CIGRE SC B4 COLLOQUIUM ON
HVDC AND POWER ELECTRONICS

20 AGRA 2015

Current status and development VSC-based HVDC technologies in power system of Russian Federation

Andrey Drozdov, Alexei Kiselev, Olga Suslova

Russian Federation





OUTLINE

VSC-based HVDC in Russia

- STATCOM 50MVar trial operation history at Vyborg substation
- TRANSBAIKAL Back-to-back converter station

Researches and development of VSC equipment

- High voltage IGBT valve development
- VSC equipment testing
- Development of MMC technology
- Real-time simulation of Power Electronic Circuit

Future VSC HVDC projects in Russia

- Back-to-back VSC link at Hani
- Power supply of isolated and passive AC networks
- Application of VSC-based HVDC technologies in cities for increasing of reliability of power supply and short circuit current limitation

cigré Agra

Trial project - VSC-based STATCOM at Vyborg substation

- 3-level NPC converter
- 18 IGBT valves with IGBT series connection
- Reactive power control +/- 50MVar, 15.75kV
- Water cooling system
- Digital Control & Protection System

- The first IGBT based STATCOM demonstration project in Russia was commissioned into operation at Vyborg substation in 2010

- Its purpose was to provide reactive power and dynamic voltage support during transients in power grids of Russia and Finland.

cigré Agra

Interconnection of nonsynchronous power grids of Far East and Siberia through VSC Back-To-Back

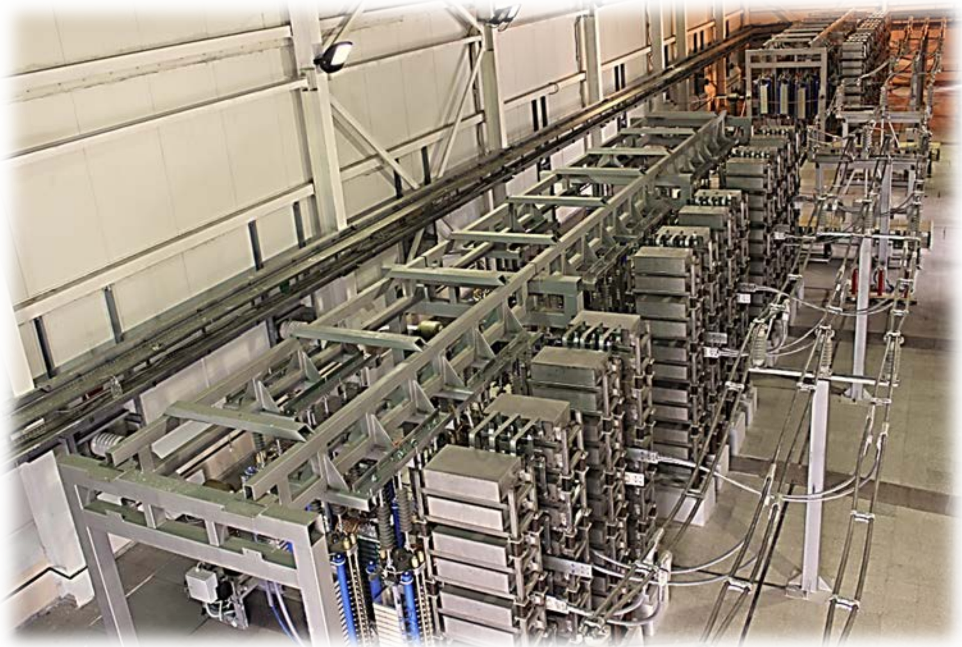
Aim of project: interconnection of Far East and Siberia power grids, improving power quality for Transbaikal railroad and power flow control during emergency generators outages in both energy systems.

Product: Complete BTB HVDC system, which is rated 240 MVA, consists of two parallel VSC links, nominal active power 200 MW. IGBT valves are arranged as three-level VSC, and connected to power grid through transformer 220/38.5 kV

Costumer: JSC“FGC UES”, JSC“R&D CENTRE of FGC UES”, JSC ECC “SOYUZ-Grid”

