines for Proper Electric Power Trade
A document expressing guidelines for electric power trade to achieve an electric power market which promotes fair competition.

Yoshikuni Sato/Hisanori Goto
Utilities Policy and Economic Analysis Sector, Socio-economic Research Center

Application Examples of Research Results

CRIEPI has pointed out the issues related to overlapping regulations by the Electricity and Gas Market Surveillance Commission and the Japan Fair Trade Commission, as well as Antimonopoly Act issues such as price bundling discount and long-term contract discount (findings published in an article featured in The Denki Shimbun and research reports of academic societies). Moreover, we also demonstrated that continuation of price regulation had the potential to hamper the progress of competition and discussed the topic of liberalization in a seminar aimed at consumers, with the media and so on.

References: Goto, CRIEPI Report Y15019 (2016)
Sato, CRIEPI Report Y15015 (2016)

2–2. Major Research Results -21

Business Management

Proposal for Design of a System Responding to the Issues Arising with the Large-Scale Introduction of Solar Photovoltaic

Evaluate issues arising from the large-scale introduction of renewable energy and conduct study to establish countermeasures thereof

Background

In Europe, solar photovoltaic(PV) has been introduced in large scale due to initiatives such as FIT (feed-in tariff for renewable energy) and this has led to issues such as a fall in wholesale electric power price and poorer economic viability of power sources for supply/demand regulation necessary to secure stable supply. In other words, Europe is now facing a “missing money” problem. Moreover, the large-scale introduction of PV for self-consumption has caused the demand for commercial power to decline, and there is concern that this will lead to increased electricity prices, thus causing demand for commercial power to fall even further and triggering a negative cycle. CRIEPI has investigated and analyzed case studies from countries leading the way in this area regarding the issues associated with large-scale introduction of renewable energy and we will use our findings to draft suggestions for Japan.

Outline of Results

CRIEPI quantitatively evaluated the impact of large-scale PV introduction on thermal power generation facilities, as well as investigated the impact on power distribution facility costs and countermeasures thereof.

◇ Quantitative evaluation of the missing money problem

Using the supply/demand operation simulator developed by CRIEPI, we tentatively calculated the balance-of-payments (BOP) of thermal power generation in the case that the outlook for long-term energy supply/demand (year 2030) actually materialized. Compared with FY2014, the tentatively calculated BOP had worsened by approximately 8 trillion yen per annum (Fig. 1), and showed that there was a possibility of not being able to secure capital cost, operational maintenance cost and fuel costs for 18% of thermal power generation facilities required to achieve a stable power supply from the income of electricity power sales. CRIEPI is using these results in the design of a system for post-electricity system reform.

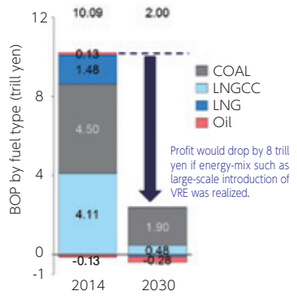


Fig. 1 Change in the BOP of thermal power generation facilities

◇ Quantitative evaluation of the fairness of consumer burden for power distribution equipment costs depending on whether or not roof-top PVis installed

In light of the fact that in Western countries, the unfairness of power distribution facility cost burden by consumers is corrected by considering whether or not the consumer has roof-top PV installed, CRIEPI gathered and analyzed relevant information and provided it to individual electric power utilities (Table 1).

Table 1 An example of retail price systems to correct unfairness

Price systems	Overview of retail price systems	Benefits of price system introduction	Points to be cautious of regarding price system introduction
Consumption-based price system	A price system proportional to the amount of electric power drawn from the distribution network	Consumers who draw relatively more electric power from the consumption network pay a larger share of facility maintenance costs	If consumers withdraw from the power distribution network there is an increased risk that costs will not be recovered
Capacity price system	A price system reflecting the maximum electric power amount drawn from the power distribution network	Less risk of inability to recover costs as costs can be recovered reflecting facility capacity, irrespective of the amount of electric power used	Cost distribution must consider the time of day the maximum demand occurs in the system and the time of day maximum demand occurs for individual consumers
Fixed price system	Consumers who draw from the power distribution network are charged a fixed rate	Less risk of inability to recover costs as costs can be recovered evenly from consumers connected to the power grid system	Needs to be designed to avoid excessive cost recovery when combined with a consumption-based price system
Time-of-day-based power system	Consumption-based price system reflecting the supply/demand status of the power distribution network	For the short-term, this system would help reduce risk of being unable to recover costs due to the existence of times in which higher electricity prices applied. For the long-term, this system is anticipated to have the effect of minimizing equipment costs	This would be ineffective in minimizing equipment costs if there were no consumers who could respond to price

Capacity mechanism

A system whereby a certain amount of money is paid based on an evaluation of the value (kW value) of maintaining electricity supply capacity (kW)

Kenji Asano
Energy System Analysis, Socio-economic Research Center

Application Examples of Research Results

CRIEPI conducted a detailed quantitative evaluation of the missing money problem. Moving forward, we propose evaluating options regarding the design of systems, such as the capacity mechanism, to find the equipment capacity necessary for stable electricity supply.
Moreover, CRIEPI provided information to electric power utilities on the debate surrounding corrective measures of the unfairness of power distribution equipment costs bore by consumers depending on the existence of PV equipment in Western countries. Moving forward, we will evaluate countermeasures for mid-to-long term issues of the power distribution equipment plan in accordance with the large-scale introduction of renewable energy. This evaluation will look at topics such as plans to strengthen power distribution which consider future uncertainties, etc. and based on this evaluation, CRIEPI will present its proposals accordingly.

