Superconducting Fault Current Limiter for Moscow 220 kV City Grid

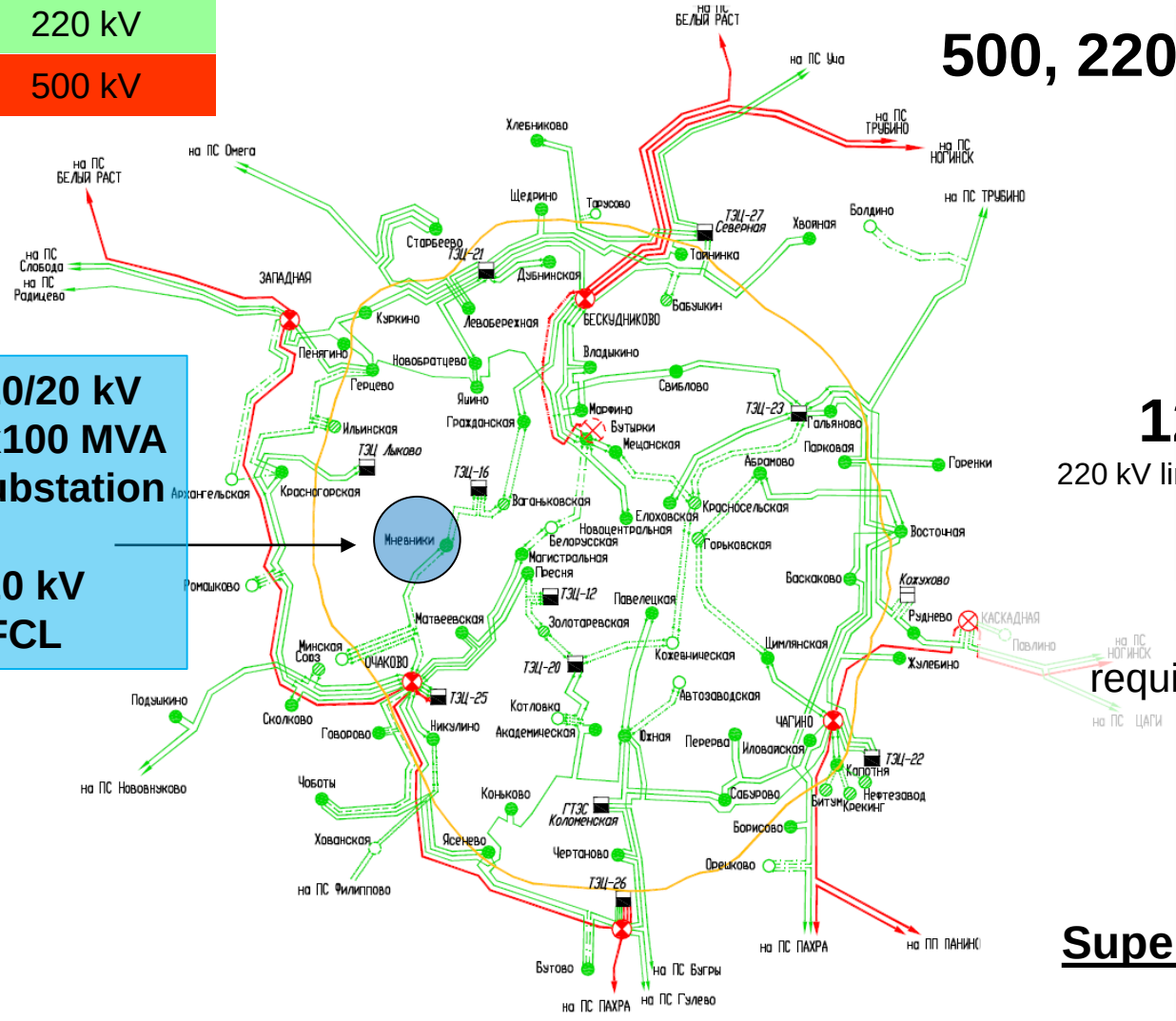
M.Moyzykh, D.Sotnikov, D.Gorbunova, S.Samoilenkov
m.moyzykh@superox.ru
+7 (495) 669-79-95

