Current Status of HTS Power Devices Development at KEPRI

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Current Status of HTS Power Devices Development at KEPRI

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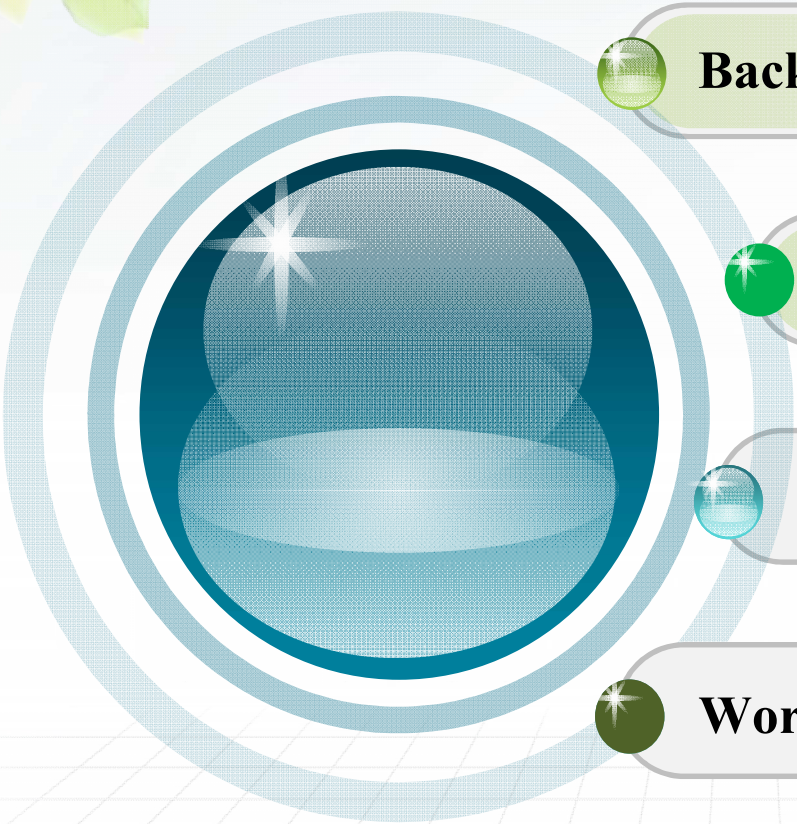
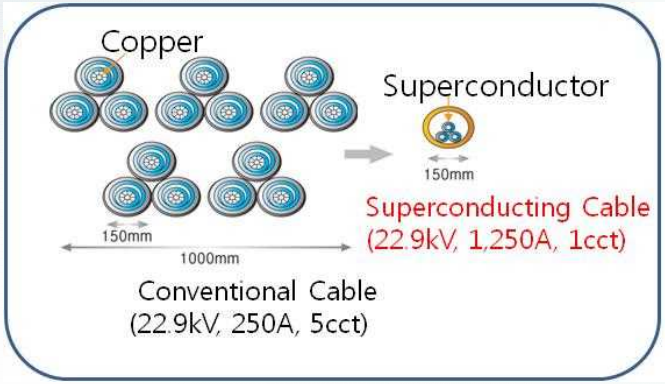


Merits of HTS Power Device

HTS Cable



With large capacities can efficiently transmit electric power (Over 5 times)

Replaces conventional cable in already existing ducts and tunnels without the expense of new infrastructure

