EUCAS 2015
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Lyon Convention Centre

Yokohama Project
(240m, 66kV, 200MVA HTS cable)

Special Session (2A-LS-O1.3)
Large Scale – Industries and utilities

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Ingenious Dynamics

1. Backgrounds

2. Demonstration Project (2007-2013)
-Japan's first live power transmission-

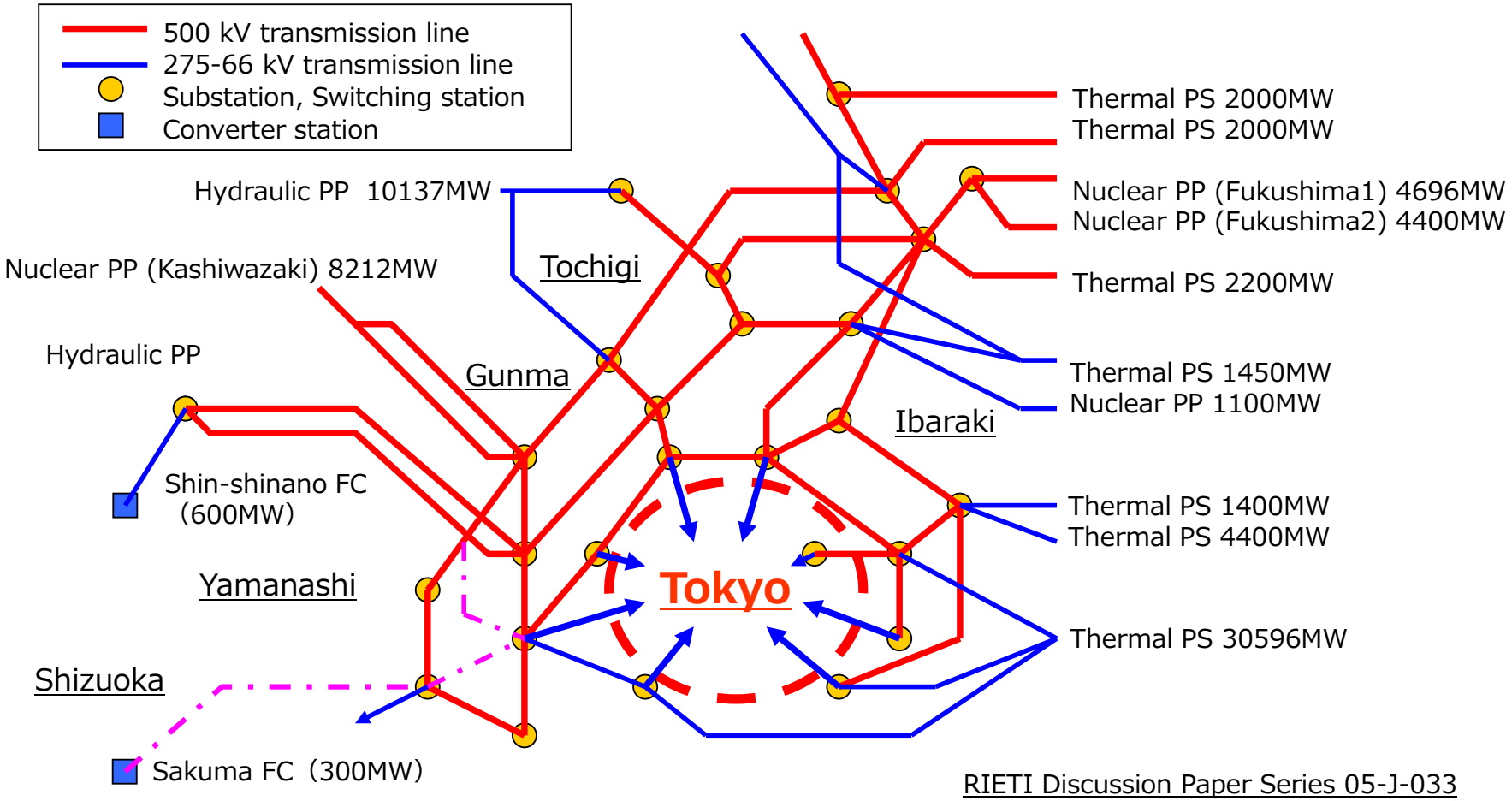
3. New Project (2014-2016)
-safety and reliability-

Background

Japan's Power grid and HTS cable

Power transmission grid (Japan)

- Power stations → Orbital lines : 500 kV overhead lines
- Orbital lines → Urban area : 275～66 kV underground cables