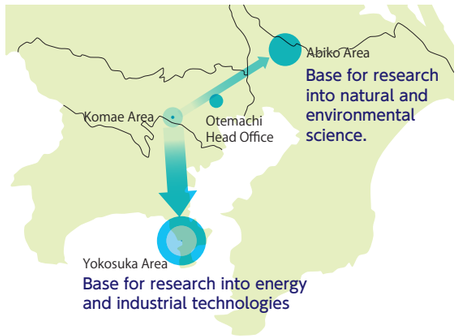
References: Asano et al., CRIEPI Report Y15022 (2016)
Brunekreeft et al.,"Evaluation of Strategy of Power Generation Business under Large-Scale Integration of Renewable Energy" Bremen Energy Working Papers No. 23, (2016)
Furusawa et al., CRIEPI Report Y15024 (2016)

3. Organization Management

Aiming for future development as a research institute, CRIEPI is developing two of its research bases and reducing fixed general running costs in order to establish a sustainable business operation structure.

■ Developing of Research Bases

・In an effort to create a research environment with a focus on strengthening collaboration between various subject fields as well as reducing general running costs, CRIEPI is concentrating its operations into the two areas at Yokosuka and Abiko. Yokosuka will be the research base for energy and industrial technologies, while Abiko will be the research base for natural and environmental science. In fiscal 2015, as part of preparations to relocate the researchers and equipment at our Komae Area to the Yokosuka Area, CRIEPI engaged in the construction of a new research building (planned for completion in July 2016) and a materials analysis building (planned for completion in May 2017), as well as made preparations such as organizing and securing office space for researchers and installation space for equipment to be transplanted.



Status of Research Base Upgrades

■ Information Dissemination

・To mark one year since the establishment of the Nuclear Risk Research Center (NRRC), CRIEPI hosted a Nuclear Risk Research Center Symposium 2015 in September 2015, which attracted around 450 participants. In addition to an overview of the Center's activities, two panel discussions were held on the topics of "Expectations towards the NRRC's activities" and "The concept of risk and corresponding rational solutions to safety issues of nuclear power facilities". Panelists consisted of business operators, members of regulatory bodies, local government representatives, media figures and academic experts and lively discussion was had, including various opinions and questions from the audience.

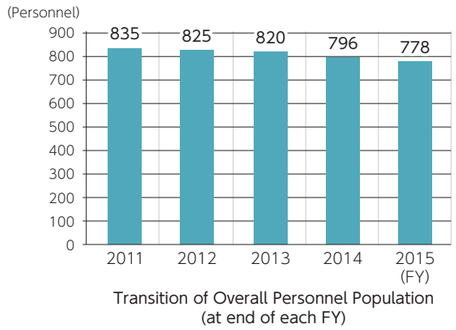
Statement of Dr. George Apostolakis
Head, Nuclear Risk Research Center

■ Cost Reduction and Streamlining of Operations

・CRIEPI made a concerted effort to further reduce costs incurred in both the research and administrative aspects in ways such as promoting competitive ordering in procurement operations, being creative regarding ordering methods to suit the specific project, detailed investigations into specifications and the review of operational task processes in indirect departments.

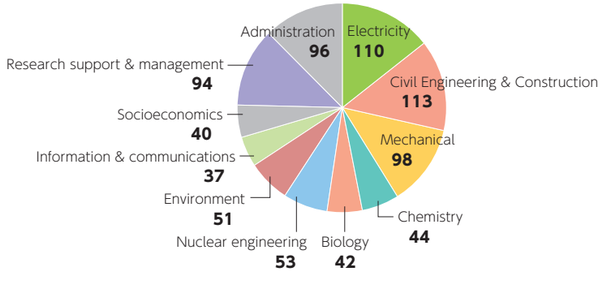
■ Personnel

・Our personnel plan of reducing the CRIEPI workforce population of 845 in fiscal 2011 to 800 by fiscal 2015 was achieved early at the end of fiscal 2014. In preparation to establish a sustainable business operations structure, we must further reduce labor cost, which is one of our fixed running costs, therefore we have revised our personnel plan to reduce the figure of 800 at the start of fiscal 2015 to around 750 by the end of fiscal 2017. As part of this effort, we have reduced the number of personnel assigned from other institutions and dispatched personnel to external parties. Consequently, the overall number of personnel working at CRIEPI at the end of this financial term was 778.



Transition of Overall Personnel Population
(at end of each FY)

・Regarding our researchers, in order to systematically develop professionals with a high level of expertise to support the basic technology of the future electricity business, CRIEPI is constantly searching for new recruits based on a hiring plan formulated with consideration to the research strategies of each subject field and regeneration of basic technology.



End of fiscal 2015　Personnel configuration by subject field

While ordinary profit was around the same as last year, the ordinary expenses of labor and general running costs were both less than last year, resulting in less ordinary decrease for the current period compared with last year.