Solves of available room lack of Ducts and Tunnels

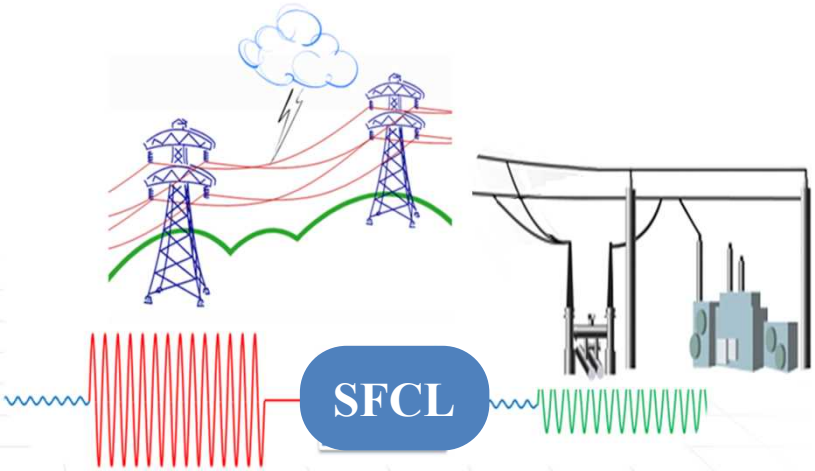
SFCL

Limits fault current rapidly, using superconductivity

Limits fault current within 1/8 cycle

Nearly no impedance

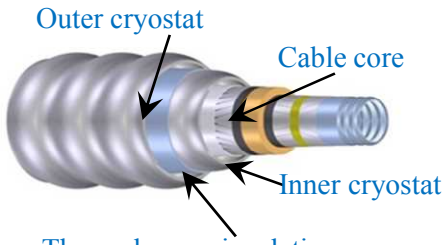
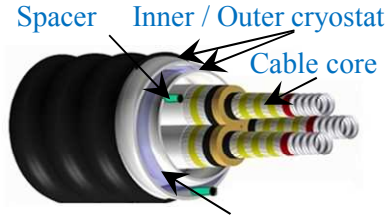
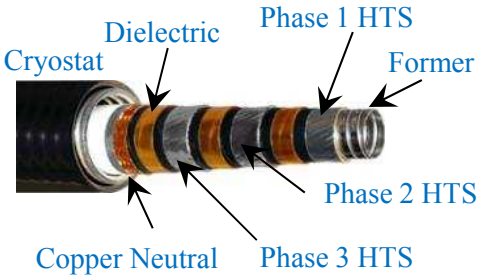
Impoves power system stability



SFCL: superconducting fault current limiter

HTS Cable

Types of HTS Cable

Rated value	Use	Type	Remark
1 phase cable (1 core, 1 shield, 1 cryostat) 	High capacity High voltage (higher than ~138 kV class)		Developed - AC 154kV 600MVA - DC 80kV 500MW (2016)
3 core cable (3 cores, 3 shields, 1 cryostat) 	High capacity Mid voltage (higher than ~66 kV class)		Developed - AC 22.9kV 50MVA/120MVA (2013)
Co-axial cable (1 core, 1 shield, 1 cryostat) 	Mid capacity Mid voltage, low voltage (13.8 kV~50 kV)		Next Plan (AC 23kV 50MVA) (2017~2021)

* Co-axial cable standard, supposition of same capacity

History of HTS Cable Projects

R&D → Demo (in grid) → D/B

2001 2007 2011 2012 2013 2014 2015 2016

22.9kV 50MVA

154kV 1GVA

22.9kV Cable
Operation & Long term evaulation

22.9kV 50MVA 410m

22.9kV 120MVA 100m

22.9kV Demo.

Icheon Project (08.11~13.10)

Fault diagnosis method
Long term operation

Icheon II (14.06~17.10)

JeJu Project (11.07~16.10)

80/154kV Class Demo.

AC 154kV Cable, 1km

DC 80kV Cable, 0.5km

KEPCO LS

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Development of HTS Cable Cooling System

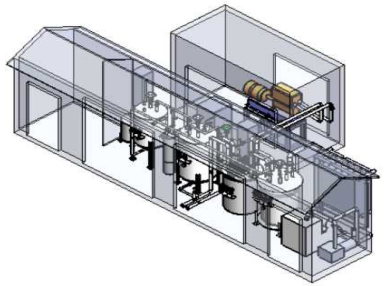
R&D (Go-chang) → Demo. (Grid) → Up Grade

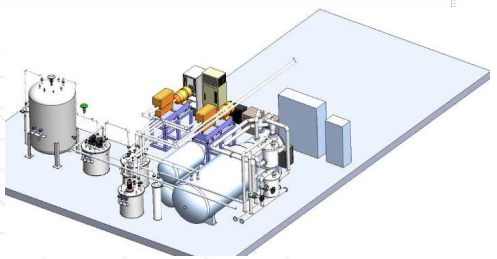
[R&D]

Decompression System	Decompression+Stirling System	Stirling / Brayton System
(3kW@66.4K, 2006~2008)	(6kW@66.4K, 2008~2012)	(3kW@69K, 2008~2012) (12kW@69K, 2013~2016)

[Demo.]

Icheon 22.9kV 50MVA (6.5kW@69K, 2011)	Icheon 22.9kV 120MVA (6kW@69K, 2013)	JeJu DC80kV 500W (6kW@69K, 2014)	JeJu AC154kV 600MVA (12kW@69K, 2016)





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Testing Facitily [Go-Change Testing Center]

➢ HTS Cable, Cooling system test facility

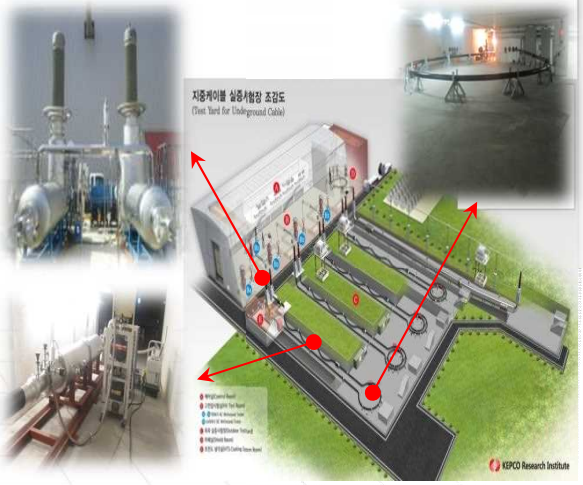
: Proof of the technical suitability of HTS cable tech.