Commissioning date - **2014**

TRANSBAIKAL BACK-TO-BACK 2X100MW 220KV 3-LEVEL NPC VSC

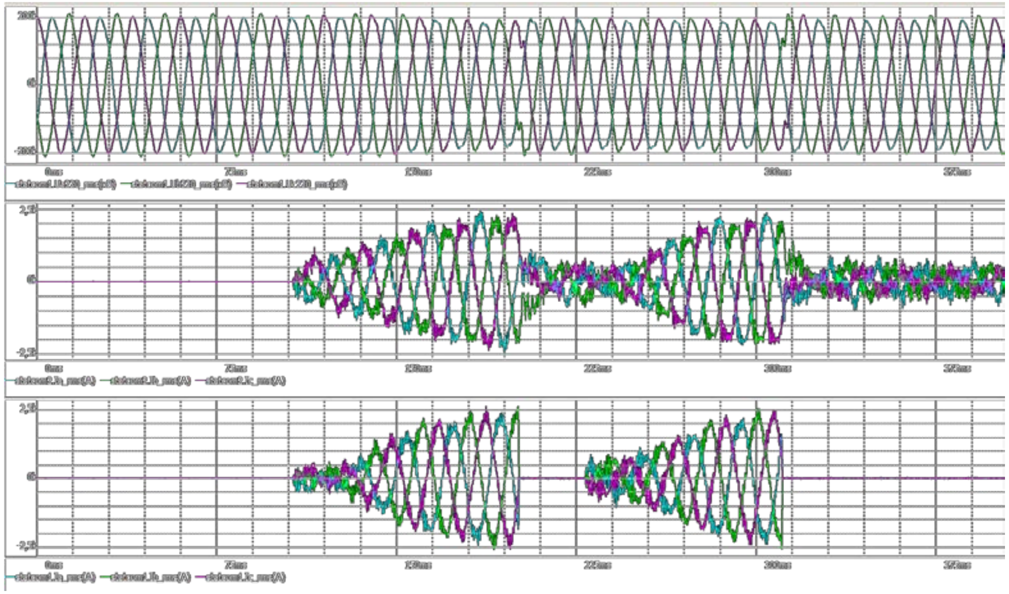


TransBaikal Back-to-Back is a Voltage Source converter based tie interconnecting the transmission grid of East Siberia with the Far East system, at the Mogocha 220kV Substation.

Frequency	50 +/-2Hz
Rated voltage	**38,5kV**
Rated current	1800 A
Total power	**120 MVA**
Active power	**±100 MW**
Reactive power	±66,5 MVar

Transbaikal Back-to-back commissioning tests

BTB DYNAMIC BEHAVIOR DURING DISTORTION IN POWER GRID



- During automatic reclosing cycle full active power could be reached in less then 75ms.
- Each VSC can operate as STATCOM or when connected back-to-back (BTB) transmit active power

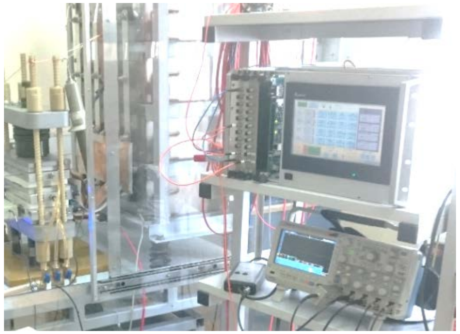
Considering VSC in weak power system (i.e. with low short circuit current) is challenging task for control system design and computation of setpoints for grid protective devices. So both BTB developers and TSO were involved in this process.

Proper coordination of electrical grid protection and BTB algorithms during reclosure cycle and distortion in power grid requires deep knowledge on possibilities and restrictions of power utilities.

System studies on impact of VSC on weak power grid were carried out, and strategy for overcoming different fault scenario was define.

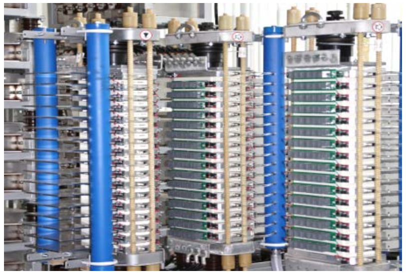
Agra

Researches and development of VSC equipment



IGBT valve design – fiber optic control & protection system realized in IGBT driver and valve control unit allows to observe IGBT valve behavior during turn-on/off transient process in normal and failure modes to study out all process on energized VSC.

Control&protection system – modular “platform”. The latest advances in DSP and FPGA techniques was applied and implemented in limited number of boards. This gives interoperability ultimate performance and exceptional reliability to create, debug, and run any HVDC algorithms in real-time mode.

