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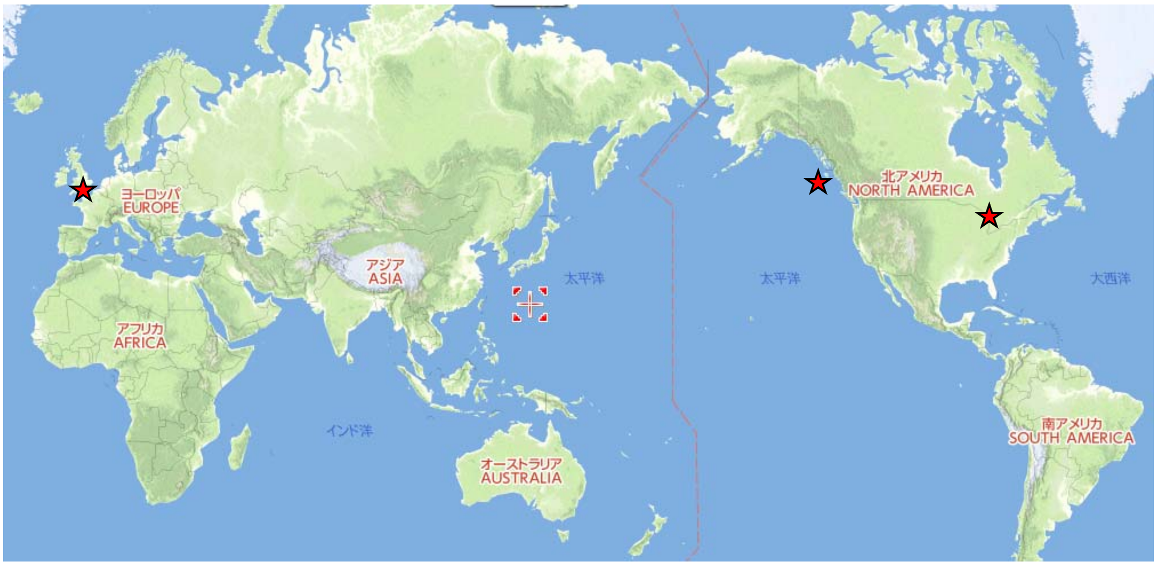
What's New in the World of Superconductivity

초전도 뉴스 −세계의 동향−

超导新闻 −世界的动向-

chāo dǎo xīnwén - shìjiè de dòngxiàng-

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC



★News sources and related areas in this issue

▸Power Application 전력응용 电力应用 [diànlì yìngyòng]

2 SFCL Systems Ordered in UK

Nexans (April 1, 2014)

Western Power Distribution (WPD), the network operator, is future-proofing the power distribution network in Birmingham in the UK, by installing two Nexans superconducting fault current limiters. The order covers the design, fabrication, and permanent installation of the innovative devices, including the associated switchgear, and has a total value of approximately EUR 2.6 million. This is Nexans third UK order for superconducting fault current limiters and the largest to date. Installation of the pioneering technology in Birmingham's network is part of the FlexDGrid project, which aims at future proofing existing networks to accept more electricity generated from sustainable resources. The new equipment helps achieve this objective by enabling higher power feed-in from distributed or renewable electricity sources. In many places

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this will remove the need for network expansion with new substations.
EUR 20 million obtained from the Low Carbon Networks Fund, a national initiative for reducing carbon dioxide emissions, finances the FlexDGrid project. The project objective is to mitigate faults, improve understanding of their causes, and reduce fault current levels. Measuring systems to monitor fault current levels are being installed in 10 substations, and five stations will additionally be equipped with current limiting technology. The Nexans fault current limiter is the only superconductor device that will be used and will be deployed in two of the five substations. The two Nexans limiters - for the Chester Street and Bournville substations in Birmingham - are designed to operate at a voltage of 11 kV with a nominal current of 1,600 A (Chester Street) and 1,050 A (Bournville).

Source: "Nexans supplies two superconducting fault current limiters for permanent use on Birmingham's distribution network
Nexans Press Release (April 1, 2014)
URL:http://www.nexans.co.uk/eservice/UK-en_GB/navigatepub_149242_-33580/Nexans_supplies_two_superconducting_fault_current_.html
Contact: Angeline.Afanoukoe@nexans.com

2G Wire Sales for SFCL Products

SuperPower Inc. (April 30, 2014)

SuperPower Inc. supplied its second generation (2G) high temperature superconducting (HTS) wire to Applied Materials, Inc. for the superconducting fault current limiter (SFCL) system to be installed for on-grid testing at the Knapps Corners substation owned and operated by Central Hudson Gas and Electric Corp. (Central Hudson) in New York. Applied Materials, one of many technology leaders involved in the energy industry, announced on April 15, 2014 that it had completed the assembly of a SFCL system for installation and on‐grid testing at a substation owned and operated by Central Hudson. Other team members include the New York State Energy Research and Development Authority (NYSERDA), Three‐C Electrical Co., as well as Central Hudson and SuperPower. System testing and evaluation is set to commence in May 2014 and will continue for one year. Performance data will be provided to the New York State Public Service Commission.

Mr. Yusei Shirasaka, President and Treasurer of SuperPower, commented, "We are very excited to be working with Applied Materials on the SFCL project. The decline of the U.S. energy infrastructure, as well as that of the world, is out‐pacing our ability to repair or replace the dated technology. Utilizing superconducting technology for energy applications, such as the SFCL, not only addresses the need for replacing the outdated equipment but also allows us to address the ever increasing demand for more power."