Net Assets Variation Statement

(Unit: 100 mill yen)

Change in general net assets

	FY2015	FY2014	Difference		FY2015	FY2014	Difference
Ordinary expenses	281.9	299.9	△ 18.0	Ordinary revenue	276.1	278.1	△ 1.9
Labor costs	94.6	100.3	△ 5.6	Ordinary benefit received	235.6	235.6	–
General running costs	187.2	199.6	△ 12.3	Operating revenue	37.3	39.3	△ 1.9
				Other revenue	1.2	1.2	0.0
				Transfer from designated net assets	1.9	1.9	0.0
				Transfer to ordinary profit decrease for the current period	5.7	21.8	△ 16.0
				General net asset decrease for the current period	5.6	22.1	△ 16.5

Change in designated net assets

	FY2015	FY2014	Difference		FY2015	FY2014	Difference
Transfer to general net assets	1.9	2.1	△ 0.2	Subsidy etc. received	1.0	0.7	0.2
				Decrease in designated net assets for current period	0.9	1.4	△ 0.5
				Decrease in net assets for current period	6.5	23.6	△ 17.0

Balance Sheet

(Unit: 100 mill yen)

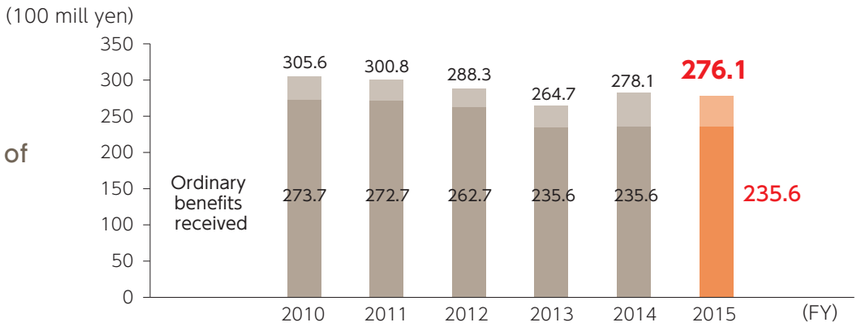
Assets

	FY2015	FY2014	Difference
Current assets	44.4	68.1	△ 23.6
Fixed assets	472.9	490.5	△ 17.5
Total assets	517.3	558.6	△ 41.2

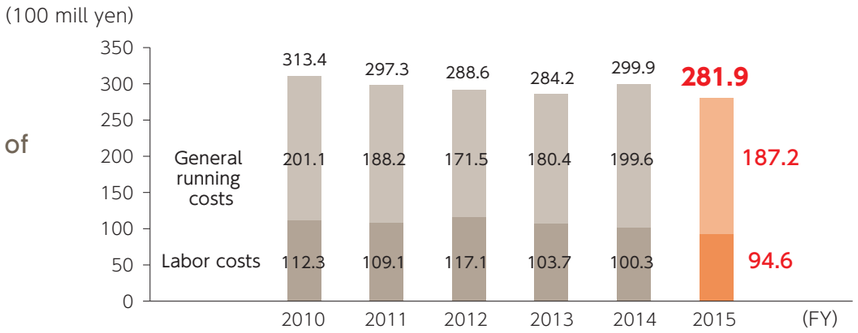
Liabilities

	FY2015	FY2014	Difference
Current liabilities	42.3	69.5	△ 27.1
Fixed liabilities	94.0	101.6	△ 7.5
Total liabilities	136.4	171.1	△ 34.7
Net assets			
Designated net assets	5.1	6.0	△ 0.9
General net assets	375.8	381.4	△ 5.6
Total net assets	380.9	387.5	△ 6.5

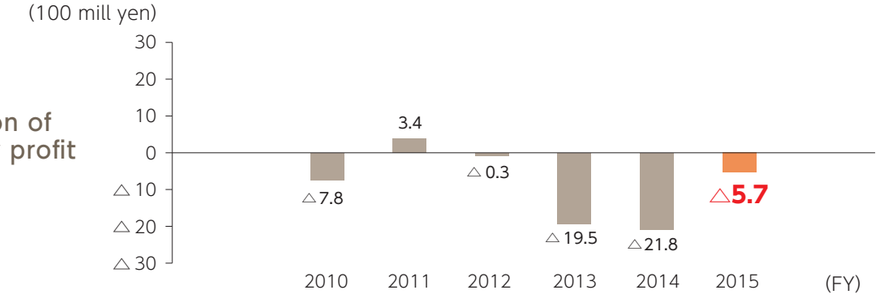
Transition of ordinary revenue



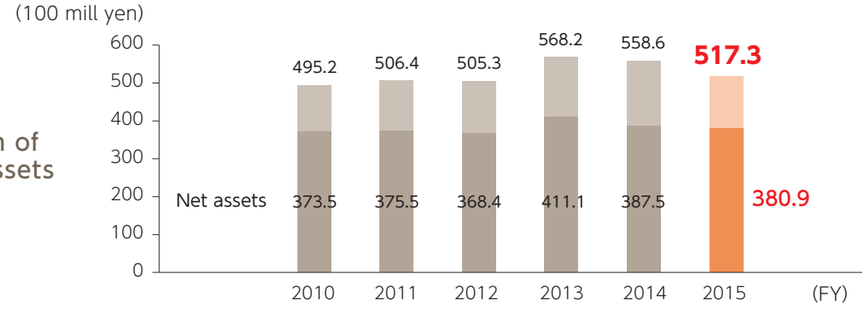
Transition of ordinary expenses



Transition of ordinary profit



Transition of overall assets



2. Financial Statement

Balance Sheet

As of March 31, 2016

(Unit: yen)