www.superox.ru

Motivation

220 kV

500 kV



220/20 kV 3x100 MVA Substation

220 kV SFCL

500, 220, 110, 20, 10, 0.4 kV

Voltage-classes in Moscow

18,653 GW

Declared net capacity

1290 km

220 kV lines total length

54

220 kV substations

Rapid growth

requires new technologies for fault current management

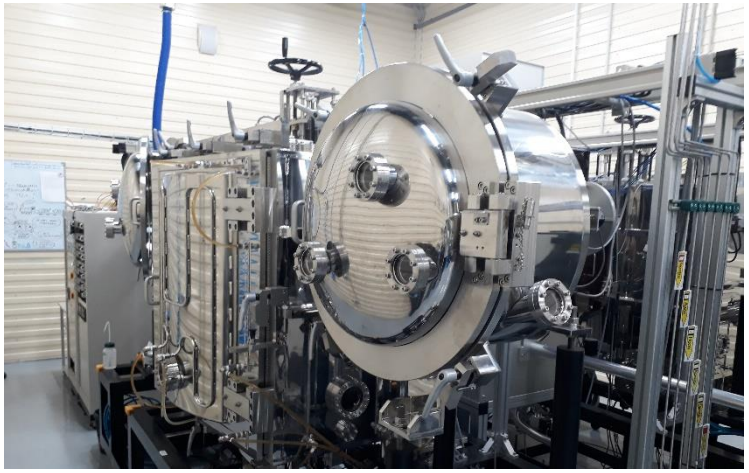
SuperOx SFCL 220 kV Project

Scope

- First SFCL in Russian Power Grid
- 220 kV – class
- In operation by 2018
- SuperOx manages full project

