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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

5km Long HTS Cable for Resilient Grid

AMSC (16 July, 2014)

AMSC announced that ComEd, a unit of Chicago-based Exelon Corporation and one of the nation's largest electric utilities, has agreed to develop a deployment plan for AMSC's high temperature superconductor technology, which aims to construct a superconducting cable system that is expected to enhance Chicago's electric grid. ComEd provides service to approximately 3.8 million customers in Northern Illinois, which is 70 percent of the state's population, including the City of Chicago. The Resilient Electric Grid (REG) initiative is part of the U.S. Department of Homeland Security (DHS) Science and Technology Directorate's work and is led by ComEd to secure the nation's electric power grids against severe weather-related disasters, terrorists attacks, or other catastrophic events, thereby making the entire system more durable.

Anne R. Pramaggiore, President and CEO, ComEd stated, "We view this project as a natural extension of the infrastructure improvements and technological upgrades that have been under way for the past two years as we develop and deploy the smart grid. Linking our critical urban infrastructure to this superconductor system would provide added reliability, resiliency and security to Chicago's Central Business District." Currently, grid infrastructure design in many U.S. cities makes restoration of power following an unpredictable catastrophic event laborious and costly. The REG system provides a self-healing solution when parts of the grid are lost during a catastrophic event. The ComEd installation would be the first commercial application of this advanced technology in the United States able to addressing critical challenges facing the power grid.

Daniel P. McGahn, President and CEO, AMSC stated, "As provided in the DHS contract, AMSC will initiate a similar deployment plan with at least two other U.S. utilities. Utilities around the world are investing tens of billions of dollars on smart grid technology designed in part to create a more redundant and resilient grid". Daniel P. McGahn believes that AMSC's unique high temperature superconductor technology has the potential to enable the REG system to play a pivotal role in protecting infrastructure assets that are vital to electrical systems. The partnership with ComEd and DHS will now enable AMSC to offer this system solution to cities in America and around the world. The project involves the installation of more than three miles of superconductor cable, which today would serve as a model that can be used to implement superconductor technology in the world.

Source: "ComEd to Partner with AMSC on Superconductor-based Resilient Electric Grid System"
AMSC Press Release (16 July, 2014)
http://ir.amsc.com/releases.cfm
Contact: AMSC Investor and Media Relations Kerry.farrell@amsc.com

HTS Current Limiter Installed in NY Substation

Central Hudson (17 July, 2014)

Central Hudson Gas & Electric Corp. has installed an innovative new superconducting fault current limiter, which was developed and manufactured by Applied Materials Inc., aiming to protect vital utility assets from damage caused by electrical faults, while subsequently improving grid efficiency.

The superconducting fault current limiters were installed at Central Hudson's Knapps Corners substation in the Town of Poughkeepsie. Currently, equipment at most substations is protected by circuit breakers that protect sensitive equipment during power surges. The interruptions to power serving homes and businesses can often take hours or longer to address. Operating in conjunction with conventional fault current limiters, the new superconducting fault current limiter allows current transmission with no electric losses while in standby mode, with far less energy consumption than reactors alone. This ultimately leads to power grids with enhanced power quality and voltage stability in specific applications.

Paul Haering, Central Hudson's Vice President of Engineering and System Operations is quoted as saying, "By adding fault current limiters, our goal is to lengthen the service life of equipment and lower system losses, ultimately lowering costs for our electricity customers." The company anticipates that the demonstration of superconducting fault current limiters will serve as a significant milestone in exhibiting the potential of this technology for wide-scale adoption by electric utilities globally.

System testing and evaluation will be undertaken over a period of one year, from May 2014, and the performance data will be provided to the New York State Public Service Commission. The total cost of the project is $2.5 million.