Account	Current fiscal year	Previous fiscal year	Change
Ⅰ Assets			
1. Current assets			
Cash and deposit	1,912,295,724	4,559,029,175	△ 2,646,733,451
Accounts receivable	2,292,810,542	2,093,724,144	199,086,398
Suspense payments	216,594,784	124,531,714	92,063,070
Advance payments	23,743,060	36,075,915	△ 12,332,855
Total current assets	4,445,444,110	6,813,360,948	△ 2,367,916,838
2. Fixed assets			
(1) Special assets			
Buildings	182,014,923	199,044,490	△ 17,029,567
Facilities attached to buildings	17	90	△ 73
Structures	1,254,848	1,506,426	△ 251,578
Machine and equipment	364,016,210	450,562,924	△ 86,546,714
Tools and furniture	42,055,863	52,191,042	△ 10,135,179
Lump-sum depreciable assets	1,494,158	1,276,709	217,449
Intangible fixed assets	5,552,456	8,325,379	△ 2,772,923
Special assets for retirement lump sum grants benefits package allowance	3,435,900,000	3,435,900,000	0
Special assets for acquisition of research facilities reserves	3,050,000,000	3,200,000,000	△ 150,000,000
Special assets for special project reserves	510,000,000	910,000,000	△ 400,000,000
Special assets for base establishment	3,995,408,033	5,063,494,033	△ 1,068,086,000
Total special assets	11,587,696,508	13,322,301,093	△ 1,734,604,585
(2) Other fixed assets			
Land	8,505,971,179	8,553,518,118	△ 47,546,939
Buildings	10,252,627,587	10,458,325,295	△ 205,697,708
Facilities attached to buildings	3,150,034,548	3,337,553,859	△ 187,519,311
Structures	1,260,143,361	1,301,936,553	△ 41,793,192
Machine and equipment	7,278,748,477	7,920,162,857	△ 641,414,380
Tools and furniture	1,776,705,958	1,781,777,579	△ 5,071,621
Rolling stock and vehicles	34,574,209	35,055,189	△ 480,980
Lump-sum depreciable assets	49,573,608	59,008,061	△ 9,434,453
Intangible fixed assets	698,615,565	710,378,781	△ 11,763,216
Construction in progress accounts	2,699,182,150	1,572,937,930	1,126,244,220
Total other fixed assets	35,706,176,642	35,730,654,222	△ 24,477,580
Total fixed assets	47,293,873,150	49,052,955,315	△ 1,759,082,165
Total assets	51,739,317,260	55,866,316,263	△ 4,126,999,003
Ⅱ Liabilities			
1. Current liabilities			
Accounts payable	3,914,547,169	6,603,858,643	△ 2,689,311,474
Deposits received	80,410,179	80,243,489	166,690
Advances received	2,763,544	23,925,345	△ 21,161,801
Accrued bonus	240,000,000	244,000,000	△ 4,000,000
Total current liabilities	4,237,720,892	6,952,027,477	△ 2,714,306,585
2. Fixed liabilities			
Allowance for retirement benefits for directors	483,000,000	527,000,000	△ 44,000,000
Accrued retirement benefits for employees	8,922,000,000	9,635,000,000	△ 713,000,000
Total fixed liabilities	9,405,000,000	10,162,000,000	△ 757,000,000
Total liabilities	13,642,720,892	17,114,027,477	△ 3,471,306,585
Ⅲ Net assets			
1. Designated net assets			
Special benefits	311,069,978	360,363,361	△ 49,293,383
Subsidies	120,262,827	152,692,612	△ 32,429,785
Donations, etc.	82,153,686	95,324,897	△ 13,171,211
Total designated net assets	513,486,491	608,380,870	△ 94,894,379
(including appropriation to special assets)	(513,486,491)	(608,380,870)	(△ 94,894,379)
2. General net assets	37,583,109,877	38,143,907,916	△ 560,798,039
(including appropriation to special assets)	(7,638,310,017)	(9,278,020,223)	(△ 1,639,710,206)
Total net assets	38,096,596,368	38,752,288,786	△ 655,692,418
Total of liabilities and net assets	51,739,317,260	55,866,316,263	△ 4,126,999,003