2. Engineering and production

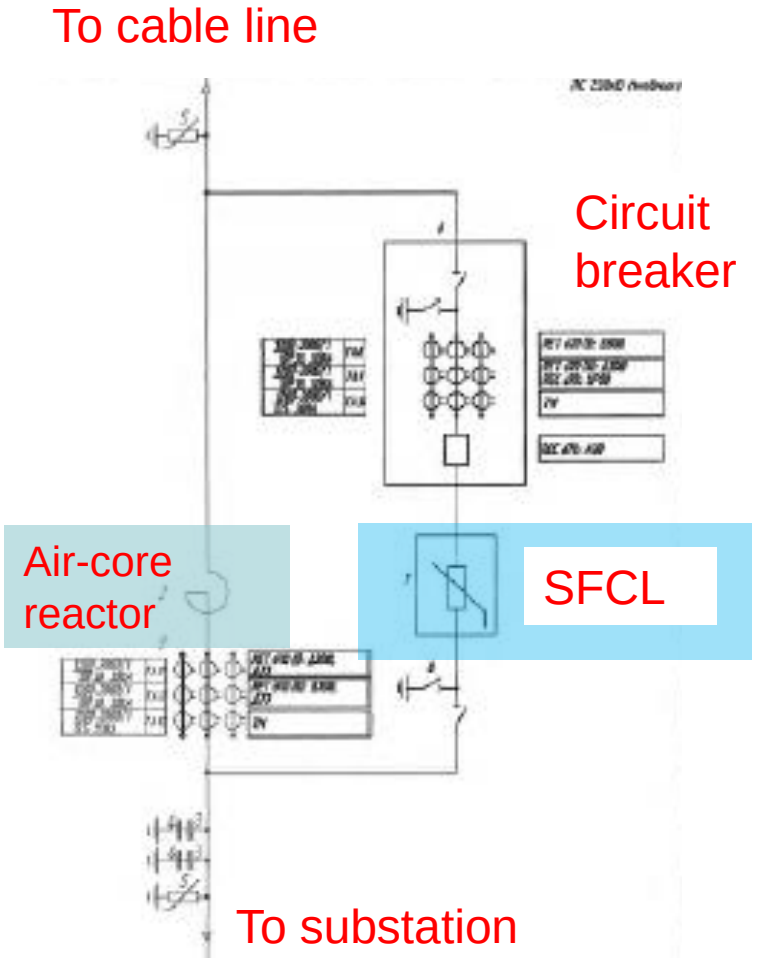
1. Superconductor manufacturing



3. Onsite construction

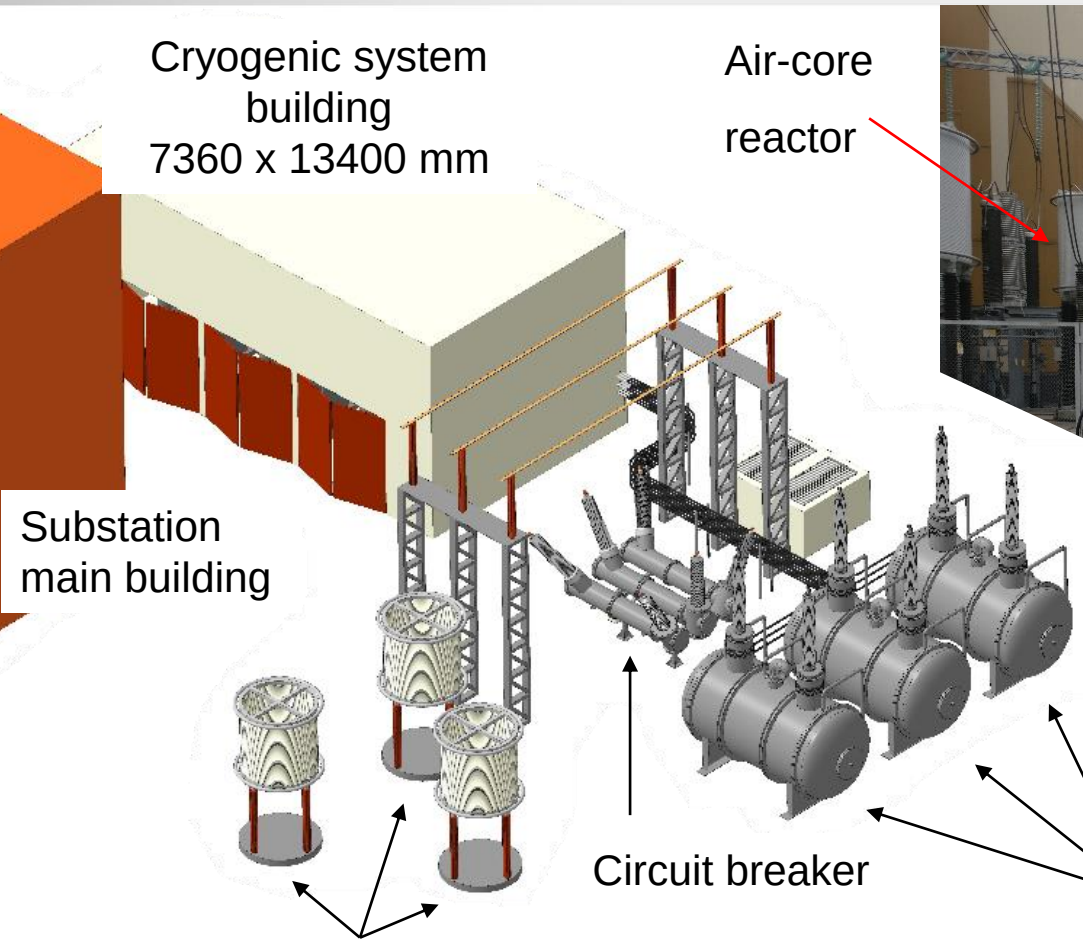
Utility requirements

Specification	Unit	Value
Nominal voltage (line)	kV	220
Maximum operating voltage	kV	252
Lightning impulse withstand voltage	kV	950
AC withstand voltage	kV	440
Nominal frequency	Hz	50
Nominal current (RMS)	A	1200
Resistivity (nominal state)	Ohm	0,01
Resistivity (limiting state)	Ohm	40
Installation - SFCL		Outdoor
Installation - Cryogenics		Indoor



Installation of SFCL into 220/20 kV substation to compliment existing air-core reactors

Substation Layout



Onsite activity 2017:

Auxiliaries relocation / Equipment foundations / Cryogenic system building

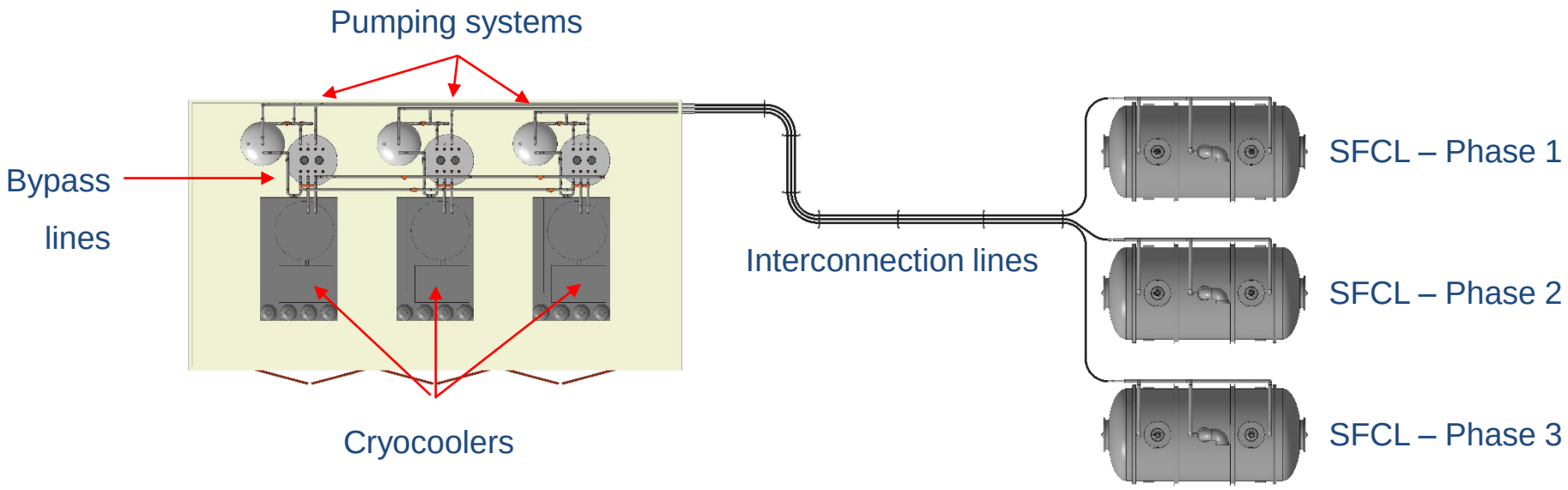
SFCL Cryogenics

Main hardware:

1. 3 SFCL Phases
2. 3 Cryocoolers
3. 3 Liquid nitrogen pumping systems
4. Interconnection and bypass lines (160 m total)

Key features:

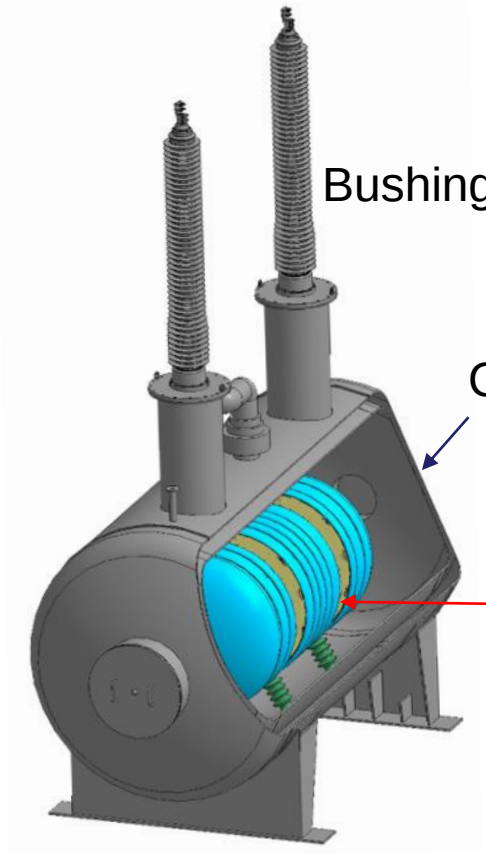
- Flexibility:65-77 K temperature interval to tweak critical current
- Capacity: max heat generation 3000 W
  cryocooler power 6000 W
- Redundancy: only 2 of 3 cryocoolers required for nominal operation
- Maintenance: possible without disconnection of SFCL from 220 kV



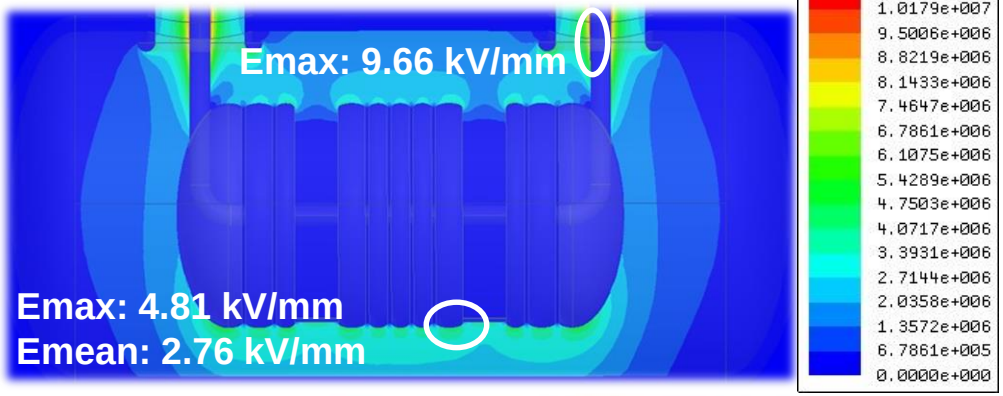
Top view of SFCL with cryogenic system

Phase design

1. Dead-tank type (grounded cryostat)
2. Cryostat
   - LN2 capacity: 11 000 kg
   - max pressure: 10 bar
3. Switching element
   - Type: resistive
   - Superconductor: 2G HTS - 8400 m (single-phase)
   - Size: OD 1650 x 3200 mm (including shielding)
   - Weight: 850 kg (including shielding)