Source: "Central Hudson deploys innovative new superconducting technology to reduce power outages caused by lightening and other surges"
Central Hudson News (17 July, 2014)
http://www.cenhud.com/about_us/news/july17_14.html
Contact: Denise Doring VanBuren, Vice President of Public Relations dvanburen@cenhud.com

►Wire

100 KA YBCO Large Current Conductor

National Institute for Fusion Science (25 July, 2014)

The National Institute for Fusion Science (NIFS), of the National Institutes of Natural Sciences (NINS) in Japan, has realized the world's highest electrical current of 100,000 amperes, measured during the development of a high-temperature superconducting coil that is applicable to a fusion reactor magnet.
Using the latest developments in yttrium-based high-temperature superconducting tapes developed and produced in Japan, by simply stacking 54 superconducting tapes, each 10 mm in width and 0.2 mm in thickness, the so-called "joint winding method", allowing NIFS to manufacture a conductor of exceptional mechanical strength. For the conductor joints, imperative for the production of the large-scale coils, low-resistance joint technology was developed via collaborative research studies with Tohoku University. The joint winding method has also impacted the development of high-temperature superconducting magnets used in medical instruments and power-electric devices.

Prototype conductor test results conducted at 20 K, measured an electrical current exceeding 100,000 amperes. The overall current density exceeds 40 A/mm^2 including the jackets, and this is of practical use for manufacturing large-scale fusion reactor magnets. The effects of this technology are anticipated to impact other technologies in the future.

Source: "Magnets for fusion energy: A revolutionary manufacturing method developed"
NIFS Public Release (25 July, 2014)
http://www.eurekalert.org/pub_releases/2014-07/nion-mff072514.php
Contact: Nagato Yanagi yanagi@LHD.nifs.ac.jp

Status of Long Length Wire Equipment

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Superconductor Technologies Inc. (31 July, 2014)

Superconductor Technologies Inc. (STI) provided an update of its Conductus® superconducting wire manufacturing assembly process. Whilst the SDP and IBAD machines are the first two steps of the Conductus process that are already operational and producing templates that meet production requirement, STI now expects to have the final machine or 1km Reactive co-evaporation (RCE) system operational at the end of the third quarter of 2014.
Jeff Quiram, STI's president and CEO, stated, "While we had planned to have the 1 km RCE machine operational at the end of the second quarter, to date we have encountered several delays related to equipment failures at our supplier's fabrication plant for the vacuum deposition chamber. The vacuum deposition chamber is currently scheduled for delivery to our Austin facility in late August."

The final assembly of RCE machine is within the planned budget. STI projects a ramp in capacity during the fourth quarter of 2014, and being at full operational capacity in 2015. STI anticipates this machine to produce an initial capacity of 750 kilometers of Conductus® wire per year.

Source: "STI provides an update on Conductus superconducting wire production equipment"
STI Press Release (31 July, 2014)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle_Print&ID=1953464&highlight
Contact: Investor Relations Cathy Mattison or Kirsten Chapman invest@suptech.com

►Device

$30M in funding for Quantum Computing

D-Wave Systems Inc. (11 July, 2014)

D-Wave Systems Inc., the world's first commercial quantum computing company, announced that it has raised a further $30 million in funding, bringing the total to $160 million, from both new and existing investors including Goldman Sachs (GS), BDC Capital (BDC), Harris & Harris Group (HHGP) and DFJ. The funding will be used to further the development of D-Wave's quantum computing technology, allowing the company to achieve further software development and deliver a potential software application ecosystem.
Vern Brownell, CEO at D-Wave stated, "This funding is a strong endorsement of D-Wave's ability to deliver the first viable quantum computer to organizations in need of a new caliber of computing." The funding is anticipated to enable D-Wave to launch a product to market and to evolve its software applications in multiple spheres.

D-Wave has been expanding its global presence over the past year. The funding is also expected to allow for continued growth in the important markets including US, Europe and Asia, through key partnerships with experts worldwide.

Source: "D-Wave Systems Secures $30M (CAD) Funding to Accelerate Quantum Computing Software Development"
D-Wave Systems Press Release (11 July, 2014)

http://www.dwavesys.com/press-releases/d-wave-systems-secures-30m-cad-funding-accelerate-quantum-computing-software
Contact: media@dwavesys.com

Superconducting-Silicon Qubits

Joint Quantum Institute (2 July, 2014)

Researchers propose a "bottom-up" nano-fabrication as a method to fabricate superconducting quantum devices such as Josephson junctions and qubits. They aim to make superconducting wires and junctions, from which qubits and sensors can be made, by precisely doping acceptor atoms (such as boron or aluminum) in silicon.