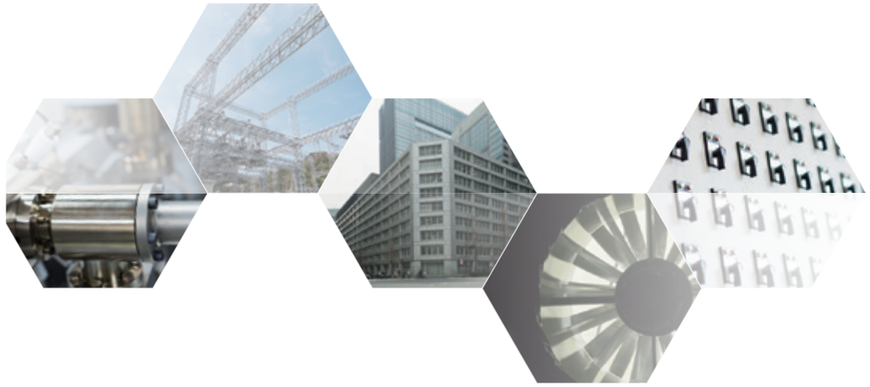
Statement of Changes in Net Assets

From April 1, 2015 to March 31, 2016

(Unit: yen)

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	23,565,000,000	23,565,000,000	0
[2] Operating revenue	(3,736,470,427)	(3,934,904,356)	(△ 198,433,929)
Consigned research operating revenue	2,774,762,795	2,595,035,679	179,727,116
Other operating revenue	961,707,632	1,339,868,677	△ 378,161,045
[3] Other revenue	(120,808,812)	(120,747,952)	(60,860)
Interest received	16,618,198	7,605,705	9,012,493
Facility usage fee received	79,257,258	78,020,293	1,236,965
Miscellaneous revenue	24,933,356	35,121,954	△ 10,188,598
[4] Transfer from designated net assets	197,105,186	196,474,301	630,885
Total ordinary revenue	27,619,384,425	27,817,126,609	△ 197,742,184
(2)Ordinary expenses			
[1] Operating expenses			
Labor	(8,598,452,383)	(8,994,556,998)	(△ 396,104,615)
Salary and benefit	6,984,078,741	7,001,720,008	△ 17,641,267
Retirement benefit	592,824,028	1,030,040,436	△ 437,216,408
Welfare	1,021,549,614	962,796,554	58,753,060
General expenses	(18,032,648,591)	(19,195,543,266)	(△ 1,162,894,675)
Supplies	1,918,375,604	1,840,610,215	77,765,389
Printed materials	360,229,217	345,422,554	14,806,663
Utilities	855,463,238	942,168,597	△ 86,705,359
Outsourcing costs	5,742,133,729	6,593,060,516	△ 850,926,787
Joint research contribution	647,060,220	799,176,286	△ 152,116,066
Repair expenses	1,443,438,910	1,503,189,521	△ 59,750,611
Rent	317,241,433	293,212,280	24,029,153
Taxes and dues	493,542,441	509,600,453	△ 16,058,012
Travel and transport	677,465,509	675,361,319	2,104,190
Communication and transportation	78,358,443	75,685,649	2,672,794
Other	607,438,831	557,618,728	49,820,103
Depreciation	4,891,901,016	5,060,437,148	△ 168,536,132
Subtotal of operating expenses	26,631,100,974	28,190,100,264	△ 1,558,999,290
[2] Administrative expenses			
Labor	(870,199,630)	(1,037,382,202)	(△ 167,182,572)
Director remuneration	158,070,000	142,100,000	15,970,000
Salary and benefits	540,360,361	580,315,089	△ 39,954,728
Retirement benefit	41,891,202	85,929,699	△ 44,038,497
Welfare	71,358,067	142,037,414	△ 70,679,347
Transfer of allowance for director retirement benefits	58,520,000	87,000,000	△ 28,480,000
General expenses	(693,950,383)	(770,637,284)	(△ 76,686,901)
Supplies	5,387,419	22,093,545	△ 16,706,126
Printed materials	43,234,680	31,288,987	11,945,693
Utilities	6,073,183	24,590,796	△ 18,517,613
Outsourcing costs	110,451,038	120,876,881	△ 10,425,843
Repair expenses	11,368,418	9,093,823	2,274,595
Rent	338,806,563	341,356,242	△ 2,549,679
Taxes and dues	41,315,458	47,465,917	△ 6,150,459
Travel and transport	22,438,327	20,173,619	2,264,708
Communication and transportation	7,775,172	7,800,548	△ 25,376
Other	75,232,913	100,774,824	△ 25,541,911
Depreciation	31,867,212	45,122,102	△ 13,254,890
Subtotal of administrative expenses	1,564,150,013	1,808,019,486	△ 243,869,473
Total Ordinary expenses	28,195,250,987	29,998,119,750	△ 1,802,868,763
Current ordinary profit	△ 575,866,562	△ 2,180,993,141	1,605,126,579
2.Non-recurring change			
(1)Non-recurring profit			
[1] Gain on donation of fixed assets			
Gain on donation of facilities	10,380,000	21,706,204	△ 11,326,204
[2] Gain on sale of fixed assets			
Gain on sale of equipment, etc.	107,777,836	270,169	107,507,667
[3] Transfer from designated net assets	2,103,177	23,241,748	△ 21,138,571
Total non-recurring profit	120,261,013	45,218,121	75,042,892
(2)Non-recurring expenses			
[1] Loss on retirement of fixed assets			
Loss on retirement of facilities, etc.	105,192,490	83,721,772	21,470,718
[2] Loss on sale of fixed assets			
Loss on sale of facilities, etc.	0	161,447	△ 161,447
Total non-recurring expenses	105,192,490	83,883,219	21,309,271
Current non-recurring change	15,068,523	△ 38,665,098	53,733,621
Current general net assets change	△ 560,798,039	△ 2,219,658,239	1,658,860,200
General net assets beginning balance	38,143,907,916	40,363,566,155	△ 2,219,658,239
General net assets final balance	37,583,109,877	38,143,907,916	△ 560,798,039
Ⅱ Designated net assets change			
[1] Subsidies received, etc.			
Subsidies received	63,997,783	35,621,840	28,375,943
[2] Gain on donation of fixed assets			
Gain on donation of facilities	40,316,201	43,249,645	△ 2,933,444
[3] Transfer to general net assets	199,208,363	219,716,049	△ 20,507,686
Current designated net assets change	△ 94,894,379	△ 140,844,564	45,950,185
Designated net assets beginning balance	608,380,870	749,225,434	△ 140,844,564
Designated net assets final balance	513,486,491	608,380,870	△ 94,894,379
Ⅲ Net assets final balance	38,096,596,368	38,752,288,786	△ 655,692,418