SuperPower also provided the second‐generation high temperature superconducting (2G HTS) wire for the European Union (EU) collaboration program, called Project ECCOFLOW. The ECCOFLOW SFCL was designed, built and tested by a team of fifteen European organizations that include five European utility companies.

Source: "SuperPower wire further advances the future commercialization of SFCLs"
SuperPower Press Release (April 30, 2014)
URL:
http://www.superpower-inc.com/content/superpower-wire-further-advances-future-commercialization-sfcls
Contact: Mickey Lavicska, mlavicska@superpower-inc.com

▸Wire 선 재료 線材料 [xiàn cáiliào]

MgB_2 Large Current Cable of 20 kA

CERN (April 14, 2014)

In the framework of the High-Luminosity LHC project, experts from the CERN Superconductors team recently obtained a world-record current of 20 kA at 24 K in an electrical transmission line consisting of two 20-metre long cables made of magnesium diboride (MgB_2) superconductor. "The test is an important step in the development of cold electrical power transmission systems based on the use of MgB_2," says Amalia Ballarino, head of the Superconductors and Superconducting Devices section at CERN. The result was achieved at a temperature of 24 K (about -249 °C) using a test station that was purpose-designed and assembled at CERN. The temperature is kept homogeneous over the 20-metre length of the line by a forced flow of helium gas. Following intense development, the full 2 x 20-metre long MgB_2 superconducting line was successfully powered to the world-record current of 20 kA, showing that this technology has great potential for the transmission of electrical power.

In the high-luminosity LHC configuration, the power converters supplying current to the superconducting magnets will be moved from their present location in the LHC tunnel to the surface or to radiation-free underground areas and they will be connected to the magnets through a new cold powering system.

Ballarino also comments, "The development was aimed at testing a 20 kA DC line operated at 20 K (-253 °C), which was also conveniently close to the CERN requirement for powering the magnets. The result of our tests is a demonstration that such high-current cables can be operated at and above the temperature of liquid hydrogen, and that the basic related technology is now proven."

Source: CERN Press Release (April 14, 2014)
URL:http://home.web.cern.ch/about/updates/2014/04/world-record-current-superconductor

Achieved 500A/cm for Long 2G Wire

Superconductor Technologies Inc. (April 29, 2014)

Superconductor Technologies Inc. (STI) successfully completed a full pilot production run of Conductus® wire achieving a minimum current of 500 Amps per centimeter (A/cm) width at 77k. The 100M equivalent of 4mm-wire was achieved by processing 50M meters of 10mm- wide wire.

Adam Shelton, STI's VP of Marketing and Product Line Management, stated, "Achieving our pilot production target of 500 A/cm, in a run that yielded 100 % of the design capacity of the systems, is a

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significant milestone that further demonstrates the effectiveness of STI's proprietary RCE-CDR process. High performance 500 A/cm wire is optimum for many of our customers as they look to increase the value proposition of their applications by either reducing size and weight, or substantially increasing other functionality."

The key remaining deliverable to address for customers is capacity. Customer projects utilize large volumes of wire per device, ranging from 100s of meters for a small magnet to 100,000s of meters for a medium size transmission power cable project. STI's strategic plan is an initial capacity of 750 km per year. The production scale RCE-CDR equipment was designed and the assemblies were ordered in late 2013. Plan is to complete the installation of a production machine capable of 1 km lengths and 750 km per annum at the end of the second quarter.

Source: "Superconductor Technologies Inc. Achieves Conductus Wire Performance Milestone
Superconductor Technologies Inc. Press Release (April 29, 2014)
URL:http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1923310&highlight

▸Basics 기초 基础[jīchǔ]

Bi2212wire and Pinning

North Carolina State University (Apr 17, 2014)

Researchers at North Carolina State University found that nanoscale impurities ranging from 1.2 to 2.5 nm wide, appear to improve Bi2212's performance as a superconductor. "The nanoscale impurities, or defects, serve as centers for 'pinning' magnetic flux in place", Golsa Naderi, a Ph.D. student at NC State says. Without those pinning centers, the magnetic vortices can move, creating resistivity and impeding superconductivity when a magnetic field is present.

Researchers also found that large-scale impurities, measured in microns, are detrimental to Bi2212's superconductivity. This is because these impurities are so large that they act as barriers to current, forcing electrons to change their paths and weakening the material's superconductivity. "Our previous work had shown that large-scale Bi2201 defects were a significant problem for Bi2212 wires, and this work bears that out," says Dr. Justin Schwartz, head of the Department of Materials Science and Engineering. The researchers now know that at the nanoscale, Bi2201 is not detrimental — and may improve performance.

A key next step will be for materials engineers to reassess long-standing processing protocols for Bi2212 wires to determine how to minimize the formation of the large-scale impurities. The paper, "On the roles of BiSrCuO intergrowths in BiSrCaCuO/Ag round wires: c-axis transport and magnetic flux pinning", is published online in Applied Physics Letters.