Yun-Pil Shim and Charles Tahan from the University of Maryland and the Laboratory for Physical Sciences have demonstrated how superconducting qubits and devices can be fabricated from silicon, employing a scanning tunneling microscope (STM) hydrogen lithography pioneered by Michelle Simmons at the University of New South Wales. Doping gas such as phosphine can be used for precisely placing impurities at a specific atomic site. Recent STM efforts have realized in replacing one-in-four silicon atoms using this methodology. The dopant density influences superconducting critical currents - higher the dopant density, the higher the critical superconducting temperature will be.

"If acceptor atoms can be placed at sufficient density over enough layers, then superconducting regions can be fabricated within the silicon and then encapsulated with crystalline silicon", said Yun-Pil Shim. Also, Charles Tahan stated, "This is the first proposal on the feasibility of SC silicon for Josephson junctions and qubits. I'm also excited about these systems' potential for other devices as such as sensors and particle detectors". The researcher's results have been published in Nature Communications.

Source: "Superconducting-Silicon Qubits"
Joint Quantum Institute News (2 July, 2014)
http://jqi.umd.edu/news/superconducting-silicon-qubits
Contact: Phillip F. Schewe pschewe@umd.edu

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Trends in the MRI Market and Current Issues Regarding Commercialization

Shunji Yamamoto, Excutive Advisor
Mitsubishi Electric Corporation

1. Introduction

It has been 30 years since the practical realization of Magnetic Resonance Imaging (MRI), allowing arbitrary cross-sectional imaging of the whole body such as the brain to be obtained without performing an operation or employing radiation. Nowadays, MRI technology is not only the mainstay of larger hospitals but is now accessible to local family clinics, and allows cancer diagnosis to be performed for a greater number of patients.

Superconductors have diffused into clinical diagnosis systems since the technology requires high magnetic fields for its operation.

2. Trends in MRI market

Conventional MRI systems have widely employed permanent magnets (0.1 T~0.4 T). With advancements in superconductivity technology, 1.5 T-class superconducting magnets have gradually superseded permanent magnets. In fact, the majority of current MRI systems employ a 1.5T-superconducting magnet for its operation. In recent years, hospitals have begun employing 3T-MRI systems that offer higher spatial resolution images over 1.5 T superconducting MRIs.

2.1 Worldwide market status

The Radiological Society of North America provides the latest easy to understand information regarding MRI systems. The society devotes a significant portion of their time and allocation for imaging diagnosis equipment, which includes MRI, CT, and Positron Emission Tomography (PET). The last annual meeting was held in Chicago, December 2013, and was attended by 60,000 people, with 10,000 presentations and around 500 manufacturing companies displaying at the exhibition.

The MRI market has seen proliferations of 3 T systems, however despite this, the 1.5 T system still remains the mainstream. Most recent systems employ a large clear bore size with short axis length allowing the flexibility to house a human body without feeling cooped up, which was the drawback of more conventional systems. A variety of methods to reduce noise have also been attempted. The degree of magnetic field homogeneity, closely related to image resolution has already been realized as a matter of course with the progress made in analysis technology and wire winding technology.

The exhibition held at the annual meeting also highlighted superconducting MRI. Here, horizontal (horizontal cylindrical) and open (C-shaped superconducting magnet) systems were presented to allow sufficient operation space for doctors, and thus has aimed to boost demands more widely.

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System structures combining PET within 3 T MRI systems have also been commercialized, enabling both PET and MRI diagnosis simultaneously. The diagnosis technology has been further improved to realize higher precision.