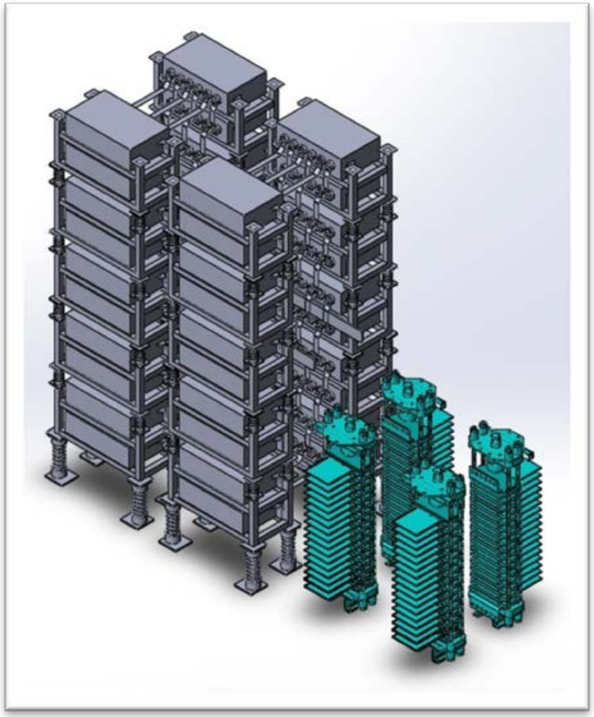


VSC equipment tests - Specially designed testing equipment - physical models, automated board testing stands, real-time high-performance FPGA based simulators.

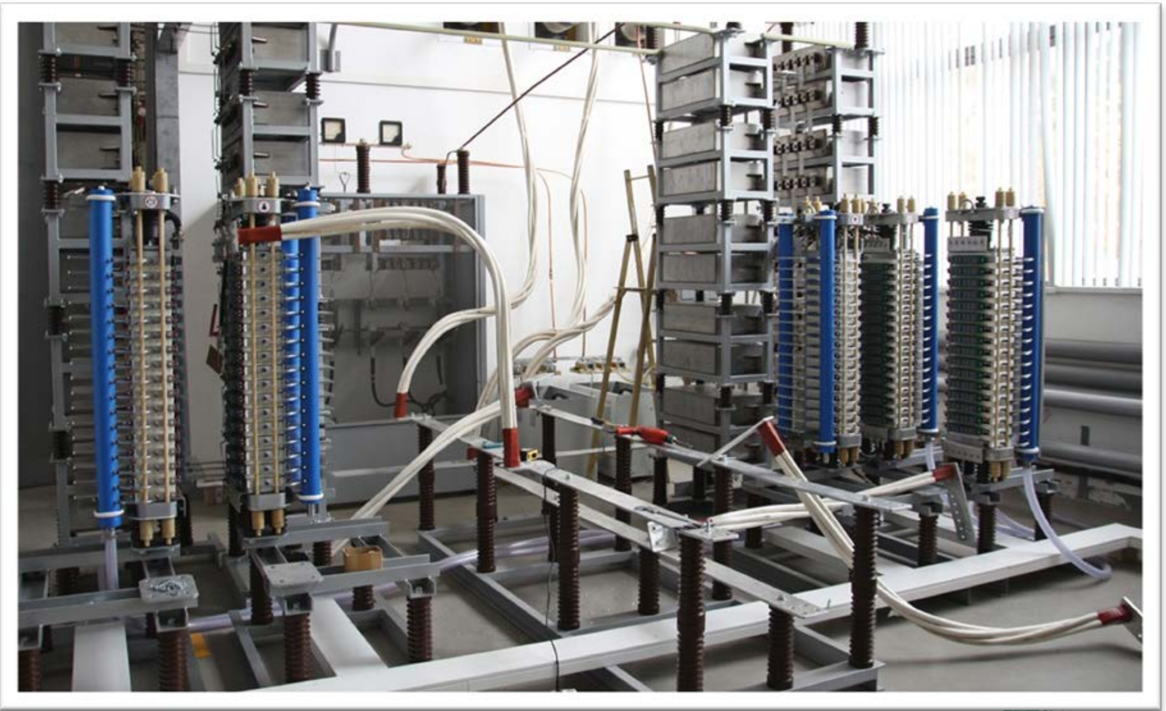
* For Mogocha back-to-back it was developed and produced the set of 25 cubicles connected with each other fiber optic.

