# High Temperature Superconductivity News

***Produced by the International Energy Agency's (IEA)***

***Technology Collaborative Program (TCP) on HTS[1]***

**Highlighting the Applied Superconductivity Conference, 2016**

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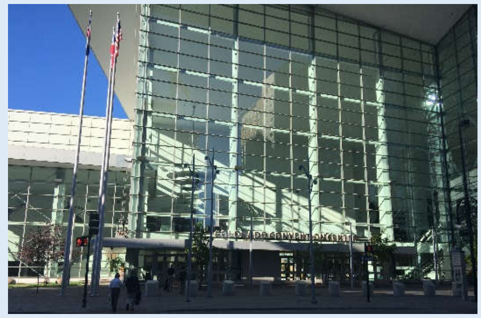
★News sources and related areas covered in this issue

[1] **Developed by Yutaka Yamada and Brian Marchionini, Operating Agents for the IEA HTS TCP**

The [2016 Applied Superconductivity Conference] was held at the Denver Colorado Convention Center (right-hand side photo) 5–9 September. More than 1600 researchers attended to hear presentations and view posters on superconducting electronics, large scale applications and materials. Videos of keynote presentations are available on the conference website for those who couldn't be there.



Colorado Convention Center

## Special Session on HTS Applications

On the first day of the conference, the IEA HTS TCP held a special session to discuss *What will Drive Market Maturity for HTS Applications in the Electric Grid*. This session had approximately 150 participants and started with an overview of the IEA HTS TCP and a summary of the [Roadmap for the Electric Power Sector, 2015-2030]. A panel discussion by distinguished experts in the applications area and materials areas followed.

Audience at the Special Session

### Panel Session—Overview of the IEA HTS TCP and Roadmap for the Electric Power Sector

With his opening remarks, Dr. Luciano Martini of RSE, chairman of the IEA HTS TCP, stressed the importance of the IEA TCP activity and the role HTS can play in changing the electric power sectors (see photo at right).

Next, Mr. Marchionini of Energetics Incorporated summarized results of the Electric Power Sector Roadmap. He discussed the challenges and needs for more widespread deployment of HTS devices.

An on-line mobile phone application allowed for open audience participation by collecting questions from attendees and administering a survey to solicit feedback.


Dr. Luciano Martini

## Applications Panel—Worldwide Progress in Electric Grid Modernization using HTS Based Devices

This session featured panelists that presented recent HTS activity in the EU, US, and Asia. Afterwards, they responded to moderated questions from Dr. Martini. (Photo at right).

- European Updates, Mathias Noe – KIT
- Japanese Updates, Hiroyuki Ohsaki – University of Tokyo
- Korean Updates, Hyerim Kim – KEPRI
- Resilient Electric Grid, Mike Ross – AMSC

Discussion with application panelists

Highlights of the presentations include:

1) HTS cable and SFCL applications are most popular now for large R&D projects and in the most advanced stage near commercialization. Dr. Matias showed a Technical Readiness Level of 8-9 for SFCL and cables.

2) For commercialization, further verification of the safety and reliability will be needed similar to the TEPCO and Jeju cable projects, as explained by Dr. Ohsaki and Dr. Kim, respectively. In addition, Dr. Noe emphasized that low cost wire and short construction times for projects are important.

3) Mr. Ross highlighted promising features from HTS cables such as high capacity in densely packed urban electric networks and new grid system configurations with current limiting functions. The Resilient Electric Grid system in Chicago is a potential project that will show the benefit of these features.

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## Wires Panel—Worldwide Progress in Superconducting Wire

In the wire session, three panelists introduced US, EU and Asia recent activities. Improvements such as high $I_c$ are being carried out at companies because the HTS wire's cost is still a key factor for the cost of the HTS application products. Speakers in the wire session included:

- Advanced Superconductor Manufacturing Institute, Venkat Selvamanickam - University of Houston
- Updates from EU, Klaus Schlenga – Bruker
- Updates from Japan and Asia, Yutaka Yamada - Shibaura Institute of Technology