2.2 Market status in Japan

The majority of MRI systems currently utilized in Japan are for cancer and vascular diagnosis. Figure 1 shows the numbers of whole-body MRI systems employed for clinical use in Japan as of April 2013. The systems produced by manufacturers each have their unique characteristics. For example, GE, Toshiba Medical Systems, Siemens, and Philips are forerunners of superconducting (mainly 1.5 T) systems, whilst Hitachi Medical predominantly offers permanent magnet systems. As shown clearly in the figure, 1.5 T superconducting and permanent magnets are employed in 80 % of the total number of operating MRIs.

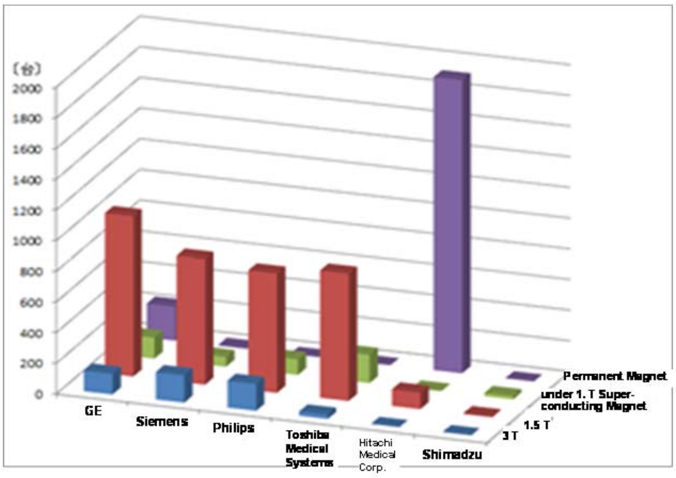

Fig. 1 The number of MRIs operating in Japan
(as of April 2013, Data from “Monthly Community Medicine”)

3. MRI issues

Significant issues pertaining to MRI magnets from the viewpoint of the superconducting magnets include 1) magnetic field strength, 2) spatial homogeneity of magnetic field, and 3) magnetic field time stability. Since the magnetic field strength is a significant characteristic of superconductors, the high density of accumulated energy can generate magnetic fields far exceeding normal conducting magnets. Issues 2) and 3) are the specific characteristics of MRI itself. To address homogeneous magnetic field specifications, the entire technological capabilities of an array of design/production/evaluation such as coil allocation designs utilizing highly advanced analysis, magnetic field adjustment technology and high-precision wire winding process technology are required. Highly stabilized magnetic fields can be realized in a so-called persistent current operation by superconducting joints.

Furthermore, from the viewpoint of patients, MRI systems exhibiting characteristics such as 4) not feeling cooped-up, 5) short time image acquisitions, and 6) oblivious to superconductivity are desirable.

4. Future prospects

Imaging diagnosis technology for clinical use is currently in the middle of remarkable advancements. Superconductor technology is fundamental to support the future development of imaging diagnosis

technologies designed for clinical use.
MRI systems exceeding 3 T, for example f-MRI, have already been employed for research on cerebral functionality. In France, an 11.7 T ultra high-field whole body MRI system is currently being fabricated.

Further opportunities towards challenging helium-less systems and the potential of high-temperature superconducting MRI magnets have improved. Yttrium-based and bismuth-based wires for high-temperature superconducting MRI have been widely researched and led to the commercialization of whole-body 0.5 T-MRIs employing MgB_2 wires. The author anticipates that significant potential still remains in the future progress in high-temperature superconductor (performance, cost).

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Current Status and Future Prospects of a Cooling System for Practical HTS Applications

Yasuharu Kamioka, President
ColdTech Associates

High-temperature superconducting (HTS) applications have an inherent handicap associated with the necessity for cooling compared with ordinary conducting equipment and that the development of cooling systems designed for practical HTS applications has been scarce up to present. Refrigerators with suitable capacity characteristics specifically designed for HTS equipment are presently non-existent, as shown in Figure 1. However, recent developments report a Turbo-Brayton cryocooler with 2kW cooling capacities at 65K, with also an ongoing development of a 10 kW-class cooler. Such coolers are specifically targeted for cooling HTS cables, however the possibility exists that they could also be employed for HTS transformers and large-scale HTS motor applications.