950 kV lightning impulse E field simulation:



Total phase dimensions:

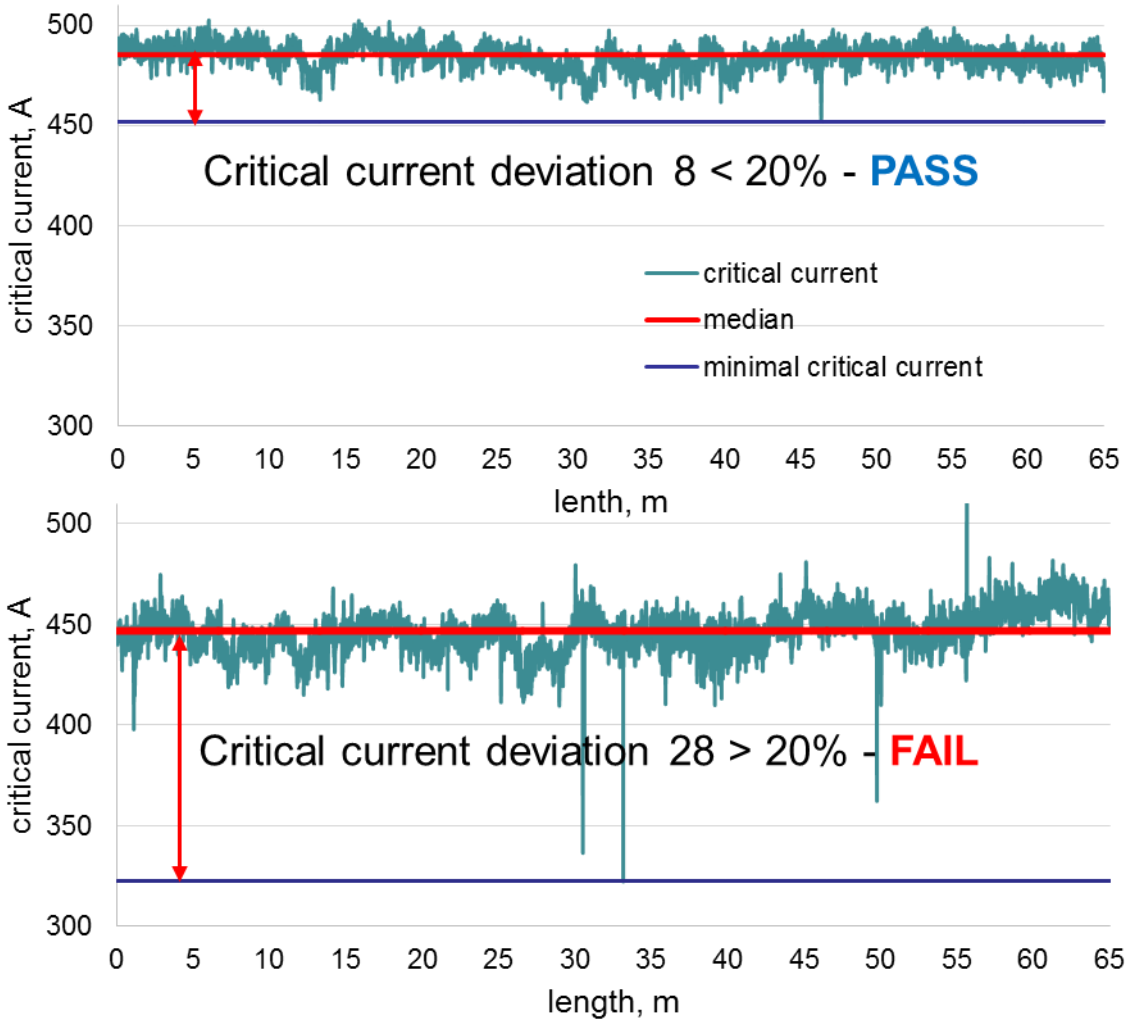
5500 x 2850 x 6500 mm / 27 000 kg (operation)