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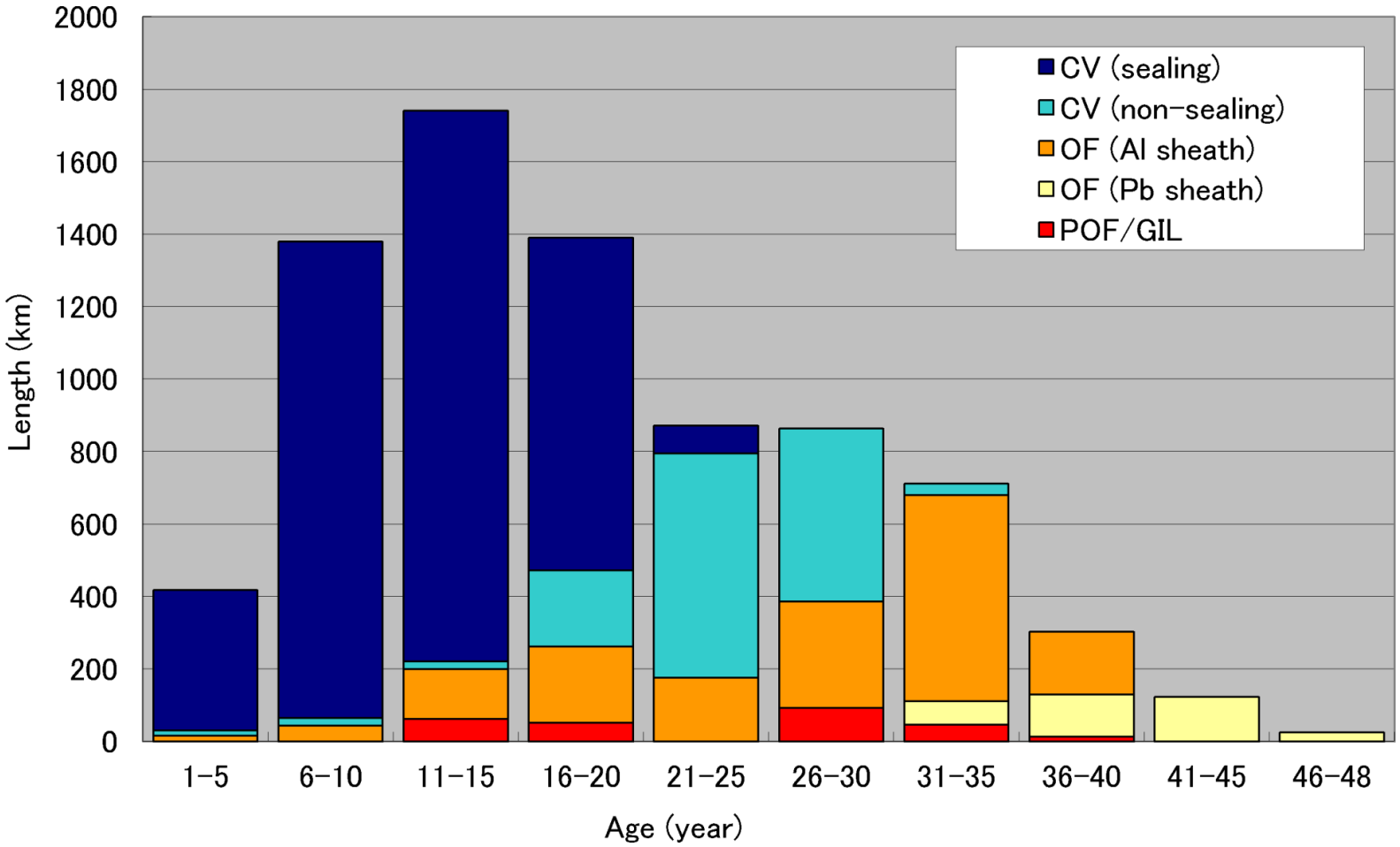
Power transmission grid (Japan)

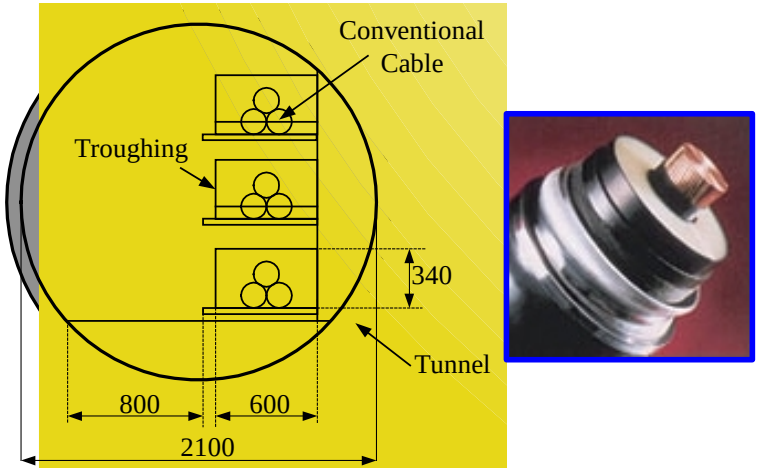


- For OF cables, 20 years have passed since the installation.
- The replacement of OF cables is planed around 2020.

