The structure design of a 300-kvar class HTS synchronous condenser prototype

Peng SONG [a], Qihong WU [a], Zhengjun SHI [b], Ye YANG [c], Luming Zhang [d], Beimin WU [e], Meng SONG [b], Timing Qu [a] *

[a] *Department of Mechanical Engineering, and State Key Laboratory for Tribology, Tsinghua University, Beijing 100084, China*
[b] *Electric Power Research Institute of Guangdong Power Grid Corporation, Guangzhou 510080, China.*
[c] *Central Research Inistitute, Tsinghua University, Shenzhen 518055, China.*
[d] *Department of Electrical Engineering, Tsinghua University, Beijing 100084, China.*
[e] *Department of Physics, Tsinghua University, Beijing 100084, China.*

ID: Wed-Mo-Po3.06-04
Date: XXX XXX 2019
Time: XXX – XXX

放一个会议标志

Introduction

- ✓ In China Southern Power Grid, the Ultra High Voltage Direct Current (UHVDC) transmission grid is being established gradually.
- ✓ Large amount of reactive power is required and consumed by rectifiers and inverters to stabilize the grid voltage.

The merits of synchronous dynamic condensers (DSC):
(compared with STATCOM and SVC)

- ➢ Quicker response, better performance
- ➢ Hardly influenced by voltage sags
- ➢ Fully capable of either leading or lagging mode

Applying HTS material

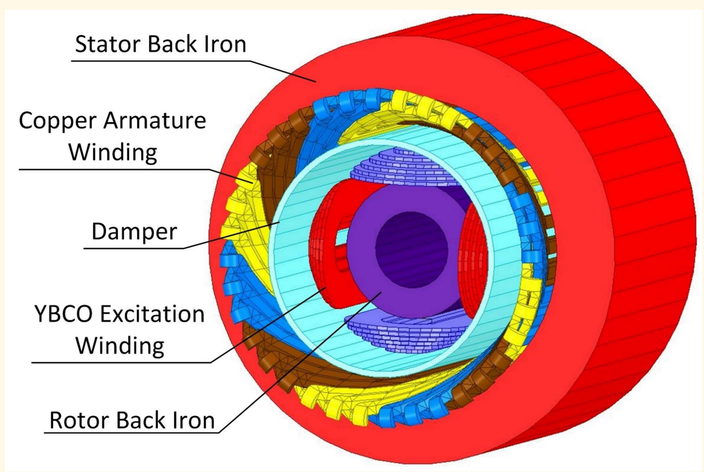
More advantages of HTS DSC:

- Smaller size, lighter weight
- Lower loss, higher efficiency
- Smaller synchronous reactance
- Less excitation current change rate

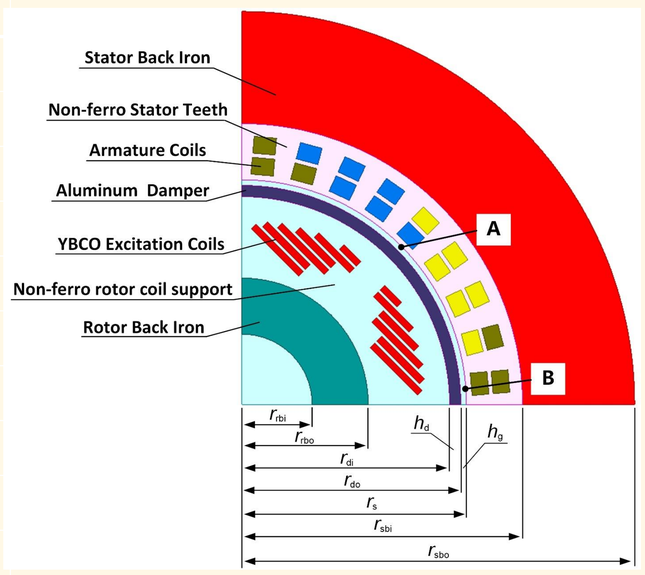
Recently, China Southern Power Grid has setup a R&D program to further study the feasibility of reactive compensation in UHVDC system.