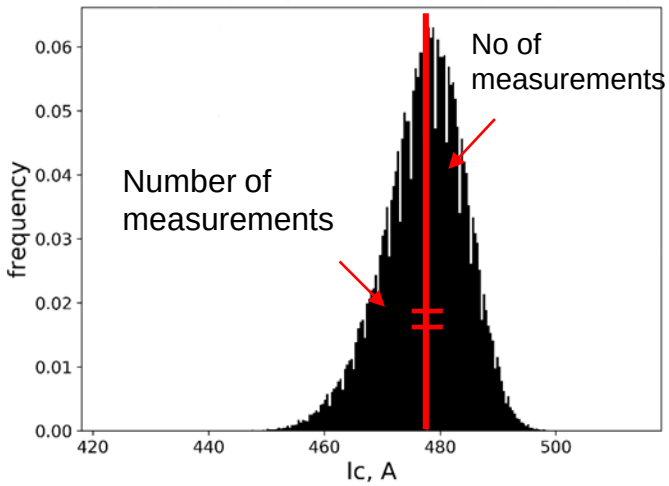
5500 x 2850 x 3900 mm / 16 000 kg (transport)

HTS specifications

Specification	Value	Comments
Superconductor	2G HTS wire	
Superconductor width	12 mm	+/- 0.1 mm deviation
Piece length	60 m	
Total superconductor length	3 x 8400 m = 25200 m	
Stabilizer	Copper	
Critical current	350 A	Minimum value per piece length
Critical current deviation	< 20 %	Relative ratio of minimal critical current to median of critical current distribution
Resistivity at room temperature (RRT)	210 mOhm/m	Specific resistivity per 1 meter
Resistivity deviation	< 10 %	Relative difference between highest and lowest value of RRT

Critical current deviation





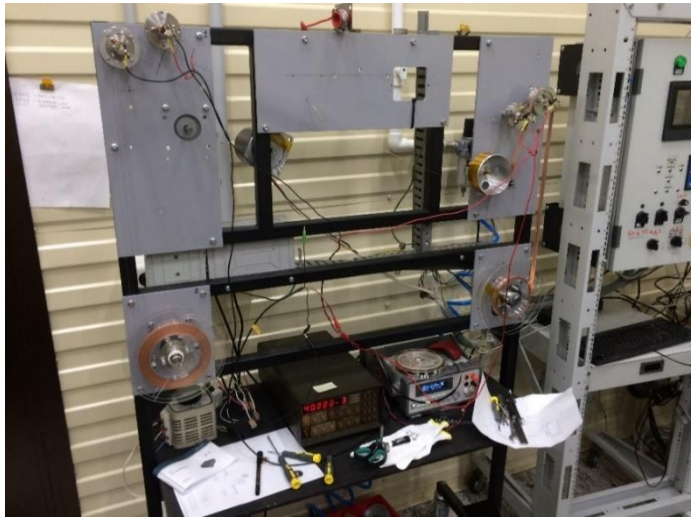
Definition: 50% of the current measurements fall above the median value (and 50% fall below it)

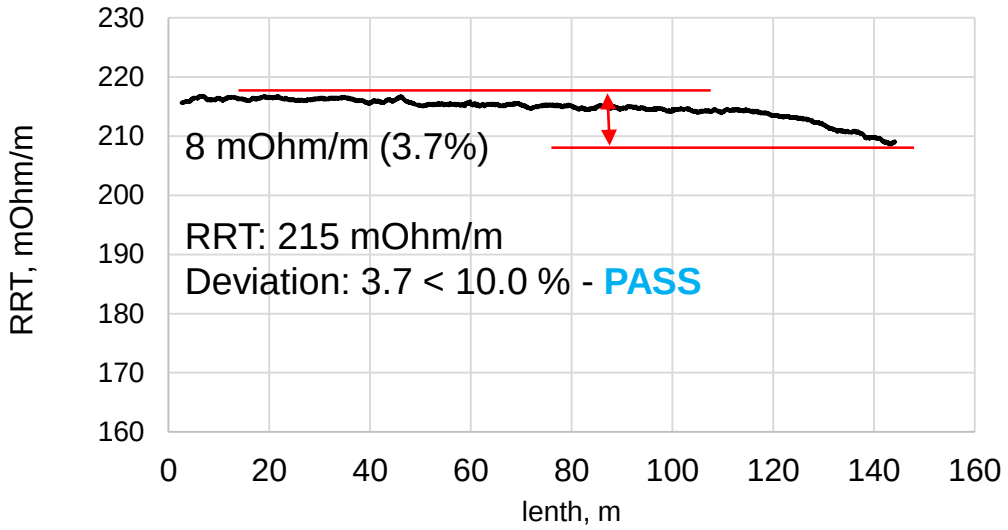
- Median-to-minimum value is selected as deviation-specific
- Represents operation of HTS wire in SFCL: lower-critical current tape experiences more load during operation