[HTS Cable system Research]

[HTS Cable Type & PQ test]

Test	test criteria	Remark
Pressure Test	14 bar	TB538
Load cycle test	2Uo/20 cycles (8hr rated current/16hr no load)	
Impulse test	±750kV/10times	
AC dielectric test	2.5Uo/30min	

* AC 154kV 600MVA (1km)



[Testing of HTS Cable]

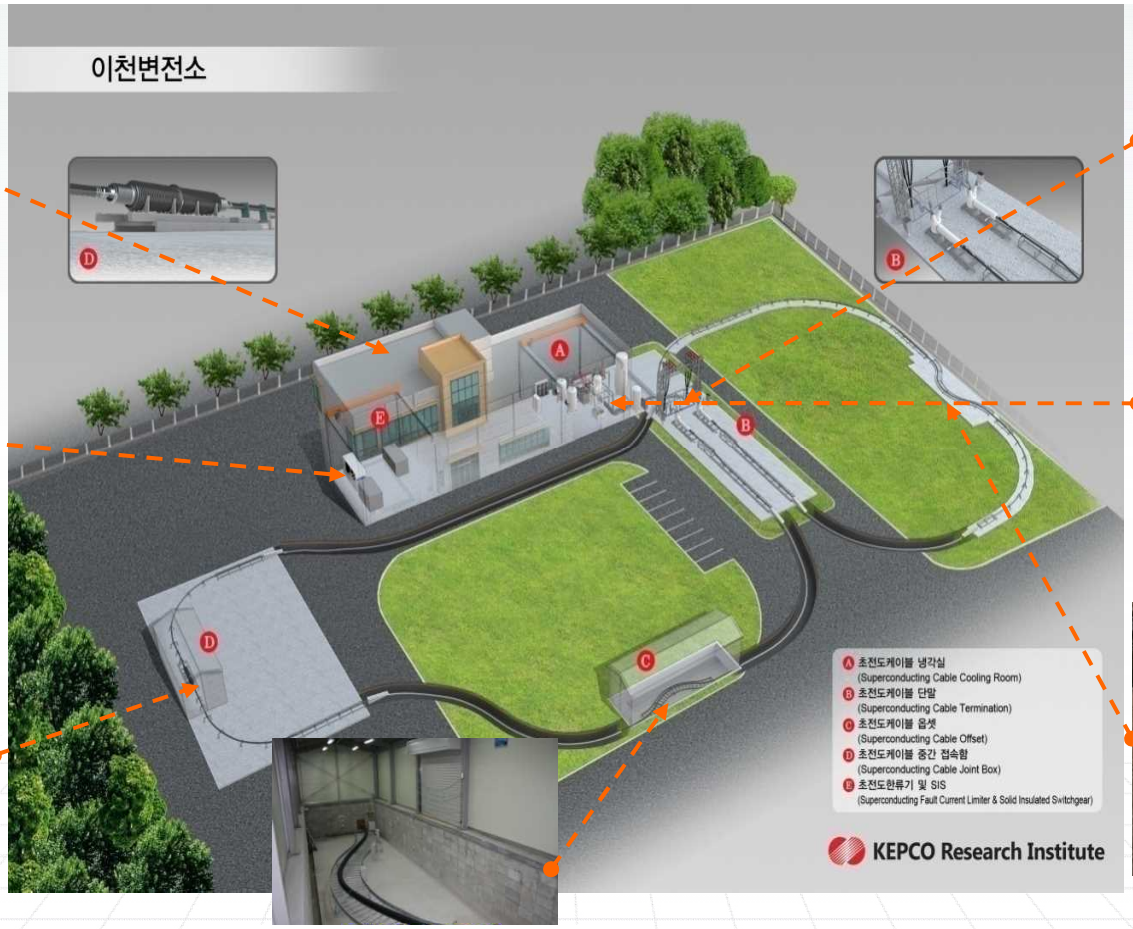
HTS Cable Demonstration (22.9 kV, 2013)