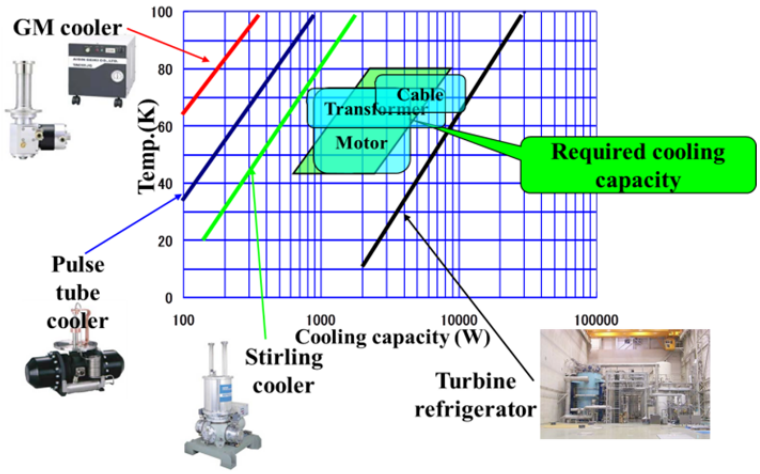

Fig. 1 Cryocoolers and cooling capacity required by HTS equipment

Table 1 lists the specifications required for cooling HTS equipment. The temperature was set at 65K since the specifications are for a sub-cooled liquid nitrogen cryogenic system. In addition to cooling capacity requirements for practical applications, the maintenance intervals are also a key characteristic and 30,000 hours (more than three years) interval is required. The author considers that a Turbo-Brayton cryocooler (with a magnetic bearing or a gas bearing system) would be deemed suitable to meet these requirements.

Table 1 Cooling system required for HTS applications

Cooling capacity	
Cable	2 - 20 kW @65K
Transformer	2 - 5 kW @65K
Motor	0.5 - 5 kW @65K
Size	Compact
Maintenance interval	30,000h
Efficiency	High >0.06 @65K

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In the case of compact cryocoolers including GM refrigerators, pulse-tube cryocoolers and Stirling coolers, even if those cooling capacities are sufficient, there still remains major issues related to the 30,000 hr maintenance interval requirements, when utilized for fault current limiter, compact motor and mixer applications for social infrastructure, factory, vehicle, and vessel. There is a necessity to determine whether in some instances that coolers with a 10,000 hr maintenance interval can be applied to some specific HTS equipment. Although cooling systems have been constructed utilizing commercially available refrigerators until now, the requirement now is to develop a bespoke cooling system applicable to individual HTS equipment. Especially at the point of heat exchange mechanism between a cryocooler and HTS equipment there is more room to develop.

A cooling system cannot be established with only a cryocooler. Other key components are the LN pump, the heat exchanger, thermal insulated container and pipes. In particular, current LN pumps can’t be used for practical application and are therefore in need of urgent development. For instance, HTS cables require discharge pressures of 1MPa, flow rates of 5 L/min-100 L/min, and 30,000-hr maintenance intervals, all of which are difficult issues to overcome. Pumps currently under investigation are the BarBer Nichols manufactured pump, the LN pump or LNG pump for industrial use. However, these pumps have either low flow rates/low discharge pressures or high flow rates/high discharge pressures with high thermal leakages, producing no pumping with low flow rates and high discharge pressures. Additionally, the maintenance intervals are insufficient. The development of a low flow rate/high discharge pressure pump is technologically challenging and thus the launch of development addressing these issues is hastily required.

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Feature Article: Forum on Superconductivity Technology Trends 2014 - R&D Activities on Common and Fundamental Technologies Shared across Medical-use Superconducting Coil Application Project

Teruo Izumi
ISTEC
Industrial Superconductivity Technology Research Association

1. Background and R&D aims for fundamental technology shared across the project

The "Fundamental Technology Project for High-temperature Superconducting Coils" was launched in 2013, and commissioned by the Ministry of Economy, Trade and Industry. The project objectives are for the development of fundamental technology with aims to realize practical high-temperature applications ranging from superconducting coils to clinical equipment, including MRIs and heavy ion medical accelerators.