Source: "Impurity Size Affects Performance of Emerging Superconductive Material"
North Carolina State University Press Release (April 17, 2014)
URL:http://news.ncsu.edu/releases/wms-schwartz-bi2212-2014/

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Contact: justin_schwartz@ncsu.edu

▸Management and Finance 경영정보 经营信息[jīngyíng xìnxī]

Financial Report and New Products

AMSC (April 4, 2014)

A couple of weeks after AMSC announced it would lay off 5 to 10 percent of its workers across Massachusetts, Wisconsin and China, CEO Daniel McGahn says the Devens-based provider of wind energy technology formerly known as American Superconductor is now on the right track. For the first time in four years, the company was able to generate cash for the quarter ending in March — a year ahead of schedule. Although the restructuring plan calls for the layoffs and the closure of a facility in Wisconsin, the company is now positioned to grow even as it consolidates its operations. The moves, AMSC said, would save the company $3 million a year starting in the fourth quarter of fiscal 2014. In the nine months ending Dec. 31, 2013, the company's revenue stood at $67.8 million, about the same as the $67 million recorded during the same period in 2012.

Over the next year, McGhan said, the company would be putting energy into two products, one focusing on the electric grid and another on the U.S. Navy. The electrical grid product, called Resilient Electrical Grid, enables an electric utility to get more capacity or more redundancy within an urban infrastructure. He believes the company will get an order within the next year.

AMSC has been working with the U.S. Navy on the product, which allows crews to "tune or cloak the magnetic signature of the ship" to avoid magnetically activated mines. The technology, called degaussing, dates back to World War II, but McGhan said the company has perfected the wiring and magnet cables in ships by making them lighter. The material also performs better than traditional degaussing, he said. He estimates the U.S. market for the product at about $100 million a year, while the total market for the U.S. and its allies sits around $1 billion a year.

Source: "AMSC CEO: 'Things are only going to get better' after restructuring"
Boston Business Journal (April 4, 2014)
URL:http://www.bizjournals.com/boston/blog/techflash/2014/04/amsc-ceo-things-are-only-going-to-get-better.html?page=all

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Feature Article:Trends of National Projects in Japan and Other Countries - Summary of Trends of National Projects Undertaken by Each Country

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC

The International Superconductivity Industry Summit (ISIS2013) was held at Fujikawaguchiko, Yamanashi prefecture, November last year. The following is a brief outline of superconductivity-related national projects undertaken by each country as of November 2013.

The major topics presented at the ISIS2013 were as follows:

USA: Investigations pertaining to wind power applications have increased. Equipment employing MgB_2 wires, which are easier to fabricate into long wires, are currently under study. Coil development for high-field applications has begun and is considered as the first large-scale coil utilizing YBCO coated conductors. A practical system design that includes resistance to electromagnetic force and solutions to quenching has been investigated. Beneficial information for future development is anticipated.

EU: Research institutions based across the EU have started wire development of EUROTAPES-Pj. However, wire lengths and I_c targets are not that high compared to the targets set in the past by Japan and USA. The development of the world's longest 1km-HTS cable (AmpaCity-Pj: Essen, Germany) is now approaching the end of the project (Final year 2016). Beneficial information is to be published in the future. Similar to the USA, four sets of investigations on wind power applications have begun in this region as well.

Korea: Whilst conventional wire development Pj has concluded, demonstration projects (500m-class AC, DC cable and others) applicable to renewable energies such as photovoltaic power generation is ongoing.

Russia: Recent intensive development has led to a rapid increase in the numbers of presentations at the summit. In addition to cables, wire development has been aggressively pursued and mainly led by ROSATOM. It seems that the background behind Russia's recent development is their concept to transmit power towards Europe in the future.

Japan: Large-scale MPACC-Pj ("Technological Development of Yttrium-based Superconducting Power Equipment" Project) has concluded. Fundamental technological development of HTS coils has newly launched, led by Toshiba, Mitsubishi, Furukawa, iSTERA and others. The project objectives are for coil development aimed at industrial-use superconducting power equipment, including MRIs and accelerators. On the other hand, Tohoku University has kicked-off the development of a 25T cryogen-free superconducting magnet, which is in accordance with their master plan of High Magnetic Field Collaboratory (Research Collaboration). The development of equipment employing commercially available wires is to be launched imminently.

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Feature Article:Trends of National Projects in Japan and Other Countries -“Development of Fundamental Technology Applicable to High-temperature Superconducting Coils” Project

Teruo Izumi, Director
HTS Conductor Processing & Power Applications Division
Superconductivity Research Laboratory, ISTEC

The project objectives are set for the realization of high-temperature superconducting coil (HTS coil) systems applicable to medical equipments encompassing MRIs and heavy ion medical accelerators. The project is being commissioned to run over a five-year term and formed from five R&D themes, supported by the Ministry of Economy, Trade and Industry.

MRI development has two thematic objectives aiming for higher resolutions together with significant reductions of helium consumption over concerns associated with its supply constraints. Theme ① of the “R&D related to a HTS coil for constant-field MRI systems” involves developing fundamental technology with the assumption of it being applicable to a 3T-MRI with performance attributes equivalent to conventional low-temperature superconducting coil systems. Theme ② of the “R&D related to a coil system for high-field MRI” is to develop fundamental technology that will be able to generate stable and homogeneous high magnetic fields of up to 10 T, and be successfully applied to MRI image processing offering higher resolutions and the ability of measuring a variety of samples compared to conventional MRIs.

Regarding the themes applicable to the heavy ion medical accelerators, R&D into high-field HTS coils with variable field capabilities will be undertaken and the findings eagerly anticipated for ultra large-scale accelerator applications in scientific technology, offering system compactness and further cost reductions. Here, R&D into an HTS coil system that is compatible to characteristic variable magnetic fields will be undertaken under theme ③, “HTS coils employed for the main magnets of a synchrotron-type accelerator”, and theme ④, “coils applicable to heavy-ion beam paths and beam application components”.