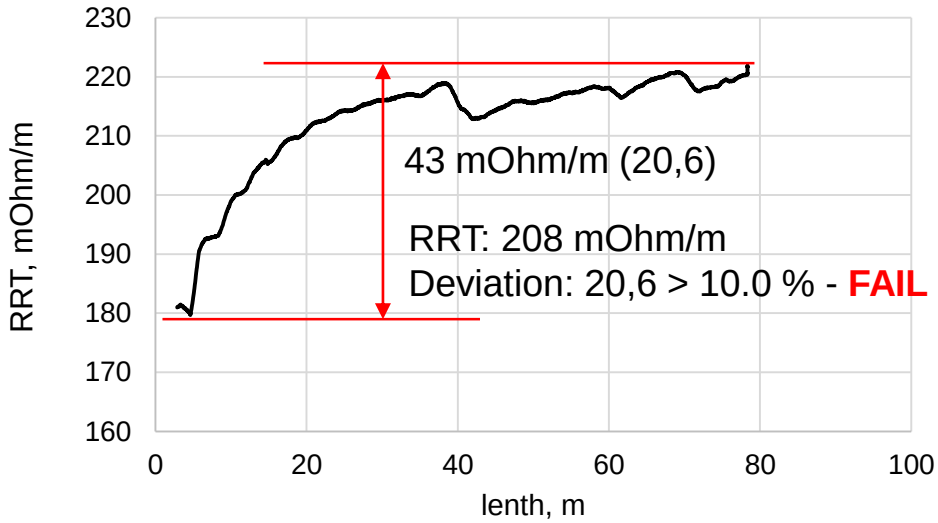
Resistivity deviation (Room temperature)

Resistivity deviation defines temperature uniformity of SFCL switching element at full load

Reel-to-reel continuous measurement machine:







Process control for stabilizer layers is critical to avoid resistivity drift – more info by:

A. Molodyk, Presentation 2MO4-04
19 September, 13:30, Room 3+4

SFCL Performance Model

SuperOx

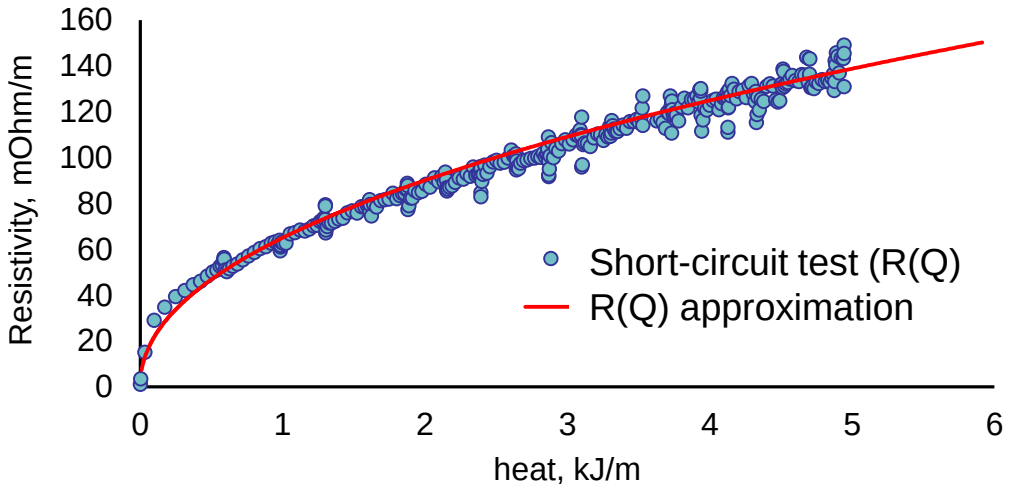
Features:

- Resistivity is a function of heat - R(Q)
- Performance model transforms R(Q) into resistivity and current as functions of time
- Adopted for EMTP (Electro Magnetic Transient Process) and RTDS (Real Time Digital Simulator) software