Icheon Substation
Norminal Votage AC : 22.9kV, Capacity: 50MVA, Length : 410m

Control Center

SFCL

Joint



Snake Installation

Termination

Cooling System

Ground Offset

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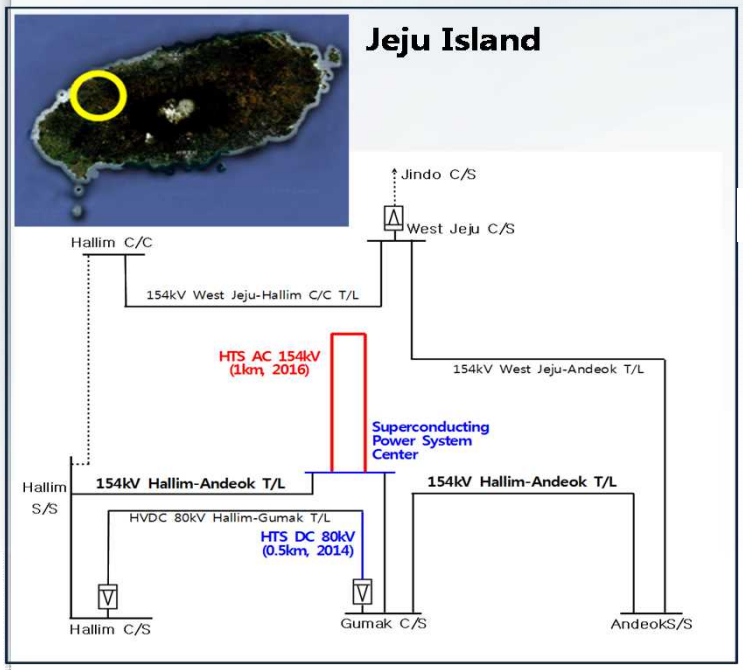
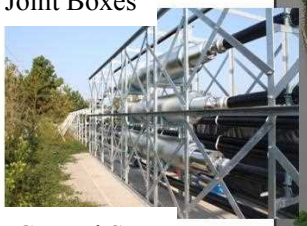
HTS Cable Demonstration (AC 154kV, 2016)

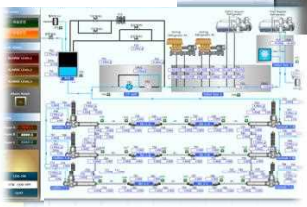


Terminations

Joint Boxes



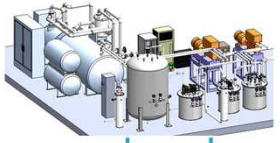
Control Sys.



Cryocooler

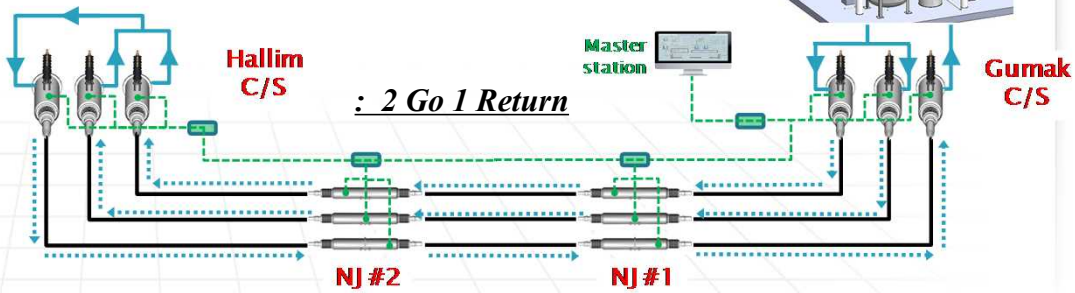
Cryocooler

Cooling Sys.



◆ Operation Condition (Design)

- Cable Length : 1km (3phases, total : 3km)
- System Loss : 12 kW
- LN2 Flow : 0.6 ~ 0.7 kg/s (2Go-1return)
- Inlet/outlet Temp. : 68 K / 76 K
- Inlet/outlet Pres. : 14 bar,g / 5 bar,g
- Cryocooler : 2 Stirling Coolers (3.2kW @ 69K) + Brayton Cooler (8kW @ 69K)



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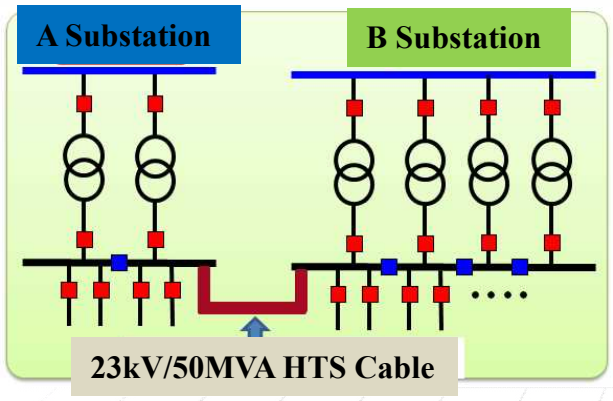
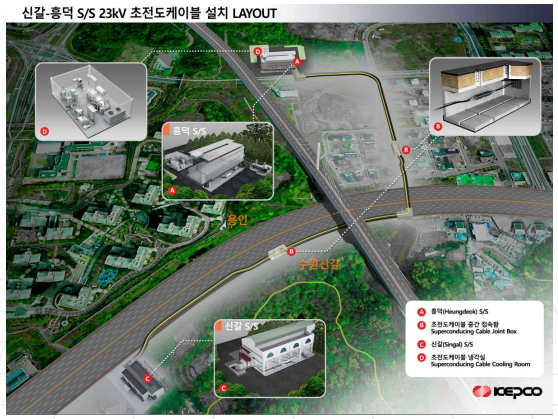
Commercial Project (Shingal Project)