Themes under ①~④ aim for the establishment of an almost real scale coil system technology employing HTS wires. Additionally, theme ⑤, “R&D of common fundamental technology” aims to progress fundamental technological issues common to coils employed in MRIs and accelerators, to realize greater performance attributes and further cost reductions. Here, R&D is focused to enhance the performance attributes of superconducting wires, the fabrication of high performance coils employing those superconducting wires, coil cooling technology without the need for liquid helium and the technological evaluation of superconducting wires and coil performance etc. Specifically, the objectives of realizing a helium-free MRI involves investigating the potential operation of an MRI that will operate in liquid nitrogen for magnetic fields up to 3 T and operation at greater than 30 K for magnetic fields up to 10 T. The development of the heavy ion medical accelerator and gantry aims for compact/light-weight and the realization of equipment that would suppress heat generation, even under high-speed magnetic field changing conditions. Categories under coil technology development include “a) understanding the

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fundamental characteristics of wires and coils" to evaluate magnetization relaxation and in-field I_c characteristics, and "b) coiling technology development" to evaluate the effectiveness afforded by different coil shapes. Development of superconducting wire technology includes "c) fabrication of long wires with high in-field I_c characteristics" in order to realize world record-breaking long wire characteristics that have so far only been realized in short-wires. Furthermore, "d) wire development with ultra low heat generation (including ultra-low resistance joint technology/evaluation technology), which corresponds to operation in varying magnetic fields, is also undertaken. Here, objectives related to suppress the heat leaks at the joins involves the development of ultra-low resistance joint technology. Major targets are 200m-600A/cm@65K, 3T, 1000A/cm@35K, 10T, 200m-filament width≦500 μm–I_c and less than 5 % deviations. These targets are intentionally set high, being anticipated for the so-called third generation wire development.

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Feature Article: Trends of National Projects in Japan and Other Countries - "Planning the Steady High Magnetic Field Facilities as part of the High Magnetic Field Collaboratory (Research Collaboration)"

Satoshi Awaji, Associate Professor
High Field Laboratory for Superconducting Materials
Institute for Materials Research, Tohoku University

High magnetic fields can be classified into two types; pulsed magnetic fields that generate a high magnetic field for a short time ranging from μs to around 100 ms; and a steady magnetic field generated over long periods ranging from minutes to hours. Obviously, pulsed magnetic fields generate far stronger magnetic fields. On the other hand, steady high magnetic fields offer superior measurement attributes, which are difficult using pulsed magnetic fields. For research involving high magnetic fields, their complimentary characteristics are beneficial. Recently, mainstream world-class high magnetic field facilities have begun collaborating as one organization to study both strong pulsed and steady magnetic fields. In Japan, the Institute for Materials Research based at Tohoku University, and National Institute for Materials Science has focused research on steady high magnetic fields, whilst the Institute for Solid State Physics based at The University of Tokyo and Center for Quantum Science and Technology under Extreme Conditions of Osaka University has studied strong pulsed-magnetic fields. To further facilitate the development of these research activities, four facilities have formed a research collaboration network to study steady and pulsed magnetic fields, "High Magnetic Field Collaboratory (Research Collaborations) – High Field Facilities of the Next Generation" project (Figure 1), as part of the "Master Plan for Large Facility Projects and Large-scale Research Projects" officially formed in 2011 by the Science Council of Japan, (http://www.scj.go.jp/ja/member/iinkai/ogata/kakoindex.html). Deliberations are currently ongoing with the Science Council of Japan regarding the submission proposal of a revised master plan entitled, "Master Plan regarding the 22nd-term Large-scale Research Project (Master Plan 2014)", and the outcomes are to be published soon(http://www.scj.go.jp/ja/member/iinkai/ogata/). A collaborative project involving steady high magnetic fields using superconductivity technology is only outlined herewith due to manuscript limitations.

Steady high magnetic fields exceeding 30 T have been generated using a hybrid magnet, which combines a wide-bore superconducting magnet and a high power water-cooled magnet. Globally, the National High Magnetic Field Laboratory (NHMFL) utilizes a 32 MW, 45 T hybrid magnet, whilst France, the Netherlands and China are now constructing a 40-45 T hybrid magnet installed with a 20 MW power source. Japan is now falling behind the rest of the world in terms of generating the strongest magnetic field, only realising 15 MW, 35 T at the National Institute for Materials Science and 8 MW, 30 T at Tohoku University. The user community (High Magnetic Field Forum of Japan) now anticipates the rapid installation of a high field facility exceeding 40 T in Japan. In order to realise this, the National Institute for Materials Science and Tohoku University have joined collaborations under the "High Magnetic Field Collaboratory" project and have proposed a planned objective mainly for the generation of a 50T-class steady high magnetic field (Figure 1). In this project, Tohoku University is leading the development of 25 T and 30 T cryogen-free superconducting magnets. The development of 20 T wide-bore, cryogen-free superconducting magnet designed for a hybrid magnet is also being led by Tohoku University. Combining this with a 30T-class

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water-cooled magnet utilizing a 24 MW power supply and to be newly installed at National Institute for Materials Science, a 50 T cryogen-free hybrid magnet will be constructed. As part of this, the objectives of Tohoku University are to deliver stable and high magnetic fields over long periods of hours, utilizing several cryogen-free superconducting magnets, mainly a 30T cryogen-free superconducting magnet. The National Institute for Materials Science plans to install several 30-35 T-class water-cooled magnets in addition to a 50 T cryogen-free hybrid magnet operated by high power supply. A major part of these plans related to the steady high magnetic field has yet to be budgeted. However, the development of 25 T cryogen-free superconducting magnet has already gone ahead with receipt of FY2012 supplementary budget approved by Tohoku University. The development of 25 T cryogen-free superconducting magnet has implications for the future R&D of a 30 T cryogen-free superconducting magnet as well as a 20T wide-bore cryogen-free superconducting magnet. The series of superconducting magnet developments employing steady high magnetic field aims to integrate the knowledge accumulated by Tohoku University, including high strength Nb_3Sn wires and conductor technologies, Y-based high temperature superconducting coil technology, cryogen-free magnet technology etc., all leading to the construction of a world-leading unprecedented steady high magnetic field facility.