HIGH VOLTAGE IGBT VALVE DEVELOPMENT

Results	IGBT valve design for different HVDC application. A proven concept of control and protection for series IGBT connection Short circuit through DC capacitor and valve test passed successfully
Applications	HVDC application – multilevel VSC, STATCOM, modular and cascaded multilevel converters, DC breaker



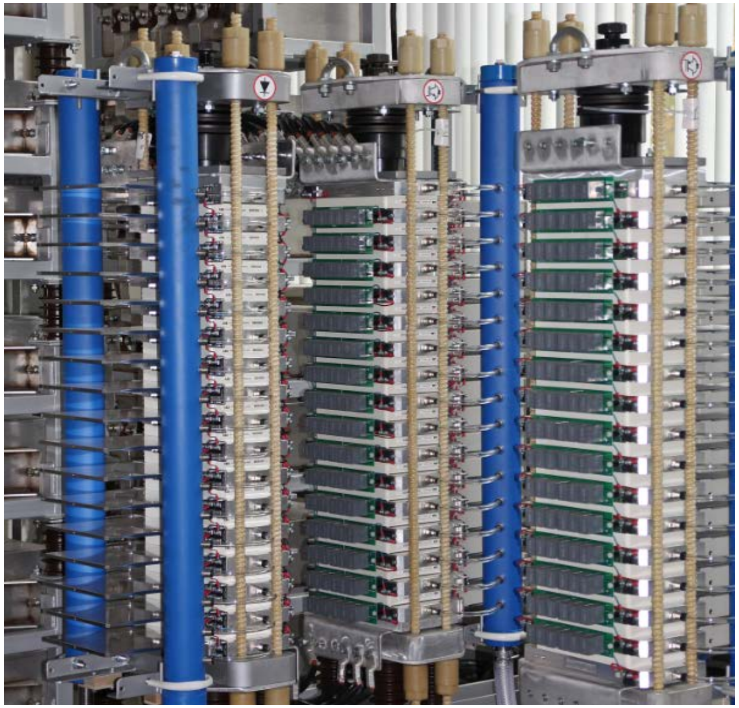
3D-layout



IGBT valve at testing lab

cigré Agra

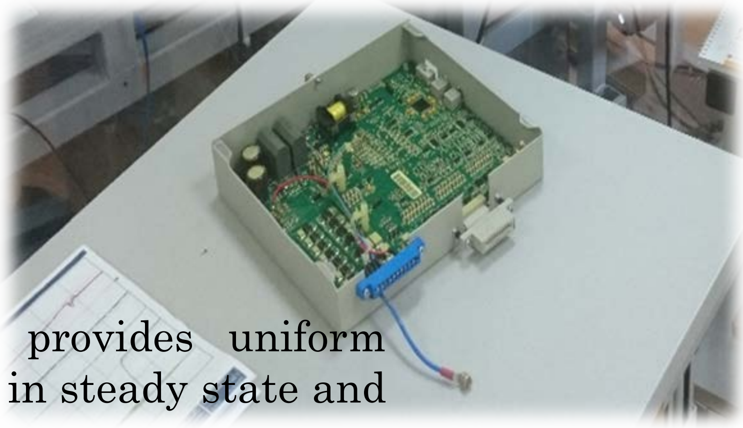
IGBT VALVE CONTROL AND PROTECTION DESIGN



VSC IGBT valve is comprised of two sub-modules has 2x16 series connected IGBT and valve control unit. It is one of the most technologically unique component of VSC HVDC.

IGBT driver is key component of a valve, which is responsible for low running loss, high margin of safety and diagnostic.

Modular and compact vertical structure for easy transport, testing and installation



IGBT driver is core component of valve

- developed to have a high immunity to EMI
- supplied with power from a single IGBT cell when a voltage applied to IGBT valve.
- An intelligence system realized in driver provides uniform distribution of voltage across valve IGBT cells in steady state and during transients.
- Data exchange between drivers and control unit based on fiber optic.
- Bandwidth of fiber channels and high speed data processing in valve control and protection unit allows commutate valve safely even if short circuit current through valve and DC capacitor