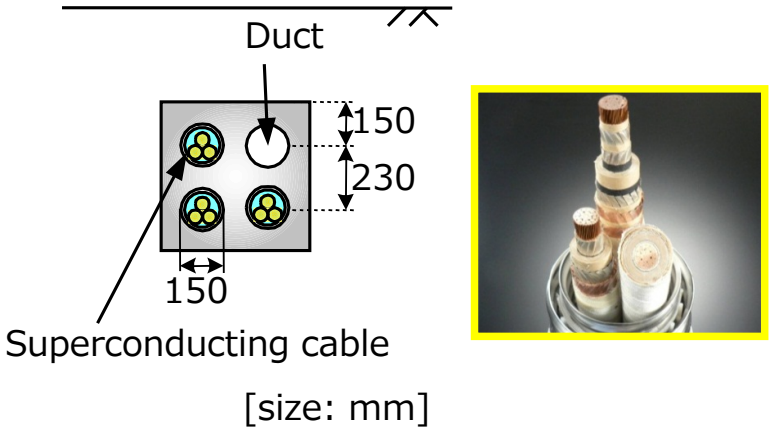
Motivation for HTS cables

Replacement of old OF cables with increasing capacity

CV cables
Tunnel image
275kV, 700MVA/3cct



HTS cables
Duct installation image
66kV, 700MVA/3cct



[size: mm]

Installed within existing conduits

Reduction of initial costs of HTS cable system

"High density" → reduction of civil engineering costs
"Low loss" → reduction of cooling system capacity

Development of HTS cables @SEI

1993

3-ph. energization (7m, 1kA)

1995

Withstand test (50m, 66kV)

1996-1999

30m prototype test (66kV-1kA, 1-ph.)

2000

Long-term test of 100m 3-in-One HTS cable (66kV-1kA, 114MVA)

2004

Over-pressure

2006

KEPCO project (100m, 22.9kV-1.25kA)

2006

ALBANY project "World's first in-grid" (350m, 34.5kV-0.8kA)

2007-2012

Yokohama project (250m, 66kV-3kA)

Demonstration Project

Japan's First Live Power Transmission

Outline

High temperature superconducting cable demonstration project

July 2007 ~ March 2014 (7 years)

Purpose

- To verify the **reliability and stability of HTS cable operation** in a live grid (**one year operation**)
  - System controllability for load fluctuation
  - Monitoring and alarming system
  - Maintenance method while cable is online