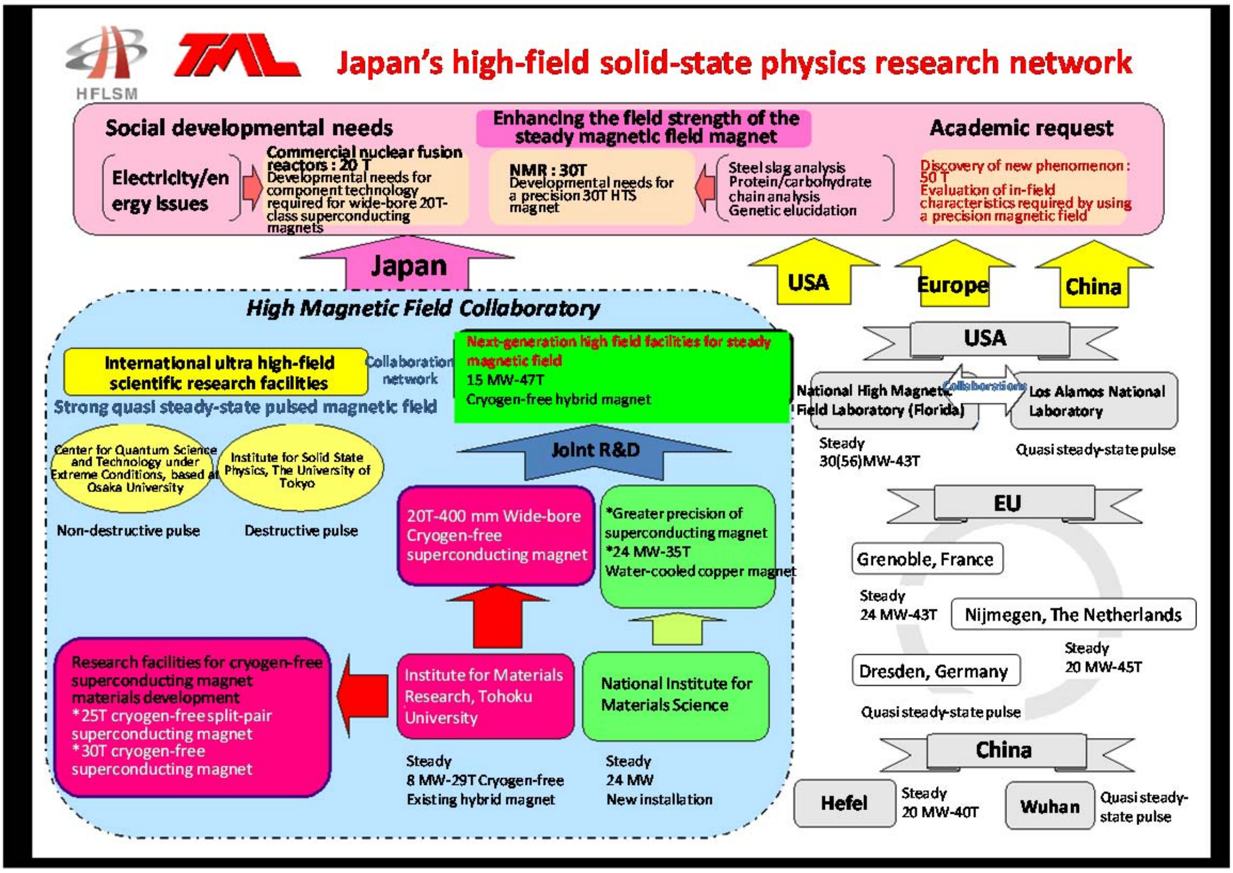

Fig. 1 Outline plan and research hub of the High Magnetic Field Collaboratory

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Feature Article: Trends of National Projects in Japan and Other Countries - Strategic-Innovation Program (Strategic Promotion of Innovative Research and Development) Undertaken by the Japan Science and Technology Agency

Kenichi Sato, Program Officer
Japan Science and Technology Agency

The R&D theme of "Creation of advanced HTS energy and electronics industry" was launched in 2009, under the "Strategic-Innovation Program (Strategic Promotion of Innovative Research and Development)" led by Japan Science and Technology Agency (JST). Five research teams are now advancing the R&D. The characteristics of this program are to promote and bring about utmost synergies from consortium R&D teams through ① R&D activities in industry-university collaborations comprising of several R&D teams, ② JST's continuous support for long-term R&D activities (10-year term at max), and ③ information sharing between R&D teams. Presently, there are 29 research institutions participating in the program. R&D cycles are categorized from stage I to III, moving on only after passing interim evaluations at each stage. JST expects that the program will see the establishment of "key fundamental technology for industry creation". Even after the conclusion of the R&D period, further research is expected to continue to realize practical superconducting systems based upon such fundamental technologies. JST's ultimate goal is that market diffusion of such technologies will lead to the creation of new industries.