Facts & Figures



Research Reports / Research Papers / Intellectual Property

This section introduces key data on CRIEPI's FY2015 activities, including the number of report publications, number of paper presentations and number of patent applications.

Fig. 1 Transition in number of reports published

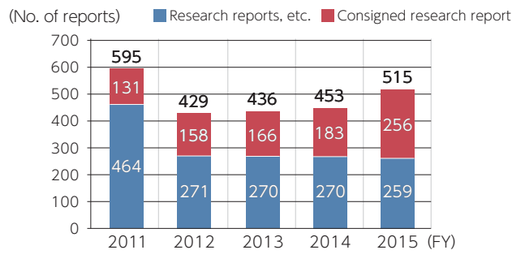


Fig. 2 Breakdown of no. of FY2015 reports by subject field

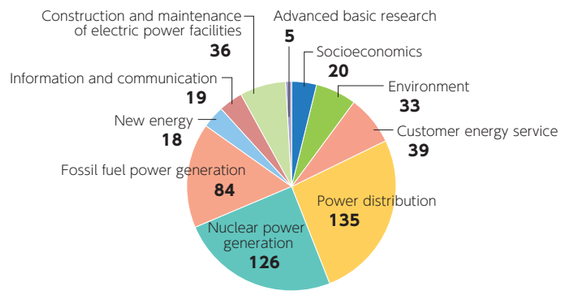


Fig. 3 Transition in no. of papers presented

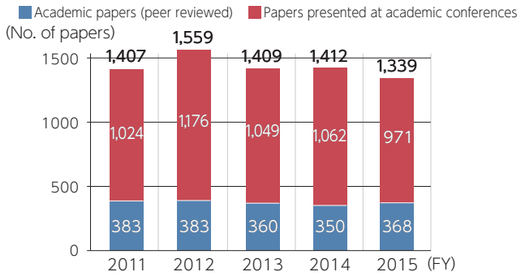


Fig. 4 Breakdown of no. of FY2015 papers by subject field

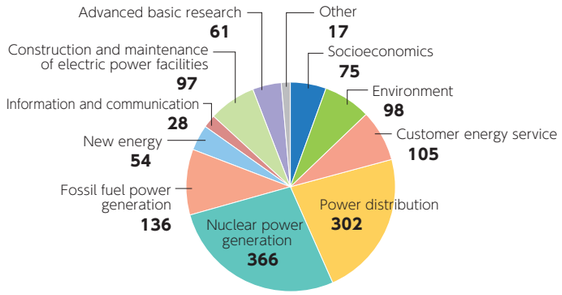


Fig. 5 Breakdown of no. of FY2015 patent applications by subject field

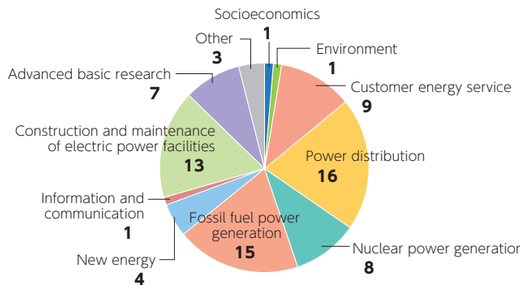


Fig. 6 Breakdown of no. of FY2015 patent registrations by subject field

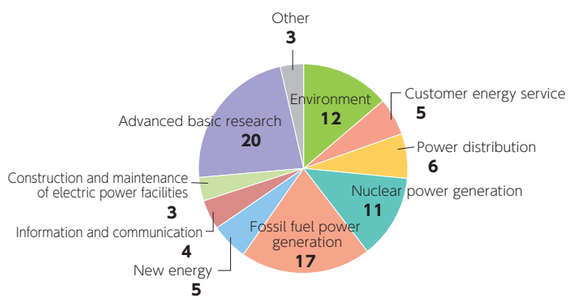
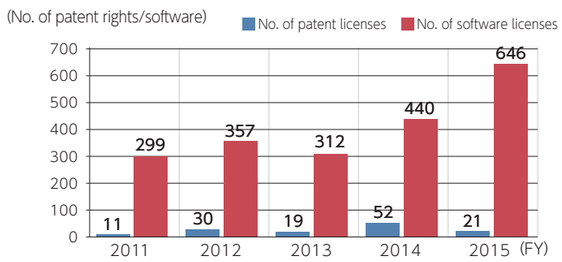
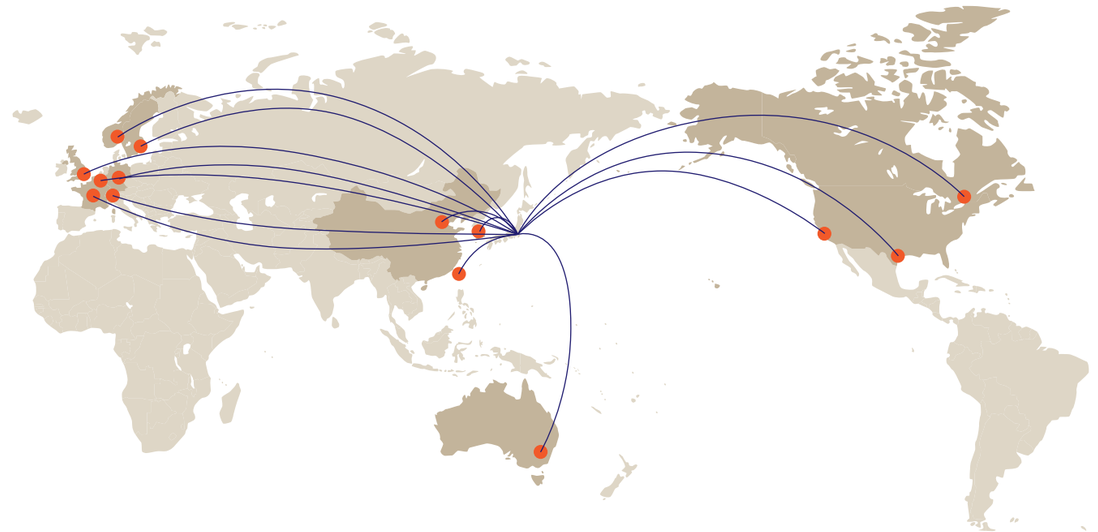


Fig. 7 Transition of patent /software licenses



Research Network

With the aim of identify the trend of the most advanced of R&D in the energy filed as well as strengthening and enhancing our research network, CRIEPI proactively promotes research cooperation agreements and engages in joint research with international partners whom uphold high technological 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 Power Exchange (KPX)
- Korea Hydro and Nuclear Power Company Central Research Institute (KHNP-CRI)
- Korea Atomic Energy Research Institute (KAERI)