Budget

3.1 B¥ (26 M$) for 7 years

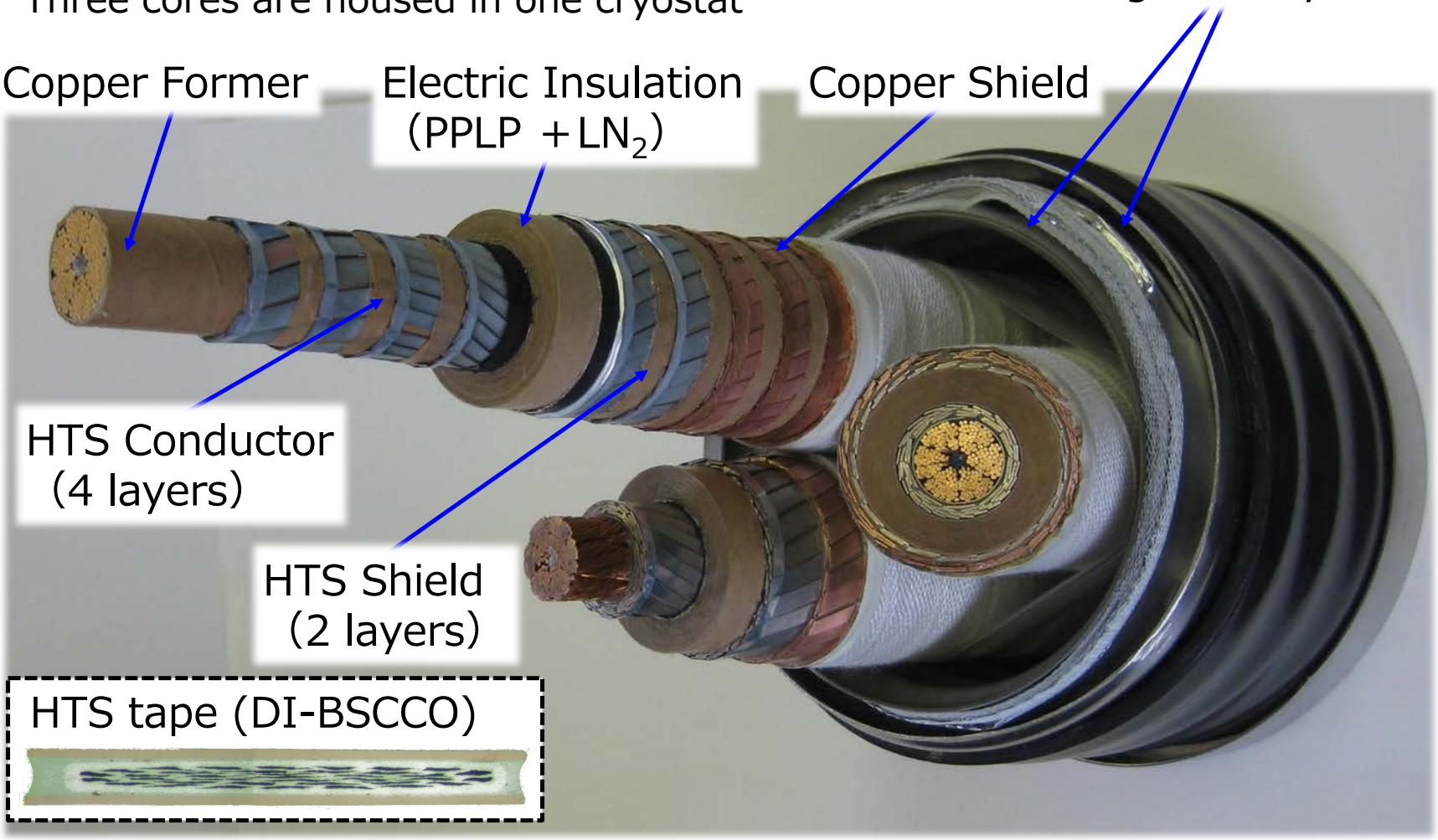
Member

NEDO (Project management)
TEPCO (Utility, Project leader)
Sumitomo Electric (Cable manufacturer)
Mayekawa Co. (Cooling system manufacturer)

Cable structure

3-in-One Type HTS Cable

Three cores are housed in one cryostat



System layout

240 meter HTS cable

Joint

Cable-B

Cable-B

Cooling system house

Trans 154/66 kV 200 MVA

Site office

Monitoring house

Existing 66 kV XLPE cable

Termination-B

Termination-A

CB2 CB1 LS2 LS1 LS3 CB

Existing 66 kV bus line

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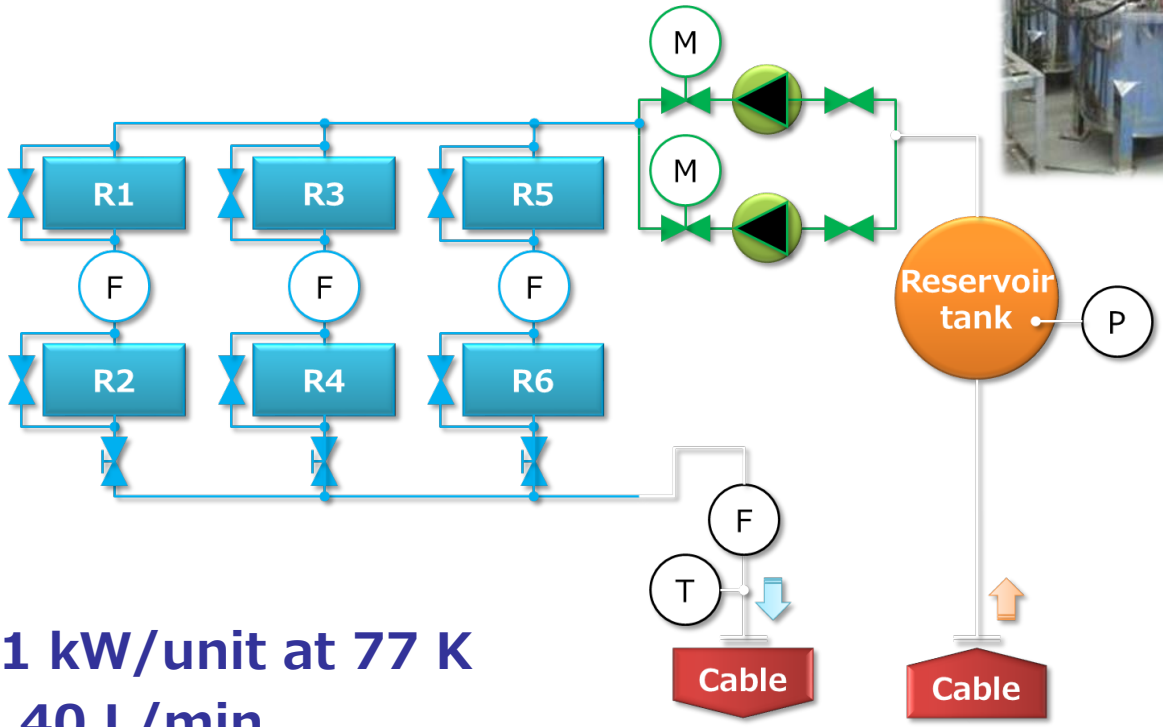
Cooling system