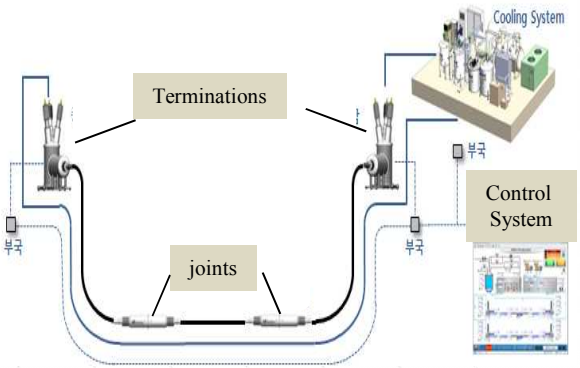
Test (Go-Chang) → Demo. (Grid) → **Commercialization**

Shingal Project (First Commercial Project)

- Period : 2016 ~ 2018
- System : AC 23kV 50MVA 1km-cct
  Cooling System : 7.5kW @69K (LN2 Circulation cooled by Turbo Brayton Cryocooler)
- Budget : US 10M (100% funded by KEPCO)
- B-Model : Sharing Power Supply Capacity by Connecting 23kV HTS Cable between Substations



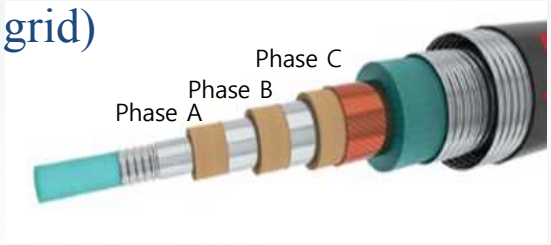




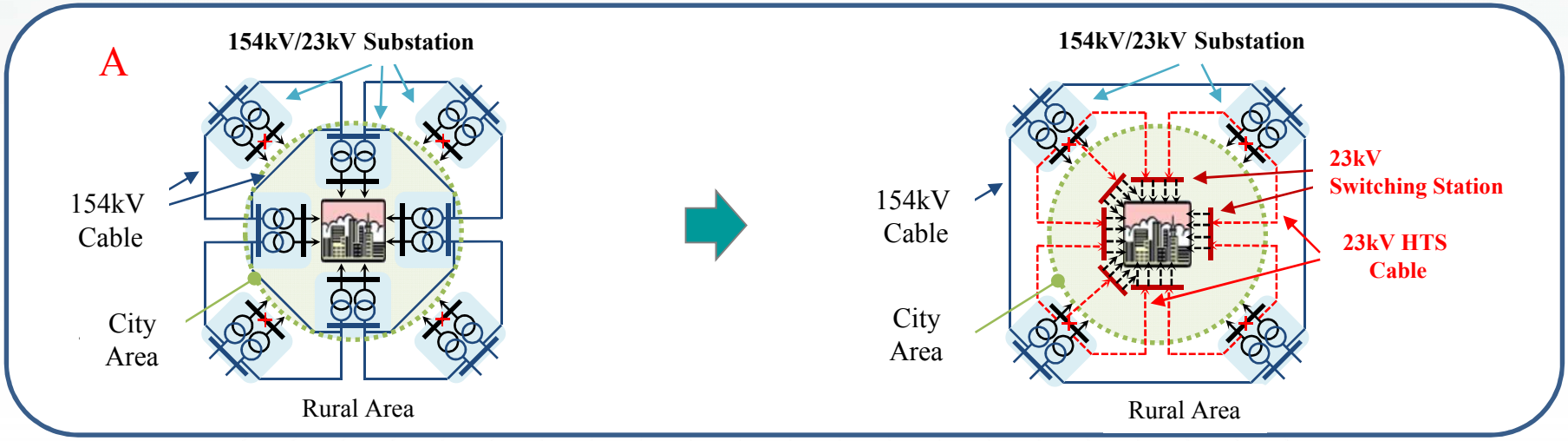
Next Project (23kV Co-axial HTS Cable, 2017~2021)

◆ Developing a new grid model using HTS Cable with economic benefits

- 23kV 50MVA Co-axial HTS cable development & demo.(in grid)
- Cooling system development for long length (~ 3km)
- Economic benefit analysis