The project comprises of three themes. The first theme is entitled, "R&D related to high-temperature superconducting coil system for constant-field MRIs". Here, taking into consideration helium supply constraints, the focus of development is towards a helium-less MRI system. The second theme is entitled, "R&D related to high-temperature superconducting coil with variable field capabilities", and is aimed at the development and realization of a compact and low cost heavy ion medical accelerator system such as the gantry and synchrotron accelerator, which has gathered attention as an effective cancer treatment. These themes involve the fabrication and performance evaluation of prototype coils of relatively similar scale to practical systems. On the other hand, the third theme entitled, "R&D activities on common and fundamental technologies shared across the project" has provided technological support to the two above-mentioned themes, as well as progressing the enhancement of component technology including "wires", "coiling technology", "cooling technology", and "evaluation technology," which are currently in the middle of ongoing development. The R&D objectives are the development of coils exhibiting advanced functionalities in order to realize a greater competitive equipment advantage.

2. Details on R&D activities on common and fundamental technologies shared across the project

Each component technology has progressively developed under this theme, further enhancing and exploiting the technological strength towards the realization of potential equipment for practical use. Here, *strength* refers to the coiling technology employing wires with high in-field I_c characteristics, wire scribing technology and wires made utilizing this process. Further enhancements of *strength* are anticipated for helium-free MRIs including their operation in liquid nitrogen as well as a compact accelerator system, which can suppress thermal leaks generated by magnetic flux creep even in variable magnetic field operations. This development requires a common component technology platform shared across the project involving "long wires exhibiting high in-field characteristics", "homogeneous wires", "control technology to alter magnetic relaxation behavior" and "wire process technology". Here, "R&D activities for common and fundamental technologies shared across the project" has progressed the development of component technology cross-sectionally from the viewpoint of improving R&D efficiency (refer to the following table).

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(a)Understanding fundamental wire/coil characteristics (2013-2015)	• Y-based superconducting wires and the transmission characteristics of coils made using these wires. • Magnetization/AC loss characteristics. • Magnetic relaxation speeds measured over a wide range of timescales including short-time relaxations immediately after the magnetic fluctuations.
(b) Coiling technology development (2016-2017)	Based upon the results of (a), prototype coils are to be fabricated by immersion-cooling in sub-cool liquid nitrogen and conduction cooling. Feasibility studies will follow.
(c)Fabrication technology development for long-wire exhibiting high in-field I_c characteristics (2013-2017)	Aiming to realize record-breaking long wire characteristics that have so far only been attained in short-wires, and at low costs for practical use.
(d)Fabrication technology development for wires exhibiting ultra-low thermal leak characteristics (2013-2017)	Development involves enhancing wire homogeneity, fine process technology, and simple superconducting low-resistance joint technology to suppress the heat generated by magnetic fluctuations and thermal leaks around joints.

3. R&D outcomes and future prospects

The R&D outcomes of the fabrication of long wires exhibiting high in-field I_c have thus far confirmed the potential realization of in-field characteristics (I_c=54⇒108A/cm width@77K,3T:94m), twice those of conventional wires. Additionally, wire-scribing processing has resulted in successfully minimizing the magnetic relaxation time to reach steady state magnetization. Future ongoing development will be pursued for the themes highlighted in the above table. Verification objectives are the coil shapes necessary to control the magnetic shielding required for spatial magnetic field homogeneity, magnetic relaxation behavior to display temporal homogeneity, and effective suppression of thermal leaks.

Acknowledgements: This R&D has been undertaken as part of the high-temperature superconducting coil fundamental technology development project, commissioned by the Ministry of Economy, Trade and Industry.