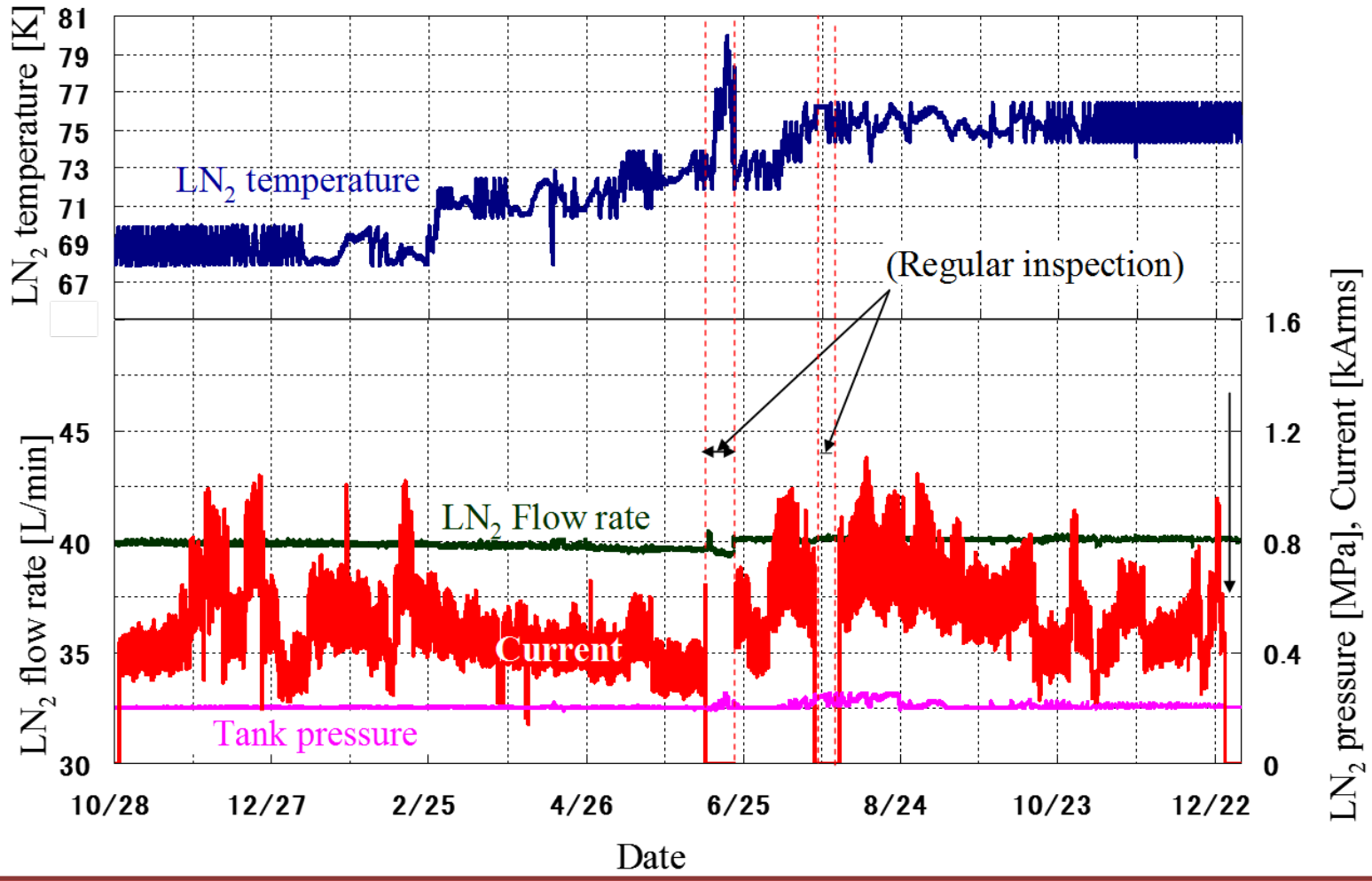
6 refrigerators and 2 circulation pumps for redundancy



- Capacity: 1 kW/unit at 77 K
- Flow rate: 40 L/min
- Pressure: 0.2～0.25 MPaG
  (Internal pressure of the reservoir tank)