Figure 1 shows the R&D agendas currently in progress and issued by the five R&D teams. The agendas involve medical equipment [1], ships[2], cancer treatment[3], altimetry[4], and railway systems[5], which are all closely related to our daily lives.

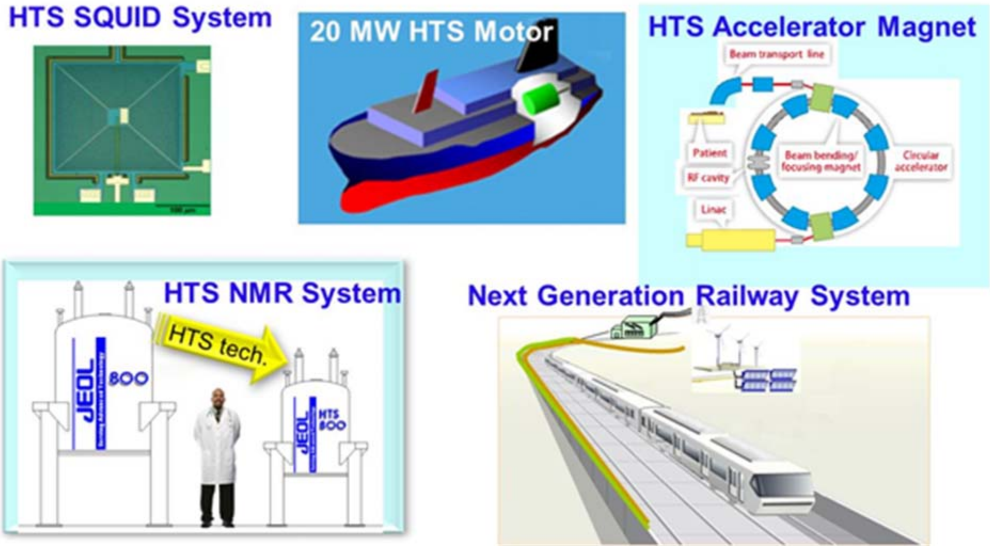

Fig. 1 "The creation of advanced HTS energy and electronics industry"

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Five years have passed since the program launch and R&D activities have seen steady progress in each agenda. With interim evaluation having been undertaken, R&D activities are now moving onto the next stage. Table 1 shows the research outcomes achieved up to 2012. The creation of a new superconductivity industry is anticipated.

Table 1 Research outcomes from "The creation of advanced HTS energy and electronics industry"

Item		Total submissions
Patent applications		19
Presentations	Japan	233
	Overseas	129
Research papers	Japan	24
	Overseas	61
Press releases		21

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Feature Article: Trends of National Projects in Japan and Other Countries

Keiichi Tanabe, Deputy Director General
Superconductivity Research Laboratory, ISTEC

- Exploring Novel Superconductor and Related Functional Materials/ Superconducting Wires for Industrial Applications [Grants-in-Aid from the Japan Society for the Promotion of Science (JSPS) 2009-2013]

This project is one of 30 themes selected by the Japan Society for the Promotion of Science for a subsided project entitled, Funding Program for World-leading Innovative R&D on Science and Technology (FIRST program). Hideo Hosono based at Tokyo Institute of Technology is the principle researcher of the project. The functional materials team in charge of new materials exploration comprises of Tokyo Institute of Technology (Hosono group, Hara sub-group), National Institute for Materials Science (Muromachi group), Hiroshima University (Yamanaka group), Kyoto University (Kageyama group) and Okayama University (Nohara group). ISTEC (Tanabe group) and National Institute for Materials Science (Kumakura group) in the wire applications team are responsible for the development of powder-in-tube (PIT) and thin film wires that employ iron-based superconducting materials and also novel superconducting materials discovered by the functional materials exploration team.

Materials exploration has yet to discover a novel superconducting material exhibiting T_c greater than 77 K, a difficult target to realize. In summer 2011, the discovery of more than 20 new parent materials at an interim evaluation stage is considered a world-leading research outcome. A novel method of electron doping by H^- ion substitution in iron-based superconducting materials has been established. This has led to a greater understanding of the entire superconductivity regions and has the potential of solving the key mechanisms of superconductivity. Regarding new functionality, it was discovered that a transition metal supporting C12A7 ($12CaO \cdot 7Al_2O_3$) electride behaved as a catalyst in ammonia synthesis offering superior functionality. Such findings significantly contribute to the progress of new projects that are aimed at realizing practical catalyst.

Based on 122 iron-based superconductors having small anisotropy characteristics, successful wire development has led to the fabrication of a thin film deposited by PLD on a single crystal and biaxially-oriented IBAD-MgO metal substrates exhibiting high self-field J_c characteristics exceeding 1 MA/cm^2. Additionally, it was discovered that these materials had more beneficial grain boundary properties compared to copper oxide materials and their in-field J_c increased significantly because of the nanoparticles dispersed in the thin films acting as strong pinning centers. The development of wires via an improved PIT processing method has recently increased J_c characteristics remarkably, producing values close to 10^5 A/cm^2 at 4.2 K, 10 T, which is a practical level. Further R&D is ongoing to realize the final target i.e. meter-long class high J_c wires.