- Korea Institute of Nuclear Security (KINS)
- Korea University
- Taiwan Power Company (TPC)

North America (including neighboring countries)

- Electric Power Research Institute (EPRI)
- Southwest Research Institute (SwRI)
- Idaho National Laboratory (INL)
- National Center for Atmospheric Research (NCAR)
- United States Department of Energy (DOE)
- United States Nuclear Regulatory Commission (USNRC)
- National Institute of Standards and Technology (NIST)
- Atomic Energy Canada Limited (AECL)

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
- Federal Institute for Materials Research and Testing (BAM), Germany
- Institute for Transuranium Elements (ITU), Germany
- Gesellschaft für Nuklear-Service mbH (GNS), Germany
- Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS), Germany
- Jacobs University Bremen, Germany
- 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

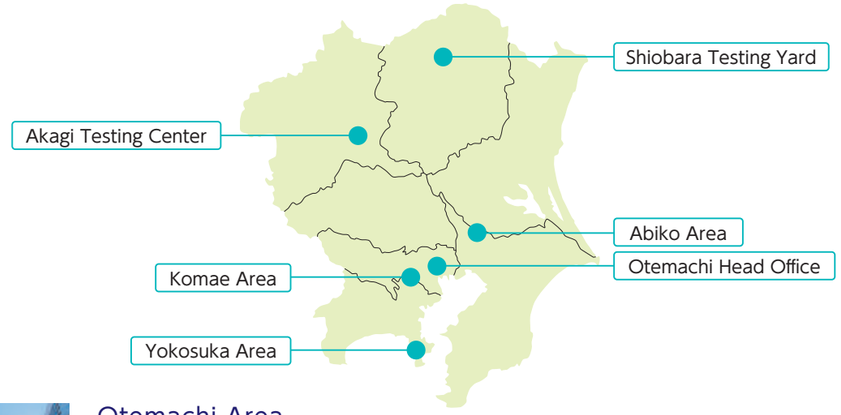
Participation in International Organizations

- 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

Komae Area

System Engineering Research Laboratory*, Nuclear Technology Research Laboratory*, Komae Operation & Service Center
2-11-1 Iwadokita, Komae-shi, Tokyo 201-8511 TEL: +81-3-3480-2111

Abiko Area

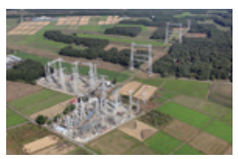
Civil Engineering Research Laboratory, Environmental Science Research Laboratory, Abiko Operation & Service Center, Procurement Center
1646 Abiko, Abiko-shi, Chiba 270-1194 TEL: +81-4-7182-1181