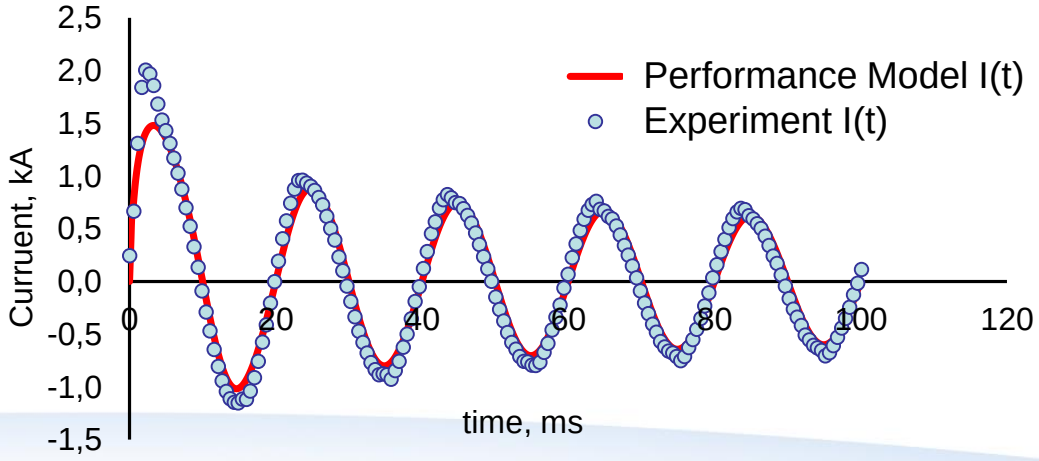
Purpose:

- Simulation of SFCL impact on grid regimes, fault current levels and relay protection coordination

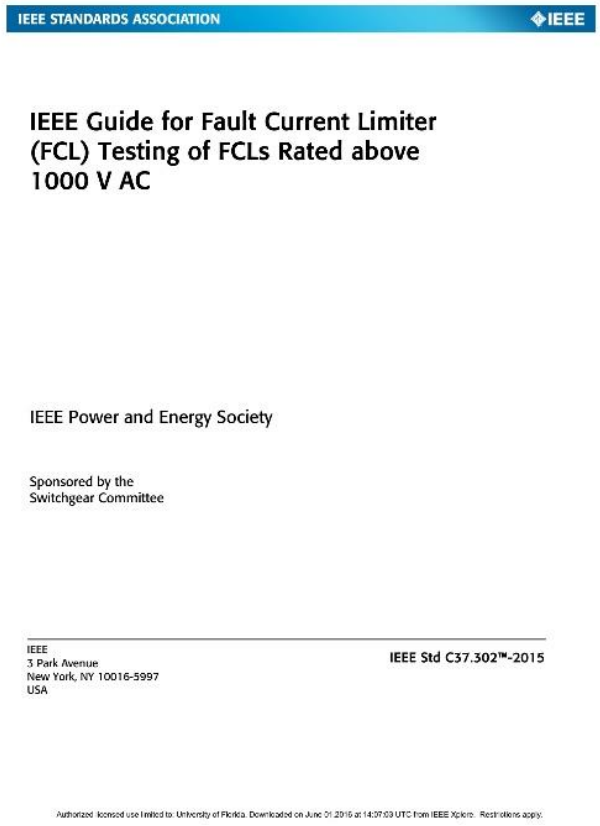
1. Approximation of SFCL resistivity vs heat R(Q) of test specimen



2. Use R(Q) to predict current vs time behaviour across SFCL



Testing


IEEE STANDARDS ASSOCIATION IEEE

IEEE Guide for Fault Current Limiter (FCL) Testing of FCLs Rated above 1000 V AC

IEEE Power and Energy Society

Sponsored by the Switchgear Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C37.302™-2015

SFCL will be tested according to IEEE C37.302-2015 standard – Utility has approved

Type Tests shortlist

№	Name of Test
1	Lightning impulse
2	Power frequency overvoltage withstand
3	Partial discharge

Acceptance test shortlist

№	Name of Test
1	Rated continuous current
2	Short-term overcurrent
3	Short-circuit current limitation
4	Power frequency overvoltage withstand
5	Partial discharge

Manufacturing and testing

220 kV bushing during testing

Cryostat acceptance

Shield manufacturing

Test cryostat for sample high voltage tests

Conclusions

1. SuperOx project is the first SFCL in Russian grid, 220 kV-class, 1200 A - for urban area power transmission – with start of in-grid operation planned in 2018.

2. SFCL features compact dead-tank design with cryogenic system aimed for continuous operation (current-carrying and current-limiting) even during maintenance procedures of cryogenic system.

3. 2G HTS tape requirements were evaluated.

4. SFCL performance model was developed to study SFCL impact on grid.

5. Acceptance tests procedure according to IEEE C37.302-2015 standard is confirmed by utility.

Thank you for your attention!

SuperOx
Nauchniy pr-d. 20-2
117246 Moscow, Russia
www.superox.ru