◆ Biz-models

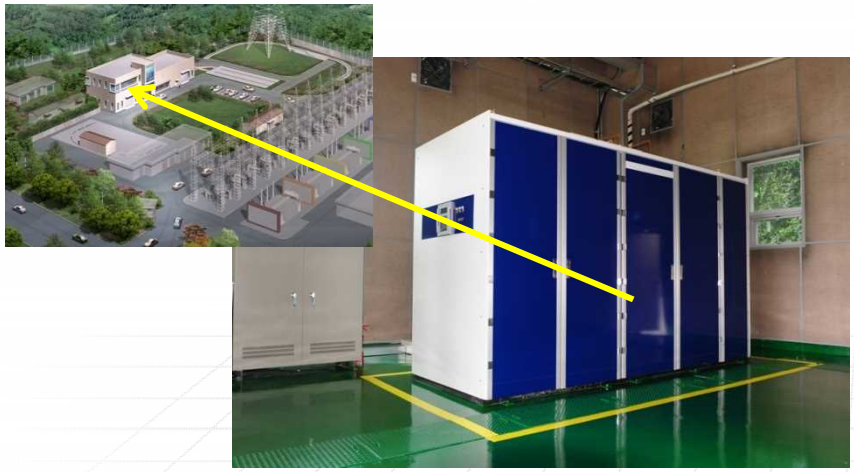


SFCL

Superconducting Fault Current Limiter

SFCL development in KEPRI

- **Developed 22.9 kV/630 A SFCL (2007)**
- **Installed and operating 22.9 kV/630 A in Icheon S/S (2011~)**
- **Developed 22.9 kV/3,000 A SFCL (2010)**
- **Developing 154 kV/2,000 A SFCL (2011~)**

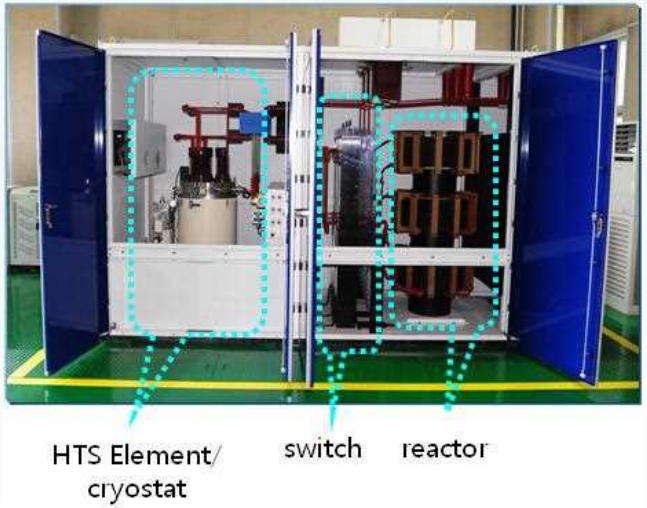


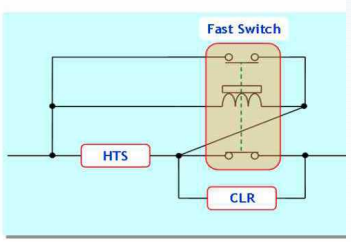
22.9 kV/630 A SFCL in Icheon S/S

154 kV 1Φ SFCL installed in Gochang

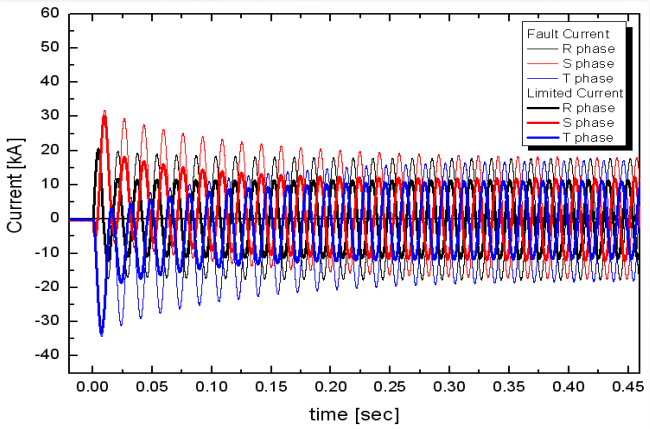
Fabrication and grid-application of 22.9 kV SFCL

- Design and fabrication: rated current 630 A, for feeder application.





Circuit diagram

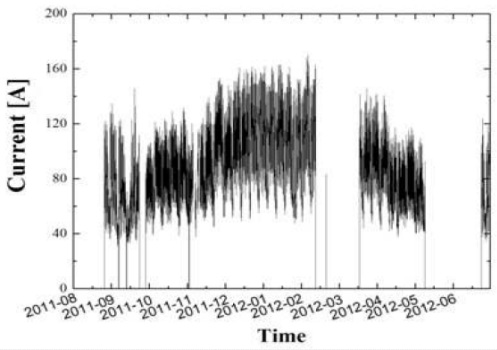


Current limitation data
(Thin line: with SFCL, thick line: without SFCL)

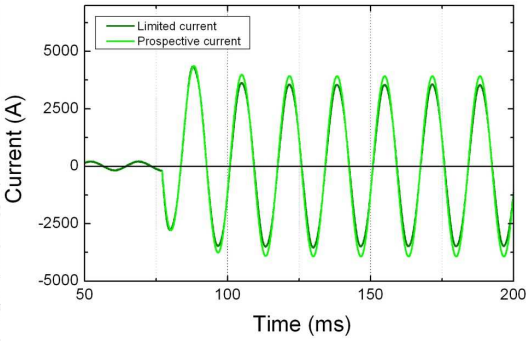
- Grid-application: installed and under operation on a D/L in Icheon Substation