Yokosuka Area

System Engineering Research Laboratory*, Nuclear Technology Research Laboratory*, Electric Power Engineering Research Laboratory, Energy 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

Akagi Testing Center

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

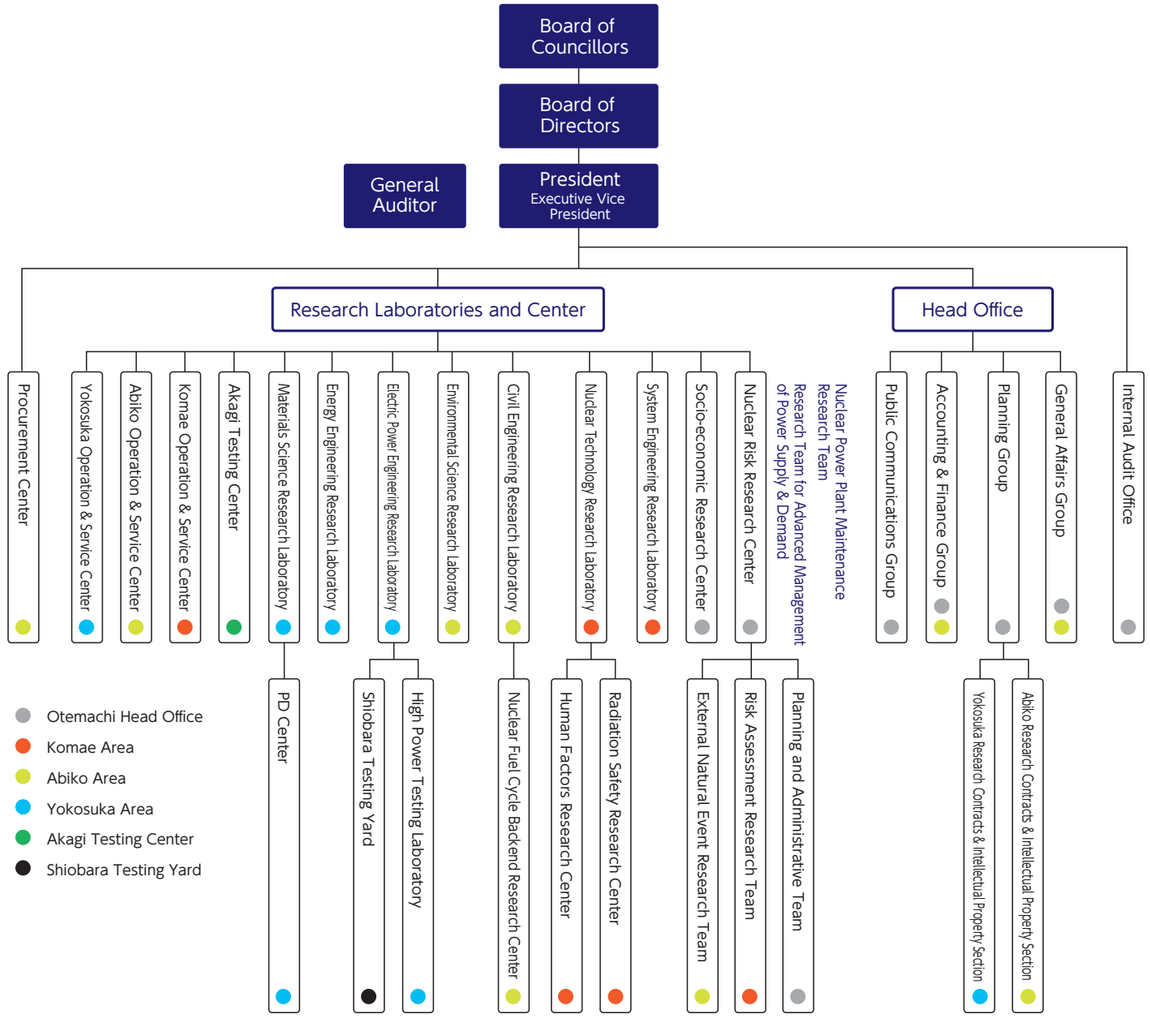


Shiobara Testing Yard

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

* Komae Area is scheduled to be transferred to the Yokosuka Area in FY2016

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

The Nuclear Risk Research Center (NRRC) was established in September 2014 with the goal of autonomous safety improvement of nuclear power plants by electrical power utilities. Through close collaboration with business operators, CRIEPI is advancing R&D initiatives aimed at risk reduction, including research into low-frequency external natural events, such as large-scale natural disasters, Probabilistic Risk Assessment (PRA), decision-making utilizing risk information and development of the latest risk communication techniques.

Special Research Teams

Special Research Teams are mechanisms for the cross-laboratory promotion of specific research projects. In FY2015, two research teams, the Nuclear Power Plant Maintenance Research Team (research contributing to maintenance activities to maintain the safety of nuclear power plants) and the Research Team for Advanced Management of Power Supply & Demand (research for the optimization of electrical power/energy supply/demand and the creation of new values related to electrical power), demonstrated their combined strength and engaged in research activities.

Keyword Index

This Annual Report features the key words and terminology with explanations in I-2. Research Reports.

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.