October 29,2012
15:22
SW ON

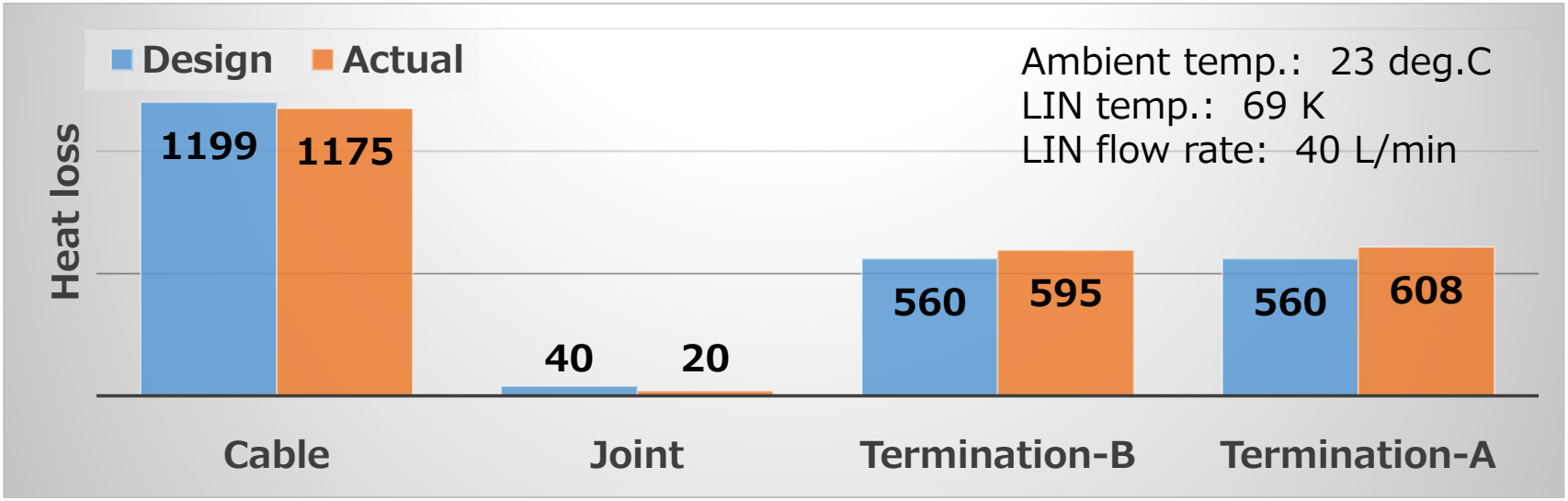
In grid operation (October 2012 – December 2013)



- The cable transmitted electricity to 70,000 house holders without any unplanned interruptions or failures.

①Heat loss at no load

Heat loss from ambient is measured and has good agreement with design (2.4 kW)