SFCL under operation in Icheon S/S

Location of
SFCL application



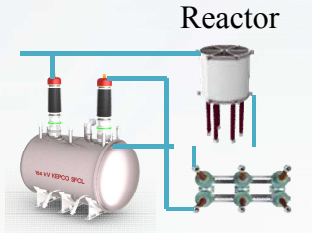
Load current in SFCL



Limited and estimated prospective
fault current for phase S

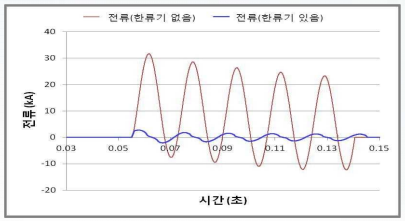
Development of 154 kV SFCL

- **154kV/2,000A class**
- **System configuration & specifications**



Rated voltage	**170 kV**
Rated current	**2,000 A**
Limitation rate	**> 40 %**
Limitation time	**1.7 sec**
Operation temp.	**71 K**

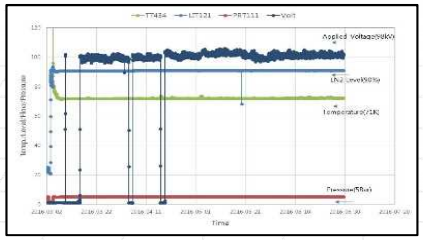
- Design, fabrication and test of components
  - **Limits short-circuit current effectively.**
  - **Designed cooling & 170 kV-class insulation**



< Short-circuit test on superconductors >

- Installed a 154 kV 1Φ SFCL prototype at Gochang **Power Testing Center**
- **Testing for long-term performance**

<154 kV 1Φ SFCL>



<Operation data>

Future plan

- Continue to test on 154 kV 1Φ SFCL
- **Demonstration of a 154 kV 3Φ SFCL (by '19)**
  - The site to be determined