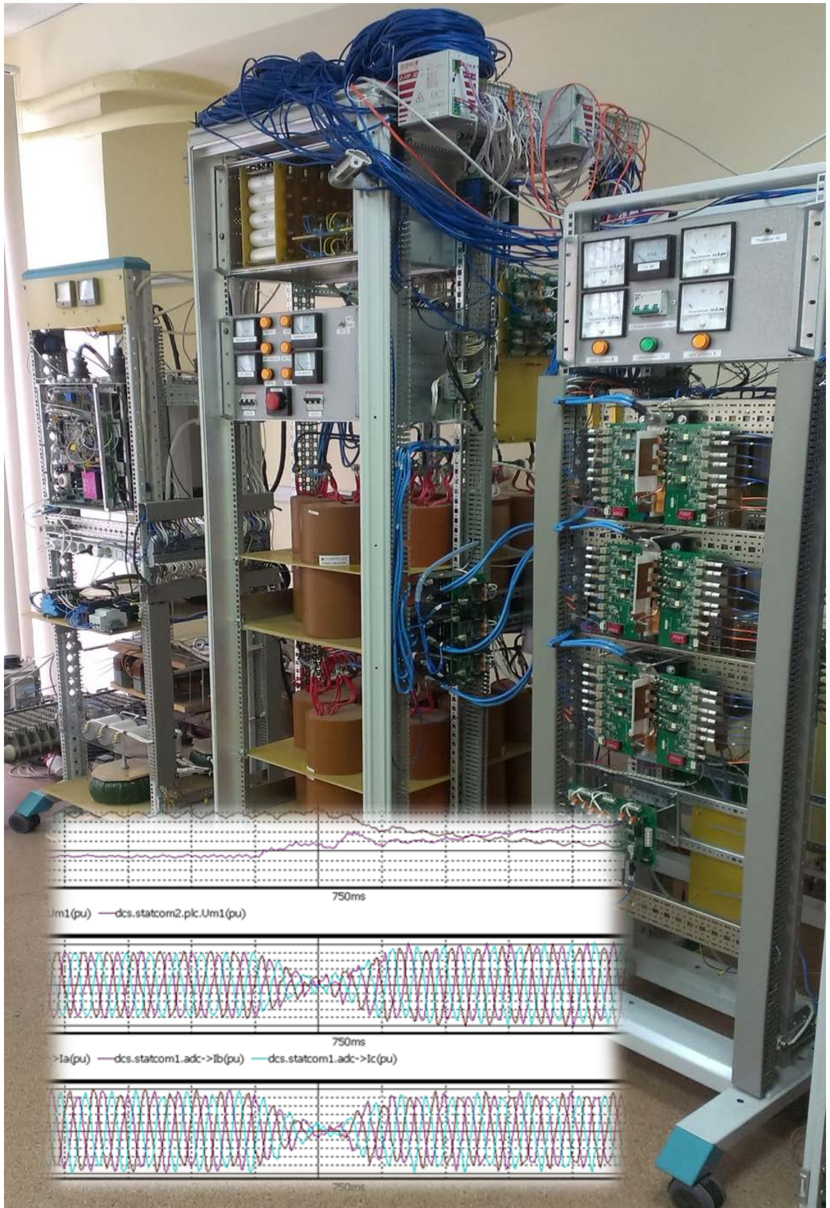
cigré Agra

VSC VALVES DESIGN AND TESTING LABORATORY

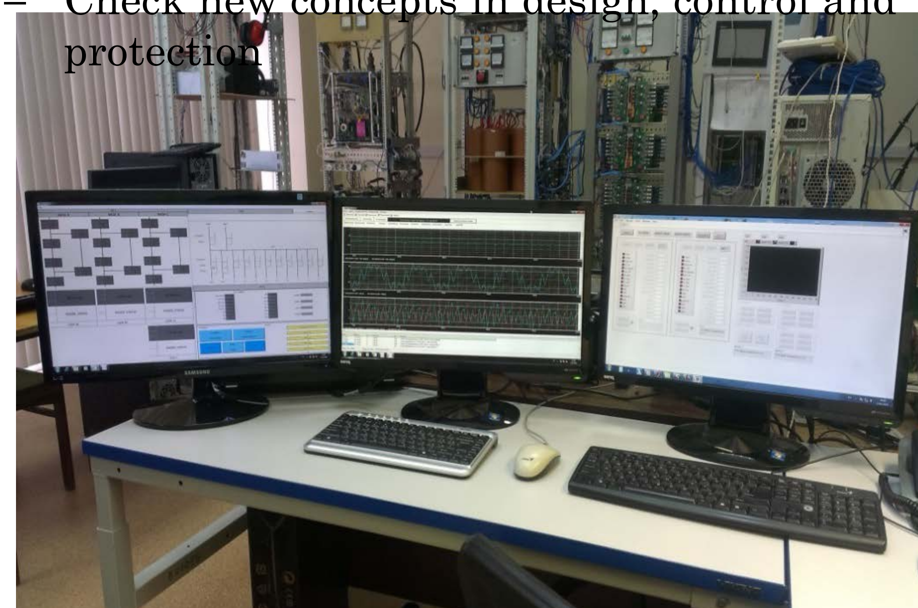
IGBT valve testing lab

- Electrical testing of IGBT valve components
- Type tests
  - IGBT overcurrent turn-off test
  - Short circuit current test
- Factory tests
- Dielectric tests for valve construction on VSC
- Production tests

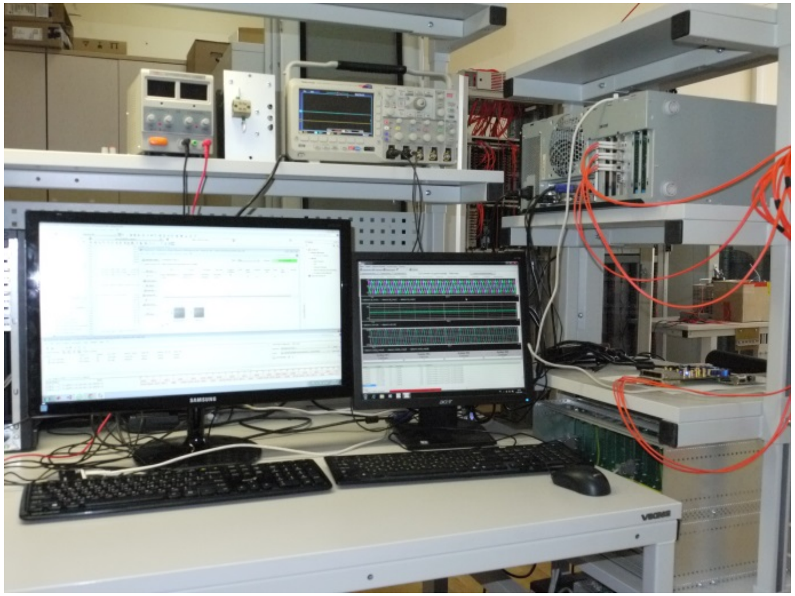
Physical simulation laboratory



- VSC scaled 1:100 (low voltage model)
- Power grid represents by converter 15kW able to make disturbances and imbalance voltages