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- Development of the Next Generation SQUITEM System and SQUID Magnetometer [Commissioned by Japan Oil, Gas and Metals National Corporation (JOGMEC) 2009-2012]

The aim of this R&D is to develop a superior system (SQUITEM 3) that offers greater portability and operability enabling the acquisition of deep underground data with greater accuracy compared to the electromagnetic exploration system (SQUITEM 1 and 2), which employed high temperature SQUID magnetic sensors owned by JOGMEC. Over a period from May 2009 to June 2010, a prototype system was fabricated. The development of system designed for practical use was undertaken from September 2010 to February 2012, with demonstration trials performed at a mining district in Australia in 2012. Whilst ISTEC developed the SQUID magnetometer comprising of a multilayered thin film high-temperature SQUID device exhibiting low-level noise characteristics, Mitsui Mineral Development Engineering Corporation (MINDECO) was in charge of the system control and the development of a receiver designed to perform data collection and analysis. SQUITEM 3 weighs a total of 26kg, significantly lighter than SQUITEM 2 and with a one-digit higher slew rate (tolerance to varying magnetic field), and its exploration attributes for deep underground measurements have been verified.

SQUITEM 3

- R&D for the Fundamental Technology for Next Generation Earth Observation Satellite/R&D for Metal Exploration Technology/Development of SQUID Gradiometer for Metals Exploration (Commissioned by Japan Oil, Gas and Metals National corporation (JOGMEC) 2009-2014)

The aim of this R&D is to realize a high temperature superconducting quantum interference device (SQUID) gradiometer for metals exploration. This project differs from the practical electromagnetic exploration system (SQUITEM 3) employing high temperature SQUID magnetometer, which was developed by ISTEC and Mitsui Mineral Development Engineering Corporation (MINDECO). Here, the project objectives for metals exploration involve the detection of terrestrial magnetic field irregularities. In order to measure variations in terrestrial magnetic fields with greater sensitivity, it is necessary to improve the sensitivity of the SQUID device and also increase the distance between the two detection coils (base line length). ISTEC is responsible of this R&D, and has developed an integrated high-temperature SQUID gradiometer with a base line of several tens of cm between its detection coils, fabricated on a Y-based coated conductor. ISTEC has also developed an electronic gradiometer that employs two SQUID magnetometers and measures electronic signal deviations by detecting differences in the signals from the two magnetometers. The ultimate goal is the development of a compact gradiometer for practical use, able to to perform portable measurements of deviations in the terrestrial magnetic field.

- Development of Wide-area Electromagnetic Logging System Utilizing Highly Sensitive Magnetic Sensor (SQUID) (Commissioned by JOGMEC 2012~)

The R&D involves employing electromagnetic exploration methods in boreholes, applicable to characteristic analysis of oil reservoirs and enhanced oil recovery (EOR) monitoring. A high temperature superconducting magnetic sensor (SQUID) exhibiting high sensitivity even at low frequencies, aims for the realization of an innovative novel technology that enables electromagnetic logging through the casing made of a steel pipe and by detecting the distribution and differences in specific resistances in the vicinity of a borehole and over a much wider area. In 2012, ISTEC and MINDECO undertook basic investigations when adopted as a theme in public participation event entitled “R&D theme of Innovative technology for oil and natural gas development”. Based upon the investigation findings, the development has advanced under the “FY2013 technology solution project (technology development/demonstration process) (Phase 1 technology development)”. Specifically, the component technology necessary for the wide-area electromagnetic logging system comprises of a SQUID magnetometer (a cryostat with built-in pressure resistant adiabatic vessel, remote SQUID control, data collection technology etc.), allowing data acquisition 1000m deep down in a borehole. Additionally, the analysis and transmitter/receiver system component technology (measurement, analysis method, conceptual design of transmitter system etc) has been developed. The current aim is to fabricate a prototype system designed for demonstration trials in Japan several years from now.

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Feature Article: Trends of National Projects in Japan and Other Countries - Demonstration Studies of High-temperature Superconducting DC Power Transmission System (Ishikari Project)

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The Ishikari project was launched in FY2012 under the "Demonstration studies of high-temperature superconducting DC power transmission system", commissioned by the Ministry of Economy, Trade and Industry. The high-temperature superconducting DC power transmission system is to be installed at the Ishikari Bay New Port Area in Hokkaido. Actual DC loading tests will be undertaken at a data center requiring DC power from actual power grids. The project ultimately aims to identify technical and regulatory issues arising.

The table 1 shows a summary outline of the prototype system to be installed. Two different prototype lines are to be demonstrated; Line 1 is connected to a local DC power source such as solar panel system, to verify the connectivity with a DC power source as well as determining loading stability; Line 2 is to be connected to an existing AC transmission system, leading to the construction of a long distance route running along a public highway. With these two different demonstration lines, any potential technical or regulatory issues can be identified and classified, paving the way towards the realization of an integrated system for practical use in the future.

The following key items will be technologically demonstrated, bearing in mind the future installation of long distance cables.

1. World's first cable connected at several places and demonstrations of thermal contraction measures during cryocooling.
2. Employing a large capacity refrigerator for the cable cooling system required for a long-line cable, and verifying the feasibility of cooling over a long distance.
3. Verifying the long distance characteristics of a straight, thermally insulated duct, which is currently expected to offer reduced heat leak and low-pressure loss characteristics, in order to improve the cooling efficiency of the cable system.

Moreover, Japan's first successful installation of a superconducting cable under a public highway and any procedure associated with Electricity Business Act regulations will be an unprecedented case in determining future safety protocols. It is therefore anticipated that regulatory issues affecting potential commercialization will be identified.