General Design Parameter

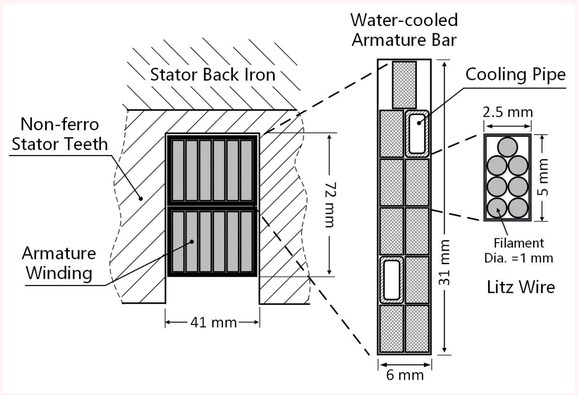
Electromagnetic	Value
rated power P_n	10 Mvar
rated voltage U_n	11 kV
Rated current I_n	525 A
poles/ slots	4 /36
Revolution speed n_0	1500 RPM
Frequency f	50 Hz
No-load $I_{f,0}$	375 A
Full-load $I_{f,n}$	428 A
Gap field B_0	~ 1.4 T
Armature load A_0	~900 A/cm



Dimension	Value
inner radius of rotor iron r_{rbi}	125 mm
outer radius of rotor iron r_{rbo}	225 mm
inner radius of damper r_{di}	370 mm
outer radius of damper r_{do}	390 mm
thickness of damper h_d	20 mm
length of physical air gap h_g	10 mm
radius of stator inner surface r_s	400 mm
inner radius of stator iron r_{sbi}	500 mm
outer radius of stator iron r_{sbo}	700 mm
length of coils straight part l_{eff}	800 mm



The Stator and YBCO Rotor Winding



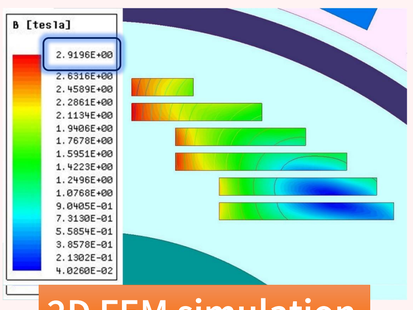
Configuration:

1. Thin filaments to reduce eddy loss.
2. Water cooling to improve A_0.
3. Air cored to avoid over saturation.
4. Litz wires twisted to form bars.
5. J_a = 10.55 A/mm^2 @ rated power.

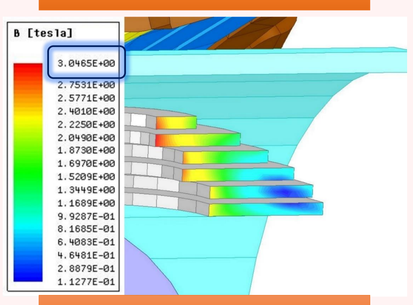
The water-cooled armature winding

HTS Rotor Winding:

- ✓ 10 mm-wide YBCO coated conductors with copper laminated.
- ✓ 6 single-pancake coils with different sizes on each rotor pole.
- ✓ Cooled by 20 ~30 K gaseous helium through conduction.

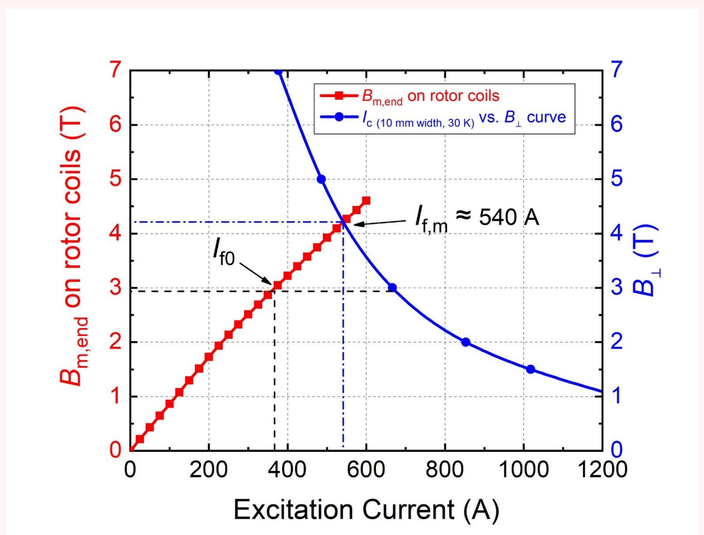


2D FEM simulation



3D FEM simulation

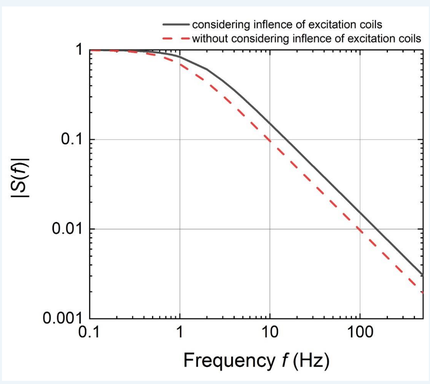
B_{max} appears on arc segments of windings