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Development of a High-temperature Superconducting DC Power Transmission System

Chubu University I-SPOT
Noriko Chikumoto, Hirofumi Watanabe, Makoto Hamabe, Yury Ivanov, Hirohisa Takano, Sataro Yamaguchi
Chiyoda Corporation I-SPOT
Hiromi Koshizuka
Sumitomo Electric Industries I-SPOT
Kazuhiko Hayashi
Sakura Internet I-SPOT
Toru Sawamura

1. Introduction

A "superconducting DC power transmission system" offering superior long distance high capacity power transmissions has gathered attention as the next generation transmission technology. In Japan, this technology has already been verified by demonstration trials conducted using a 200m-long transmission system at the Center of Applied Superconductivity and Sustainable Energy Research, Chubu University. Based upon the technology, the Ishikari Project, launched last year, aims for the construction of practical power transmission systems.

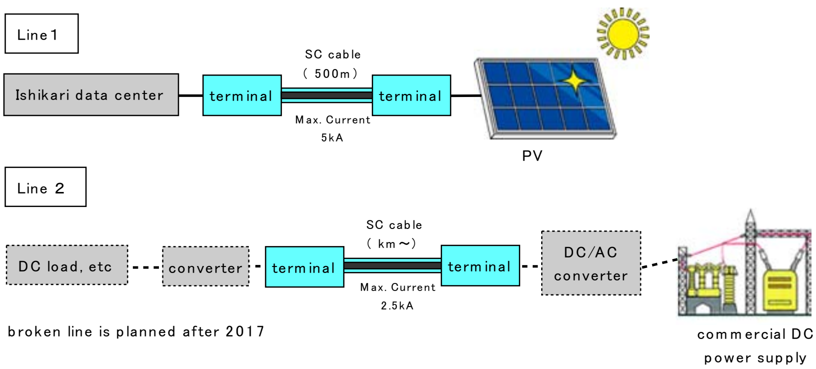

Fig.1 Schematic illustration of test lines in Ishikari Project

2. Summary of the Ishikari Project

The 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 constructed at a demonstration site located in the Ishikari Bay New Port Area. Actual power from a DC supply unit or commercial DC/AC converter will be transmitted to a data center requiring DC. The project ultimately aims to construct an entire system suitable for practical use as well as identify technical and regulatory issues that could arise during the course of realizing the future potential of long-distance transmission systems [1]. The project plan involves the installation of two different lines. To verify loading stability, Line 1 connects Ishikari data center of Sakura Internet with their solar panel system, utilizing around 500m-long superconducting cable (Sumitomo Electric's BSCCO cable, coaxial/parallel conductors). Line 2 involves the installation of a km-long transmission system along a public highway, with preparations and investigations planned for long distance power transmission (Figure 1). The first year of the project has mainly seen the designing and manufacturing/purchasing of the equipment, together with various verification trials. During this year, the second year of the project, plans are to complete the system construction at the field site and conduct operational trial.

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3. The system structure

The key issues in realizing future long-cable systems are suppressing the thermal leak volumes and enhance cooling efficiencies. To address this, the thermally insulating concentric double-pipes using straight plumbing pipes are employed to minimize coolant circulation pressure losses over such long distance. Both cable duct (65 A) and return duct (50 A) will be housed in the same outer pipe in order to reduce thermal leaks and costs. A newly developed multilayer insulation structure is chosen with an aim to reduce thermal leaks from the pipe to below 1.5 W/m. Furthermore, Peltier current leads (PCL), developed at Chubu University, have been selected for the superconducting cable terminals in order to reduce thermal leakage. For the refrigerator, a Turbo Brayton cryocooler (2 kW), manufactured by Taiyo Nissan and developed under a NEDO project, will be employed as part of superconducting cable system for the first time in the world. The advantageous characteristic of this cryocooler is the magnetic bearings, which are maintenance-free over the long term. Other investigations involve exploiting measures against thermal contractions of the cable.

Acknowledgements
This R&D has been undertaken under the "Demonstration studies of high-temperature superconducting DC power transmission system" commissioned by the Ministry of Economy, Trade and Industry.