Discussion with wire panelists

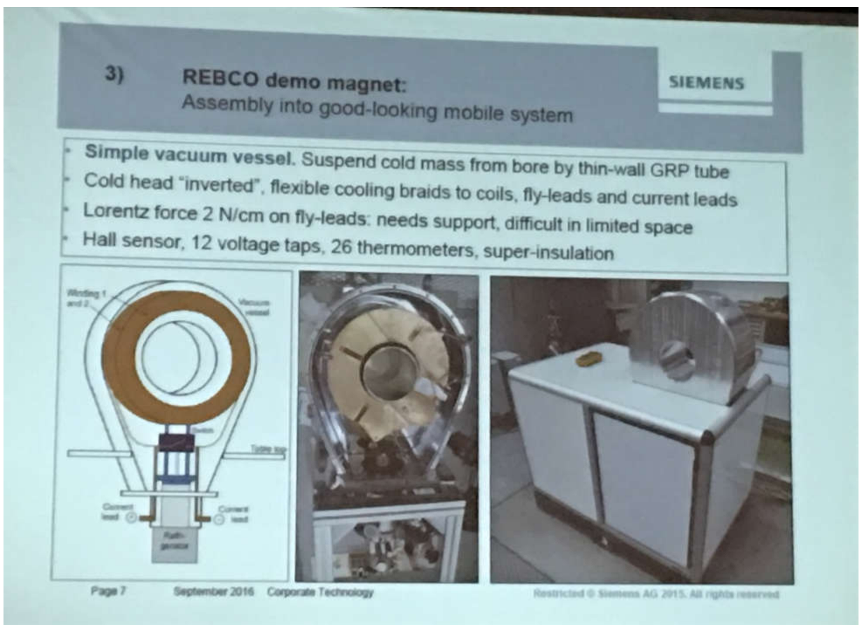
Wire R&D seems to be entering into a new phase not only for high $I_c$ and long length but also for overall manufacturing processes. This development was typically shown in the US activity: a new consortium called the Advanced Superconductor Manufacturing Institute introduced by Dr.

Selvamanickam (see the article below), which plans to develop the industrial manufacturing process through an extensive public private partnership.

During the question and answer period, the discussion covered topics such as “What is the most promising applications for HTS wire companies?” One of the answers was HTS cables because of the large amount of wires used.

## Siemens developed persistent-current-mode coil

Siemens presented on a persistent current mode HTS (REBCO) coil. The photo below shows the HTS coil and system. Although their joint technique was not public, the system, made of a REBCO coil, superconducting joint, and persistent current switch, clearly showed the whole resistance below $10^{-11}$ ohm, which can be used for all persistent mode applications like MRI and NMR as well as maglev trains.




Siemens Persistent Current Mode REBCO Coil

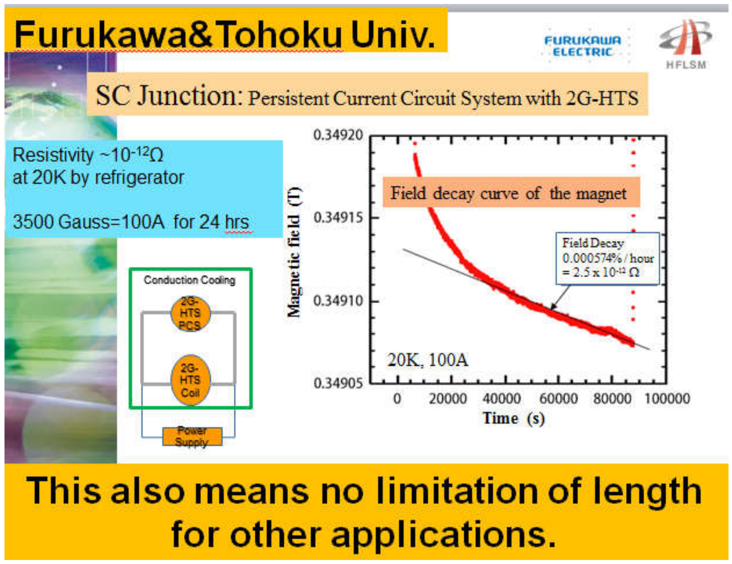
This achievement will impact the market strategy for electric power use because SMES (one promising application of superconductivity using persistent current mode) is possible and the superconducting joint method will not limit the conductor length, which will lower the unit length cost of the wire).[2] The main achievements are summarized below:

- Main magnet using 500m long REBCO tape, persistent current switch with 100m long REBCO tape
- Cryo-free system, Maximum field 1.3T in 17cm warm bore
- Persistent mode operation with system resistivity less than $10^{-11}$ ohm (enough for MRI application) at 20K for 20days with the operation current of 13A
- Fast operation of 3 minutes in open and 20 minutes in close for PCS operation

[2] *ASC 2016 presentation by M. Oomen, “HTS technology for high-field persistent current magnet systems” (9 Sept, 2016)*

# Furukawa succeeded in persistent current joint

Furukawa and Tohoku University announced in April 2016 a superconducting joint with properties described in the figure below (partially presented by Dr. Yamada in the IEA special session). They achieved low resisitvity and high persistent current of 100A for the persistent current mode operation using REBCO coil and PCS.




Superconducting Joint Property by Furukawa and Tohoku University

Like in the Siemens article above, this kind of activity has direct applications in MRI or NMR. At the same time, this progress will help develop low cost HTS wire by improving production efficiency; sometimes wire companies fail to make long continuous wire with high $I_c$, which is one cost factor. The joint techinque may solve this problem and can reduce the price of the wire.

If realized, the junction method would remove limitations on the length of the. Large applications would benefit from this in terms of the cost and delivery time, although the total resisitvity and the strength of the wire should satisfy the system requirement of the total loss and fabrication method.

These activities by Furukawa and Siemens open new possibilities for the HTS commercialization of the wire, including the power applications.[3]

# Airbus Research in All-Electric Aircraft Using HTS

Airbus Group and Siemens have signed a collaboration agreement in the field of hybrid electric propulsion. Airbus has been studying this concept for several years and the present project will continue until 2019. The main target is to improve the operational efficiency of the airplanes. The key factor is to use an HTS for generators inside, which can improve the energy efficiency of the airplane. These improvements are crucial to the future of airplanes, considering the environmental effect and cost or price competition among aircraft manufacturers.

[3] *"Persistent Current Junction of REBCO Wire" Press release (27 April 2016)* *https://www.furukawa.co.jp/release/2016/kenkai_160427.html (Japanese)*

Electric propulsion systems can significantly reduce fuel consumption of aircraft. European emissions targets aim for a 75 percent reduction of $CO_2$ emissions by 2050 compared to the values for the year 2000. These ambitious goals cannot be achieved by conventional technologies.[4]

## Italian FCL: detailed study on conductor type

Dr. Giuliano Angeli from RSE presented on their recent progress on a REBCO based SFCL. Their results clearly demonstrate the merit of using REBCO wire. They started R&D in 2014 and are currently studying REBCO SFCL as it compares to their former Bi-based system. The total length of the wire was reduced to 576 m (REBCO) from 1880 m (Bi) while the system specifications are the same (such as rated voltage of 9 kV and current limiting factor) and the rated current increased to 1000 A from 250 A. They are further verifying their results so that it can be energized on the grid.

Dr. Giuliano Angeli

One contributing factor to the difference in performance is the high resistivity of REBCO wire composed of Hastelloy (high resistive) materials compared to low resistive (highly conductive) Ag matrix in Bi wire.[5]

## Advanced Superconductor Manufacturing Institute

A new initiative in the United States called the Advanced Superconductor Manufacturing Institute is being led by the University of Houston. ASMI is a Texas not-for-profit entity, whose objective is to enable an industry-driven consortium to overcome the major technological barriers that inhibit the growth of HTS-based advanced manufacturing.

50 institutes are providing support for this consortium. This is a very timely initiative because many HTS wire companies have achieved the basic technique of long length wire production while further comprehensive efforts including application-side targets will be needed for efficient development including cost reduction. The consortium will promote R&D using industrially effective techniques to realize the fast commercialization of HTS applications.[6]

[4] *ASC 2016 presentation by F. Berg, "HTS system and component targets for a distributed aircraft propulsion system" (9 Sept, 2016)*

[5] *Giuliano Angeli, "Development of superconducting devices for power grids in Italy: update about the SFCL project and launching of the research activity on HTS cables" (9 Sept, 2016)*

[6] *ASC 2016 presentation "The Advanced Superconductor Manufacturing Institute" by Dr. Venkat Selvamanickam at IEA special session (9 Sept, 2016); http://superasmi.com/*