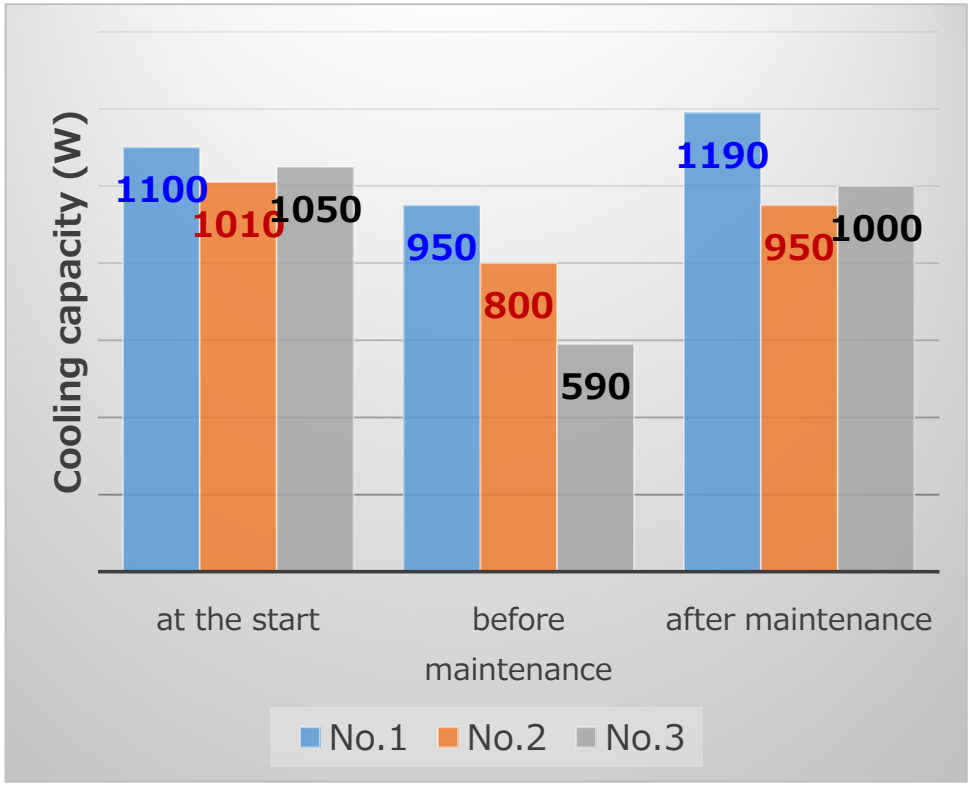
Cable

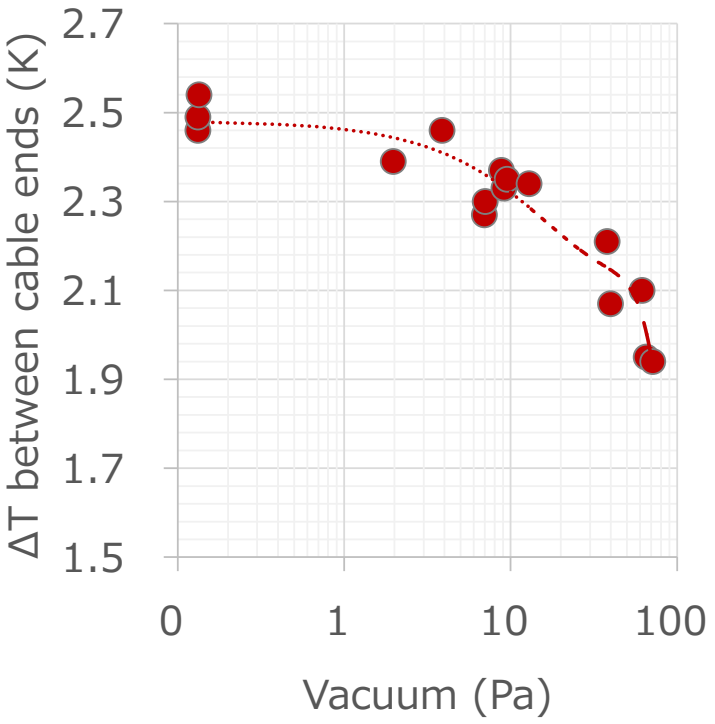
Straight section: 3 W/m
Bending section: 10 W/m
→increase by side force

□ **Heat loss reduction is essential for real product**

②Performance of refrigerator

Cooling capacity degraded during in-grid operation





- Evacuating vacuum vessel: 30～100 W/unit improving
- Factory's maintenance: 150～400 W/unit improving
- The improvement maintenance interval is essential

③Performance of cooling system

System COP = [cooling power] / [power consumption]
= 0.042

Cooling power	**2.53 kW**
Power consumption	**60.32 kW**
(Refrigerator)	55.38 kW
(LIN pump)	0.28 kW
(Cooling water)	4.66 kW

- **For bringing HTS profit into commercial use, system COP must reach to 0.1 or more**

  - **Improve refrigerator efficiency**
  - **Reduce number of valves and piping**

Remaining issues

Items	Results	Future efforts
Cryostat	Straight: 3 W/m Bending: 10 W/m	**Development of low heat loss cryostat** ・1.0 W/m level
Refrigerator	Increase of heat loss and degradation of cooling power (vacuum degradation)	**Improvement of performance of refrigerator (Brayton refrigerator system)** ・Higher efficiency ・Larger cooling capacity ・Longer maintenance interval
Safety verification	No serious accident	**Verification of safety and reliability against accidents** ・Ground fault ・Short-circuit current ・Cryostat damage

New Project (2014-2016)
-safety and reliability-

Outline

Studies on the safety and reliability of the next-generation power transmission system

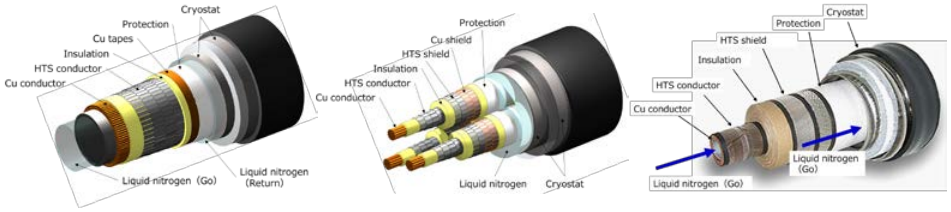
July 2014 ～ March 2017 (3 years)

Purpose

- To verify **the safety and reliability of HTS cables at accidents** by conducting model tests with actual dimension cable for 22 kV, 66kV and 275 kV class.
- To develop **5 kW class Brayton refrigerator system** with higher performance and to confirm its stable operation in the grid at Asahi SS.

Budget

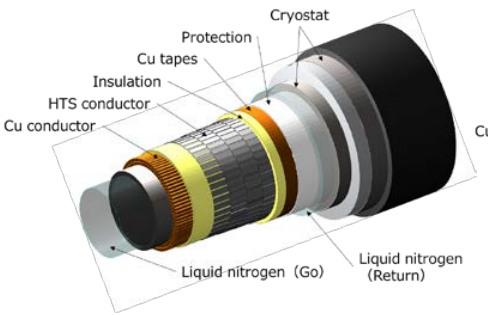
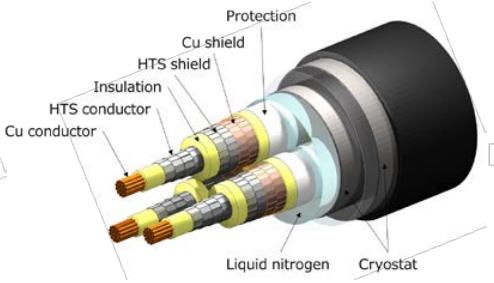
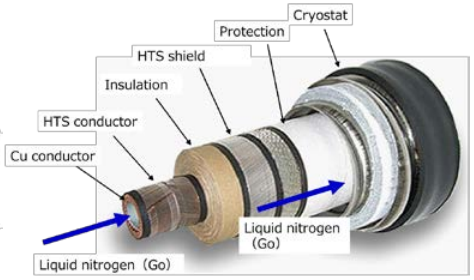
1.2 B¥ (10 M$) for 3 years