Reference:

1) S. Yamaguchi *et al*., Abstracts of CSSJ Conference, Vol.88 (2013) p.23

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Research on Over 10 MW Class Wind Turbine – R&D of Key Components for Superconducting Wind Power Generator

Hirofumi Yamasaki, Group Leader
Superconductor Technology Group
Energy Technology Research Institute
National Institute of Advanced Industrial Science and Technology

Rapid proliferation and introduction of natural energies is one of the most important issues for Japan to pursue. Developments of wind power generators are notably trending towards large-scale and offshore installations, with the aim to increase overall power capacities at their sites and thereby reducing power generation costs. Amongst the number of R&D project portfolios led by New Energy Technology Department of NEDO, which are aimed at the realization of highly practical wind power generation, is a project entitled "Research on Over 10 MW Class Wind Turbine (2013-2014)". The project team comprises of two groups; the "Total design group (led by Hitachi)" and the "Elemental technologies group (led by AIST, University of Tokyo, Mie University, and Wind Energy Institute of Tokyo)", who assumes conceptual designs of an entire wind turbine. The "Generator group (led by AIST, Furukawa Electric (Niigata University/Sophia University), Mayekawa MFG (University of Tokyo)", where the author is involved, is responsible in R&D studies investigating key components necessary to fabricate over 10 MW-class superconducting power generators.

Since the rotational speed of large-scale wind turbines is small at ≤10 rpms, it is common to employ a multistage gearbox that increases rotational speeds more than 100-times. However, it is deemed that gearboxes will reach their technological limitations for larger wind turbine installations where power generation capacities exceed 6 MW [1]. Alternative and viable propositions include a direct-drive system, which do not require a gearbox (gear-less, large-scale multi-pole synchronous generator). However, Increases in size/weight and costs associated with large capacities are significant concerns with future prospects afforded by current available technology [1]. Recent design studies demonstrate that the use of superconductor technology, which exhibits high current density/high-field characteristics, can produce compact/lightweight high capacity wind power generators [2, 3]. If this can be realized then it is anticipated that market diffusion for offshore wind farms will expand progressively. An air-core coil (superconducting wires utilized only for rotor) can realize ultra compact/lightweight power generators. However, since such systems also consume a large volume of expensive high-temperature superconducting wires, costs of around ¥3-400M expected for a 10MW-class power generator would be problematic. The utilization of an iron-core superconducting coil in a rotor also reduces weight to almost half that of a conventional power generator. The R&D team has therefore assumed the selection of an iron-core superconducting rotor that consumes one-digit less wire volume. Since it is very difficult to cool the entire iron core (inner yoke), a coil module system (figure) is employed to cool only the superconducting coil positioned around each salient pole of the iron core.

This study will focus on three key components necessary for the fabrication of an iron-core superconducting power generator: (1) superconducting coil module, (2) highly reliable Brayton Cryocooler (~1 kW@20-40 K,

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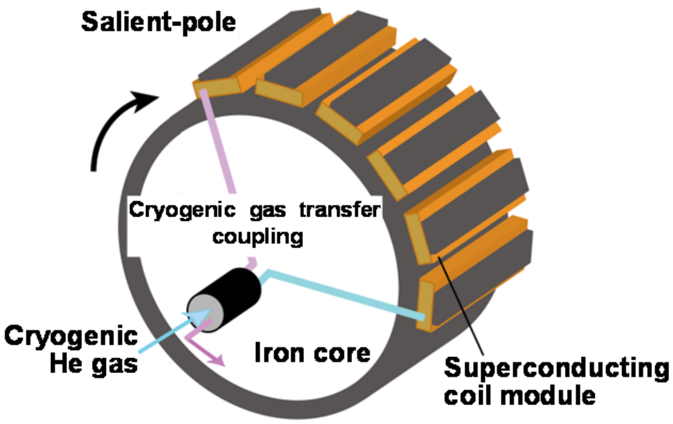
maintenance interval >30,000h), and (3) cryogenic gas transfer coupling employed for superconducting rotor. Additionally, the exploitation of outcomes from the R&D of the above-mentioned three key components and the evaluations of the entire power generator including cost assumptions will be undertaken to verify the feasibility of a 10 MW-class superconducting power generator.



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