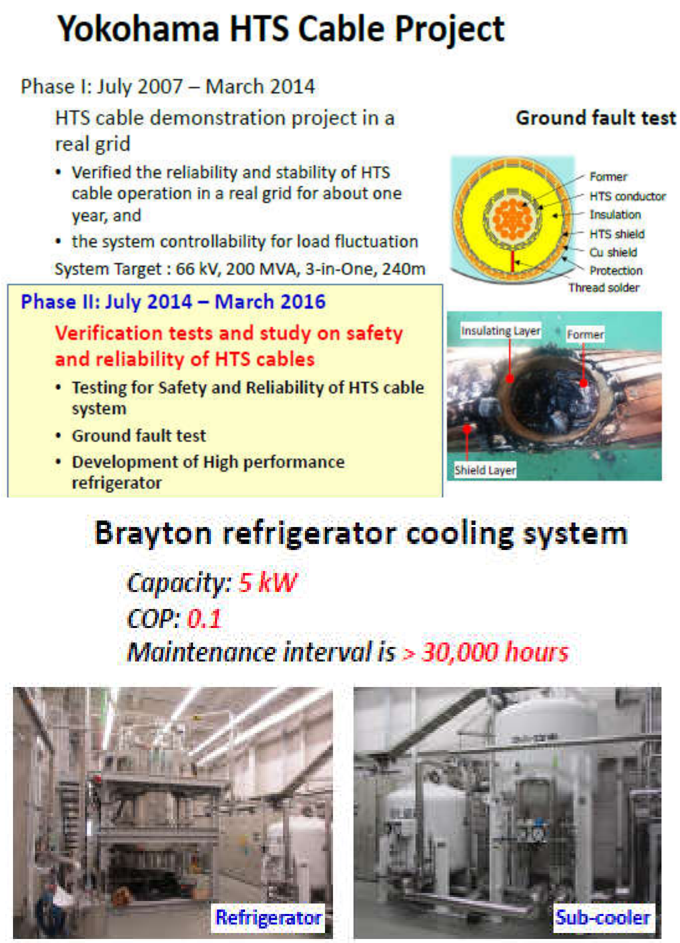
# TEPCO and SEI Cable R&D for Reliability

The Yokohama cable project has been verifying the safety and reliability of HTS cables and developing Brayton refrigerator (see figures on the right).

This year NEDO started a new project, which was presented by Dr. Ohsaki and Dr. Ohya of SEI. The new project has two main components:

1. HTS Power Transmission Cable Systems for Practical Application (2016 –2018)
    - safety evaluation test methods
    - guidelines for quick recovery from accidents and failures
    - low heat invasion technology
    - highly efficient cooling systems
    - COP > 0.11, Inspection period: 40,000 h
2. DC Power Transmission Cable System: Operational tests, and design/operation/maintenance guidelines (2016)

The contractors are Tokyo Electric Power HD, Sumitomo Electric Industries, Furukawa Electric Industries, Mayekawa MFG and I-SPOT.




TEPCO cable R&D for verification and refrigerator system (~2016). A new project started in 2016 based on this work. *Source: Prof. Ohsaki's presentation*

Besides the above items, the project includes R&D for "basic technology development of HTS power cable systems for transportation" and "High Magnetic Field Magnet System Development". The timeframe for this project is June 2016–February 2021 and a budget of 8.1 B yen (1.5 B yen for FY2016)[7]

[7] *ASC 2016 presentation by Ohsaki (IEA session) and by Ohya "Study on safety and reliability of HTS cable system" (7 Sept, 2016); related source:"NEDO started new project for accelerating the industrialization of HTS for main 4 applications" (17 May, 2016) (in Japanese)*