Demonstration studies were kicked-off by the consortium that comprises of collaborations with four research institutions including, Chiyoda Corporation, Chubu University, Sumitomo Electric, and SAKURA Internet. The consortium established the Ishikari Superconducting DC Power Transmission System

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(I-SPOT) on 20th January 2014, who will lead future demonstration research trials. Research job descriptions of each corporate are briefly classified as: Chiyoda Corporation mainly responsible for fabricating the cooling facility piping; Chubu University responsible for prior testing trials pertaining to design as well as designing terminals and insulated double-pipes; Sumitomo Electric for cable fabrication and installation (including the joints); and Sakura Internet for the DC power transmission systems connecting a solar power plant and a data center.

As of March 2014, the fundamental design of the prototype system and fabrication of each component related to Line 1 is almost completed. Full-scale installation and construction is now expected to start around May. Until the end of FY2014, the plans are to complete post-installation tests and perform trial operations for Line 1, and to complete the installation of the prototype system required for Line 2.

Table 1 Summary of prototype system

Installation location		Ishikari Bay New Port Area, Hokkaido
Transmission type		DC
Transmission cable		High-temperature Superconducting Cable (BSCCO coated conductor (manufactured by Sumitomo Electric))
Line 1	Transmission distance	About 500 m (including joints)
	Power station	DC power source such as solar plant
	DC distribution facility	Ishikari Data Center, Sakura Internet
	Transmission cable capacity	Around 50 MW
Line 2	Transmission distance	About 2 km (including joints)
	Planned power source (power plant and transformer facility)	Commercial-use AC power source
	Targeted user	DC load etc.
	Transmission cable capacity	Around 50 MW

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Feature Article: Trends of National Projects in Japan and Other Countries - Japan's National Project – Research on Over 10 MW Class Wind Turbine (Research and Development of Key Components for Over 10 MW-Class Superconducting Wind Power Generator)

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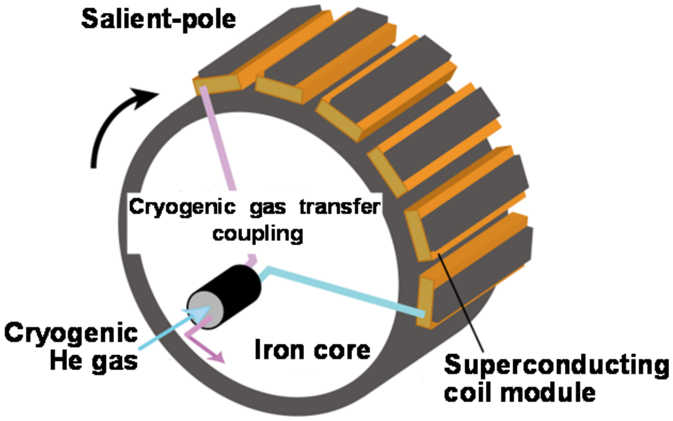
Rapid increases for the introduction and expansion of natural energies are one of most important issues that Japan needs to prosper in. Trends in the developments of wind power generators are notably aiming towards large-scale and offshore wind turbines, increasing overall power capacities at their locations, thereby ultimately reducing power generation costs. Such developments have led the New Energy Technology Department of NEDO to undertake the "Research on over 10 MW class wind turbine (2013-2014)" amongst one of its R&D projects aimed at the realization of highly practical wind power generation. Two major R&D themes are categorized as, "Conceptual design of an entire wind turbine" and "Next generation wind power generators". Under the latter theme, a team comprising of National Institute of Advanced Industrial Science and Technology, Furukawa Electric (Niigata University/Sophia University), and Mayekawa MFG (The University of Tokyo), leads R&D of key components necessary to fabricate over 10 MW-class superconducting power generators.

Quest for larger wind turbine power generator capacities is accompanying the fact that the wind gearboxes will reach their technological limitations. Therefore, a direct-drive system without the needs for a wind gearbox seems a viable alternative prospect. However, increases in size/weight and cost associated with large capacities are significant concerns with future prospects afforded by current available technology [1]. Recent design studies demonstrate that by the use of superconductor technology, which has high current density/high-field characteristics, we can produce compact/lightweight high-capacity wind power generators[2]. If this can be realized, it is expected that market diffusion for offshore wind farms will expand progressively. Electromagnetic design studies of a superconducting power generator for large-scale wind turbines have shown that an air-cored coil (superconducting wires utilized only for rotor) would realize ultra compact/lightweight power generators. However, they also concluded that costs would be problematic with around 3-400 million Yen expected for a 10 MW-class power generator, which are mainly due to the large consumption of expensive high-temperature superconducting wires. The utilization of an iron-cored superconducting rotor also realizes reduced weight, almost half that of a conventional power generator [3]. The R&D team therefore selected an iron-cored superconducting rotor that consumes one-digit less wire volumes, taking into account near-future wire costs. Since it is impossible to cool the entire iron core (inner yoke), a coil module (Figure) is employed to cool only the superconducting coil positioned around each salient pole of the iron core.

This study focuses on three key components necessary for the fabrication of an iron-cored superconducting power generator: (1) superconducting coil module, (2) refrigerator with high reliability, and (3) cryogenic gas transfer coupling employed as part of the superconducting rotor. Additionally, the exploitation of outcomes from the R&D of the above-mentioned three key components and the evaluations of the entire power generator including cost assumptions will be undertaken to verify the feasibility of a 10 MW superconducting power generator.



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