Member

NEDO (Project management)
TEPCO (Utility, Project leader)
Sumitomo Electric, Furukawa Electric, Fujikura (Cable manufacturer)
Mayekawa Co. (Refrigerator manufacturer)

Cable specifications

Items	22 kV/12 kA	66 kV/2 kA	275 kV/3 kA
Structure	 **Single**	 **3-in-One**	 **Single**
Made by	SEI	SEI	Furukawa, Fujikura
Application	Feeder line of generator	Urban underground	Urban underground
Neutral grounding	Resistance	Resistance	Solid
Ground fault current	about 100 A	~ 1500 A	~ 31.5 kA (underground) ~ 63 kA (overhead)
Short-circuit current	~ 63 kA	~ 31.5 kA	~ 63 kA

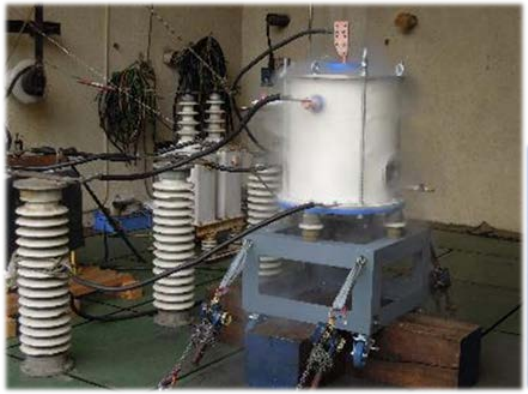
Member and research items

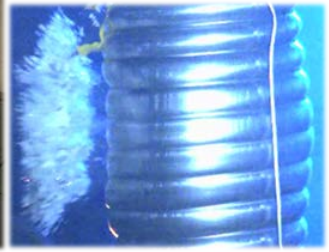
Research items		TEPCO	SEI	Furukawa	Fujikura	MYCOM
① : Testing for Safety and Reliance						
Design and Plan of testing method		◎	○	○	○	○
Short-circuit current test	22 kV		◎			
	66 kV		◎			
	275 kV			◎	○	
Ground fault test	66 kV		◎			
	275 kV			◎	○	
Cryostat damage test	Vacuum deterioration		◎	◎		
	LN_2 leakage		◎			
② : Development of High Performance Cooling System						
Low loss cryostat		○	○			◎
High efficiency cooling system		○	○			◎
③ : Study on recovery method		○	◎	○		○

Research items

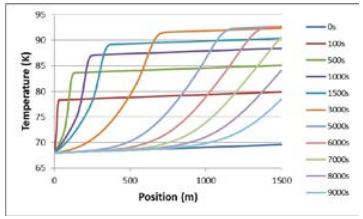
Safety & reliability verification

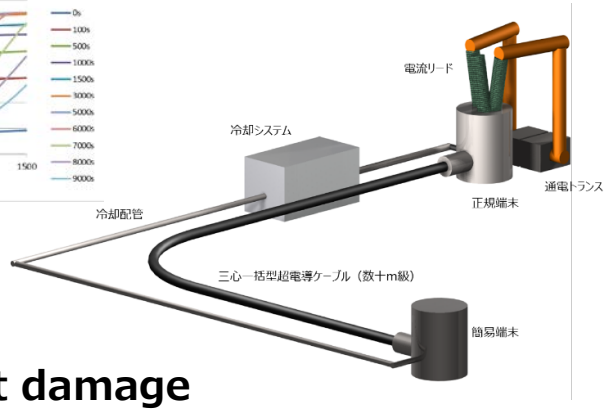
- Ground fault





- Short-circuit current

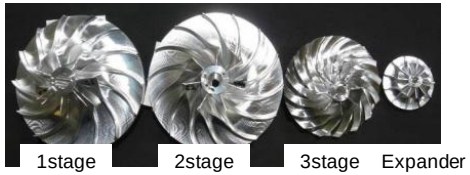




- Cryostat damage

Brayton refrigerator system

- Large capacity: 5 kW
- High COP: 0.1
- Maintenance interval: 30,000 H



Low loss cryostat

- Heat loss: 1.0 W/m

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Conclusions

- **Demonstration project**
  - Stability and reliability in normal operation has been verified by real grid interconnection tests.
  - Development of a high efficiency cooling system and a low loss cryostat is essential for practical use.
- **New cable project**
  - The aim is to verify and improve the safety and reliability of HTS cable systems in the event of the following accidents: (1) ground fault, (2) short-circuit current, (3) cryostat failure.
  - We are also developing technologies such as (4) a low heat loss cryostat and (5) a high efficiency cooling system.