- Proof of control and protection algorithms
- Full scale control system (SW &HW) tests
- Training of customer staff for operating HVDC
- Check new concepts in design, control and protection



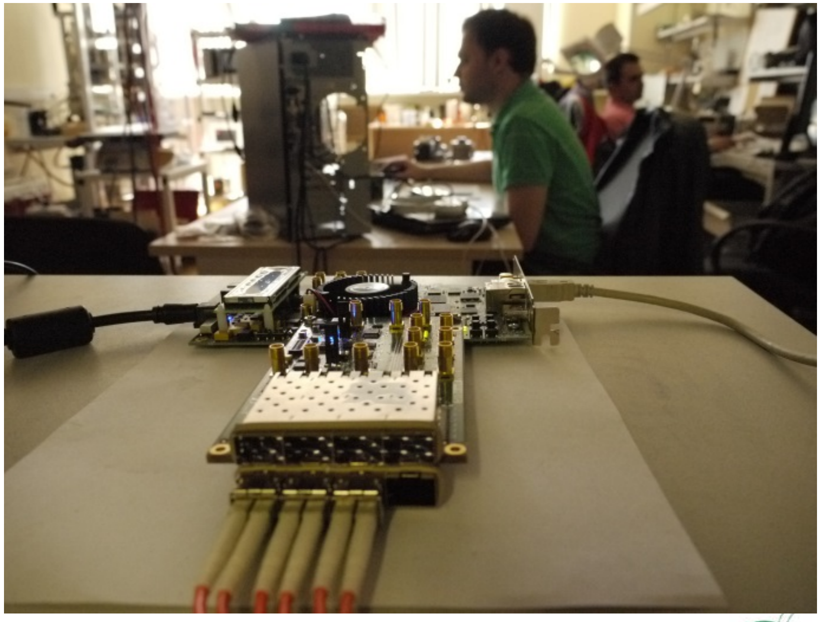
DIGITAL REAL-TIME SIMULATION LAB



Cost for delays in commissioning time and testing outweigh the investment cost of any simulator

Factory tests on real-time simulators are part of R&D process with the aim on verification of the functional performance of the controls and protections.