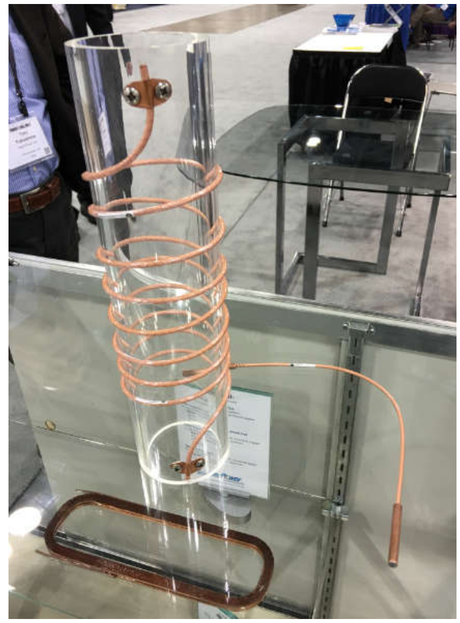
## REBCO and $MgB_2$ Combined Conductor

Other than FCL and Cable, new types of combined REBCO and $MgB_2$ conductors were explored. One example was for ROEBEL and CORC conductors, but many other types were presented for large current applications.[8]

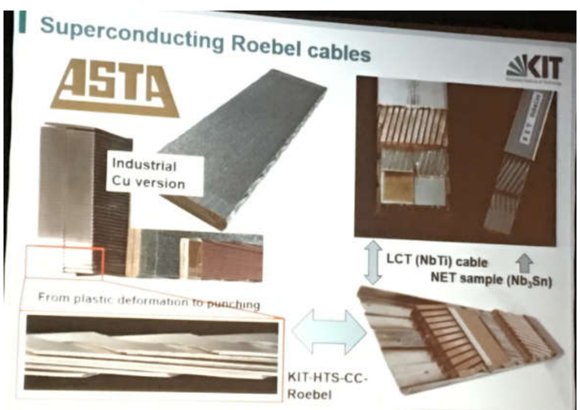
This type of R&D was well-known for the $MgB_2$ bus bar activity in the Best Paths project, and for the application of accelerators in ITER and CERN. This time, similar R&Ds are increased using REBCO wire.

REBCO wire is difficult to use for simple magnet applications because of its rectangular and thin tape form. However, using combined form or shape, some have been trying to improve the mechanical or AC loss properties. This also realized the round shape which can be easily wound to a coil.

SMES applications also need a large capacity and these kind of combined conductor activities will benefit these power applications.



Cable using CORC conductor at Superpower/ Furukawa exhibition booth





Various types of REBCO conductor for high current using ROEBEL and CORC conductors

[8] *ASC 2016 presentations (5 to 9 Sept, 2016): For example, "Special Session: HTS high current cables I- IV"*

## Recent Activity in China

Recent activities in China on HTS R&D were summarized by Dr. Xiao and shown in the table below. Dr. Yamada will expand on these activities in the next IEA HTS TCP newsletter based on his travel to China.

**Research Teams for Large-Scale Applications (15 Teams)**

| Research Institute or Company | Research Activities |
|---|---|
| IEE-CAS | FCL, Cable, SMES, Transformer, Electric Machine, NMR, MRI, High Field Magnet, accelerator magnet, Fusion Magnet and other applications |
| HUST | FCL, SMES, Electric Machine |
| WHI-712 | Electric Machine |
| Tsinghua Univ | MRI, Cable, FCL, SMES |
| Tianjing Univ/Innopower | Cable, FCL |
| CEPRI | Cable, SMES, FCL |
| NCUEP | Cable |
| SWJTU | Maglev |
| SICT | Cable |
| Western Superconductor | MRI, High Field Magnet |
| Hefei-CAS | Fusion Magnet, High Field Magnet |
| IHEP-CAS | Accelerator Magnet, MRI, ADS magnet, Magnetic separation |
| IMP-CAS | Accelerator Magnet, ADS magnet |
| IAEC | cyclotron accelerator magnet |
| TIPC-CAS | Fusion Magnet, high field Magnet |
| SIAP-CAS | Magnet for FEL, Cavity |

Chinese recent activity on large scale applications (Xio at ASC 2016). Courtesy of Xio, IEE-CAS

China has more than 10 wire companies developing HTS and LTS wires using various methods. Their goals are to reach 1 km length and an $I_c$ of 100-200A, which is similar to other worldwide goals.[9]


REBCO wire facilities at Shanghai Superconductor Technology Corporation (SSTC), photo courtesy of SSTC

[9] *Source: ASC 2016 presentation by Xiao, "Recent research activities of applied superconductivity in China" (9 Sept, 2016) and the visit to SSTC and SCSTC*