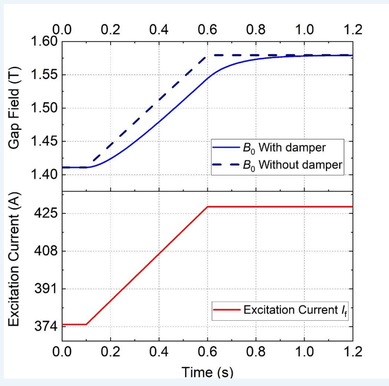
B_{max} on YBCO coils vs I_c-B* properties

*I_c-B properties from Robinsons Research Institute, Victoria University of Wellington, New Zealand

The damper (screening and damping layer)



The screening effect to higher-order harmonics



The damping effect to fast forced excitation

Conflict of damper usage:

Positive:

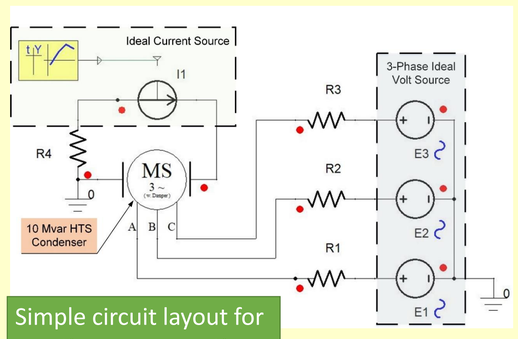
Screening higher-order stator harmonics.

Negative:

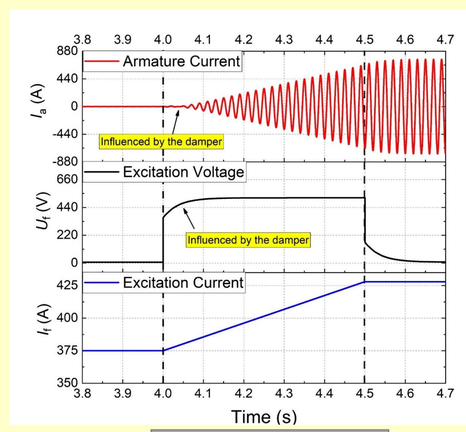
Damping the forced excitation ramp rate.

Using analytic formula and FEM software to study the screening and damping effect.

The Simple Circuit Simulation

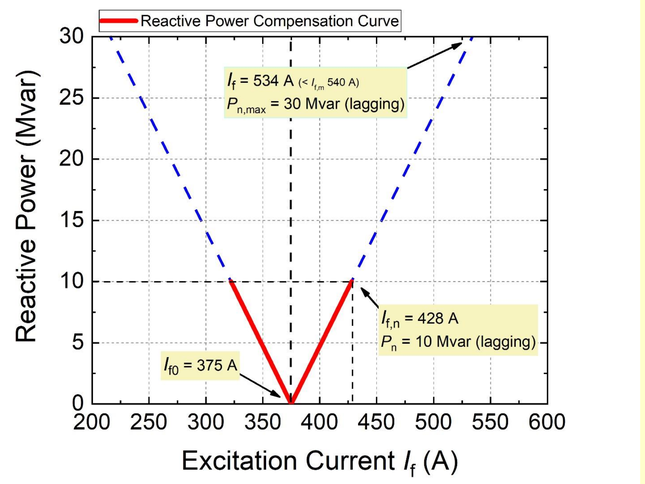


Simple circuit layout for reactive compensation



Simulation results

- ➢ Using ANSYS Simplorer, the V-shape reactive compensation curve was simulated.
- ➢ The HTS DSC was treated as a synchronous motor model with damper.
- ➢ Volt Source and Excitation Source are ideal.



The V-shape reactive compensation curve

Presenter: Peng Song, Postdoc.
Phone: +86 10 6279 4261
Mobile: +86 13264258278
E-mail: songp@mail.tsinghua.edu.cn

This work is supported by the National Natural Science Foundation of China (51475257), the Tribology Science Fund of State Key Laboratory of Tribology and "10 Mvar HTS Dynamic Synchronous Condenser Prototype R&D Project" (Project Number: GDKJXM20172779) from S&T Program of Guangdong Power Grid, Ltd.