- Minimize disturbances to the AC-system during commissioning and identify and solve problems as early as possible
- It is important to perform factory tests
- Shorten time for commissioning



cigré Agra

Back-to-back VSC link Hani

- Aim of this project is increasing reliability and transmission capacity of DC link connecting East and Siberia power grids
- VSC Rating - 200 MW (2x100 MW)
- Commissioning is planned in 2019

cigré Agra

Power supply of isolated and passive AC networks

Features of the Far East and Siberia power grids*

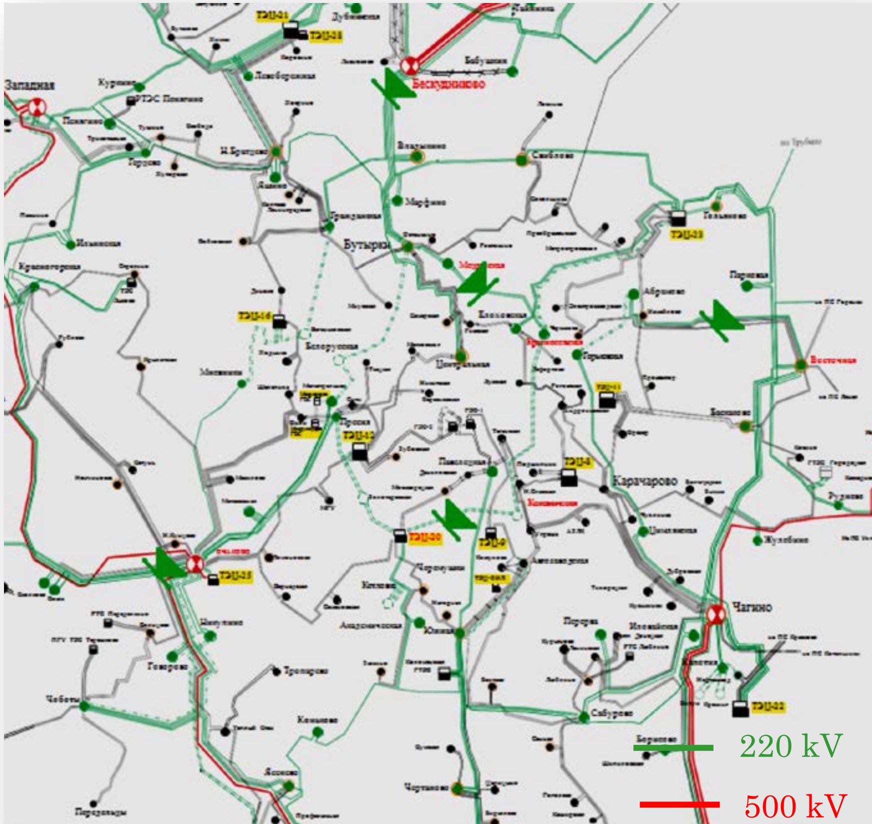
- Weak connection to Unified Power System of Russia
- Up to the present moment East power grid had no electrical interconnection with other power grids
- Few isolated AC networks: Norilsk-Taimyr (Far North on the Taimyr half island), Chukotka, Magadan, Kamchatka and Sakhalin (Far East)
- Large number of small isolated power region

Problems and challenges:

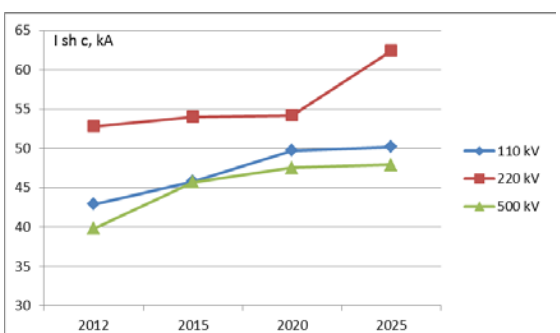
- Loss in reliability of power supply
- Integration with Russian Unified Power System
- Need to maintain larger generating reserve margin - more than 23 % of the maximum load
- Development of network infrastructure
- Underutilization of capacity of thermal power plants and reduce their effectiveness
- Access to electricity markets in the Asia-Pacific region

*Data from presentation PJSC «Rosseti» «Strategic priority: energy security and development of the electric grid infrastructure of the Far East»,2013.