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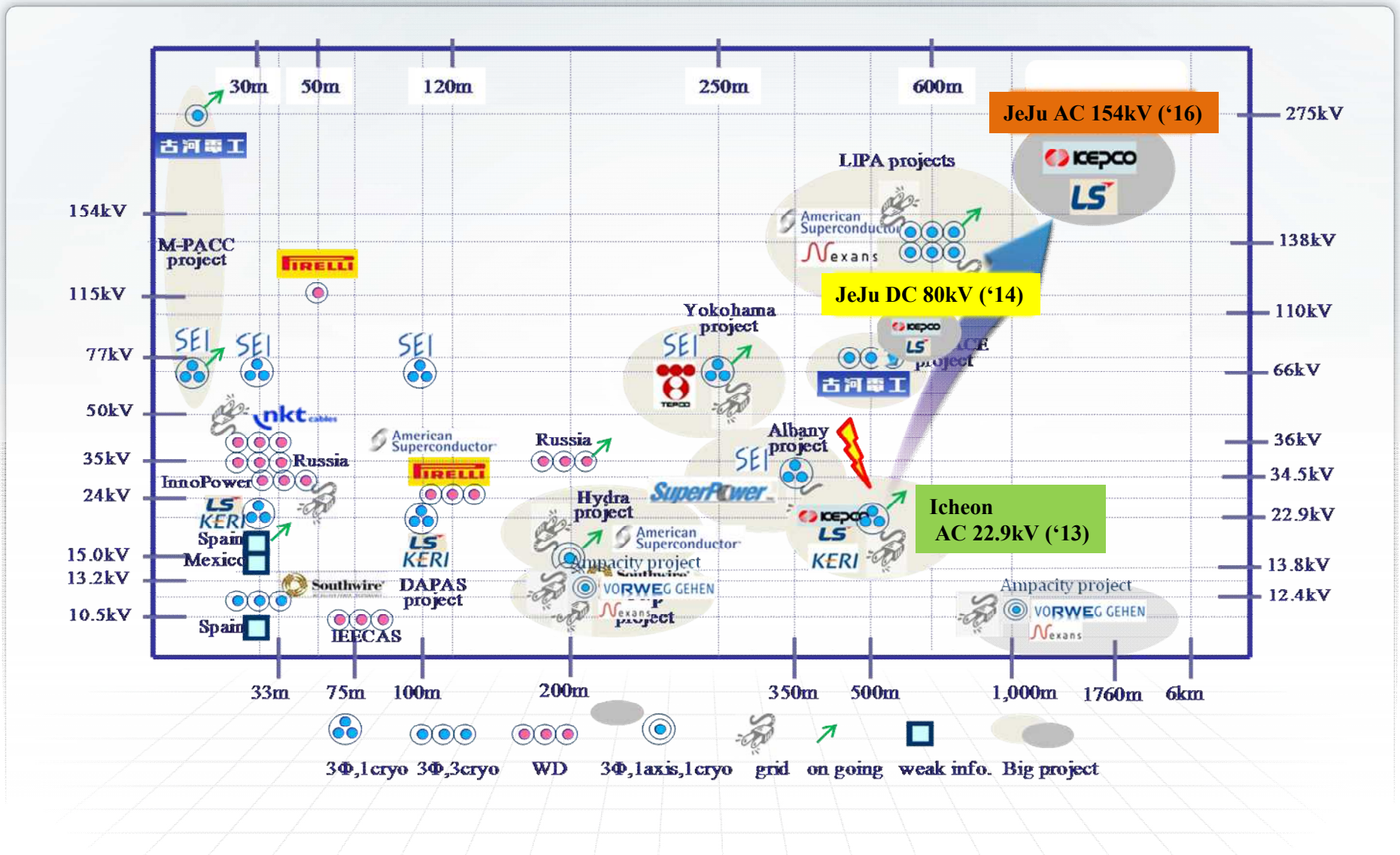
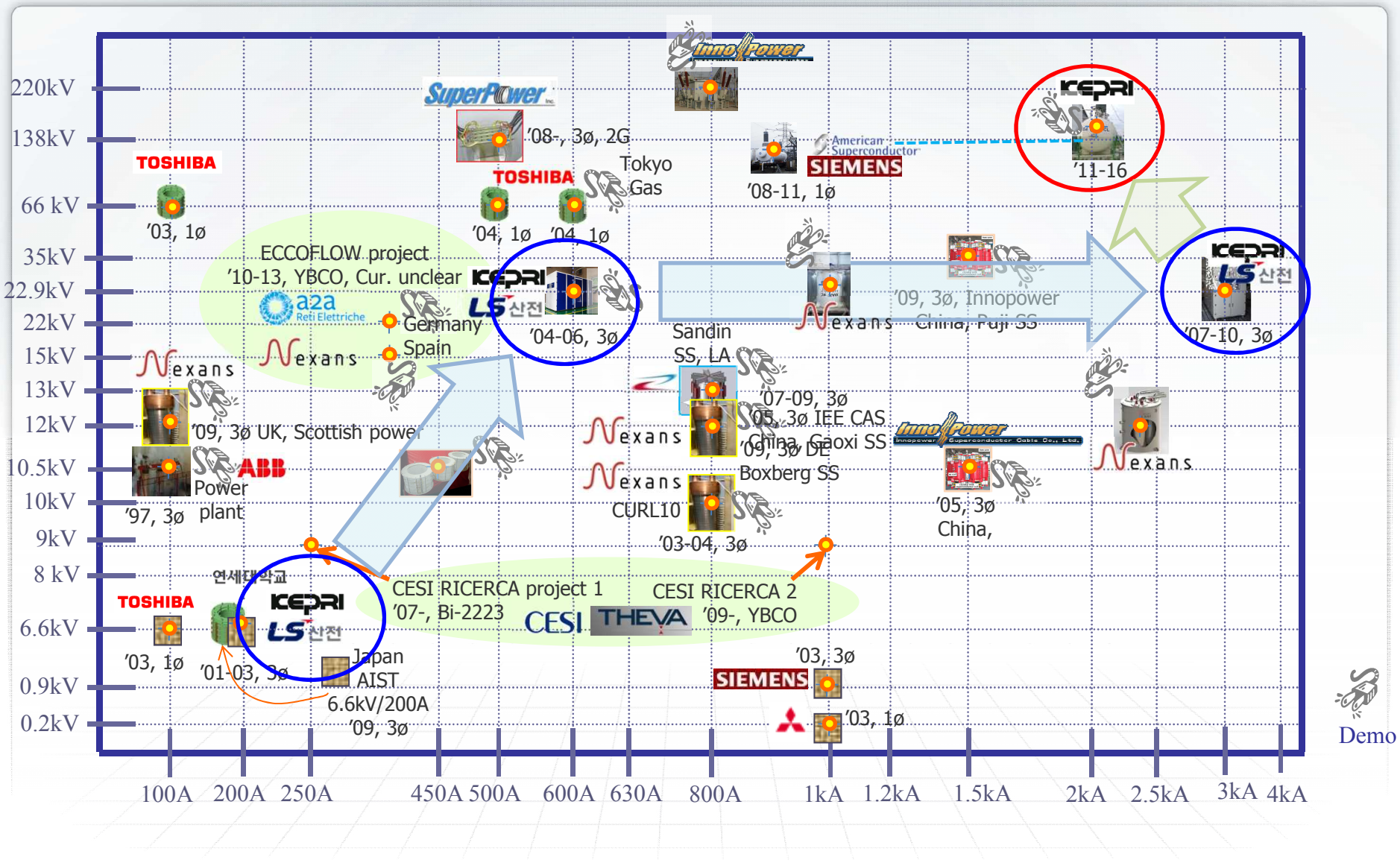
Worldwide Tech. & Demo. Status

Worldwide development and demonstration of HTS Cables



Worldwide development and demonstration of SFCLs



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Thank You for your Attention