Application of Back-to-back VSC in megacities



Maximum values of short-circuit current

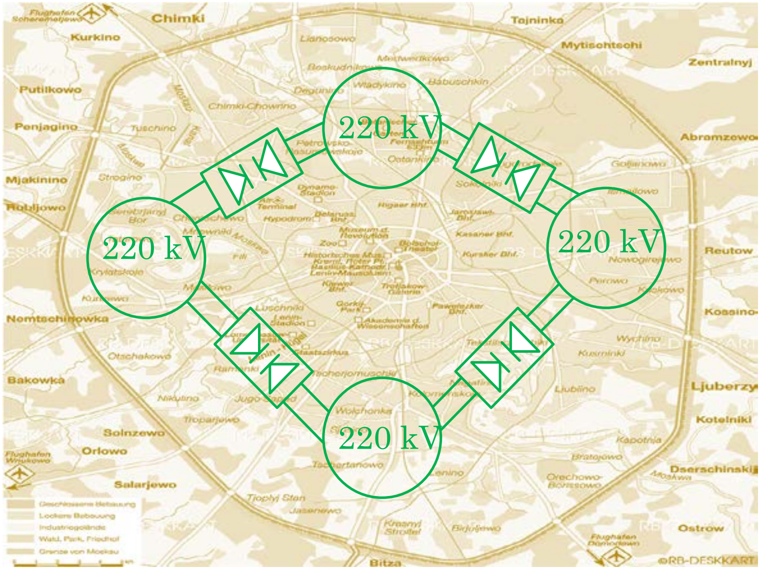


Features of Moscow power system:

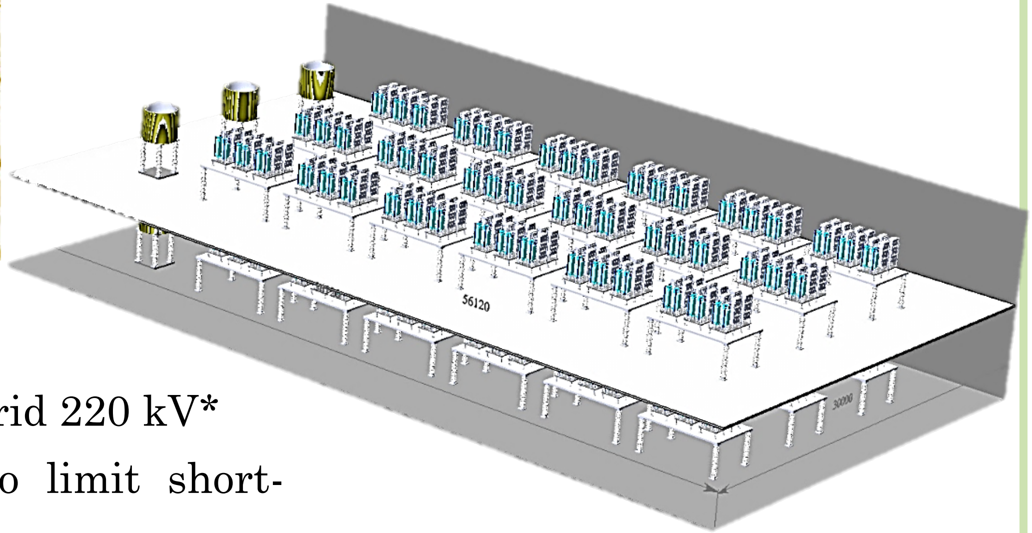
- Constrained territorial distribution of power facilities
- Large concentration of power plants
- The complex topology of the electrical network, meshed network
- High current loading
- The maximum level of fault currents in the networks 110 – 220 kV, trend to a permanent increase in short circuit currents levels as the development of network and generation
- The high density and a steady increase of electric load consumers
- A high proportion of consumers witch do not allow interruptions in electricity supply, including short-term

Application of Back-to-back VSC in megacities

Increasing of reliability of power supply and short circuit current limitation



Compact and Modular cascaded VSC back-to-back 220kV 400MW

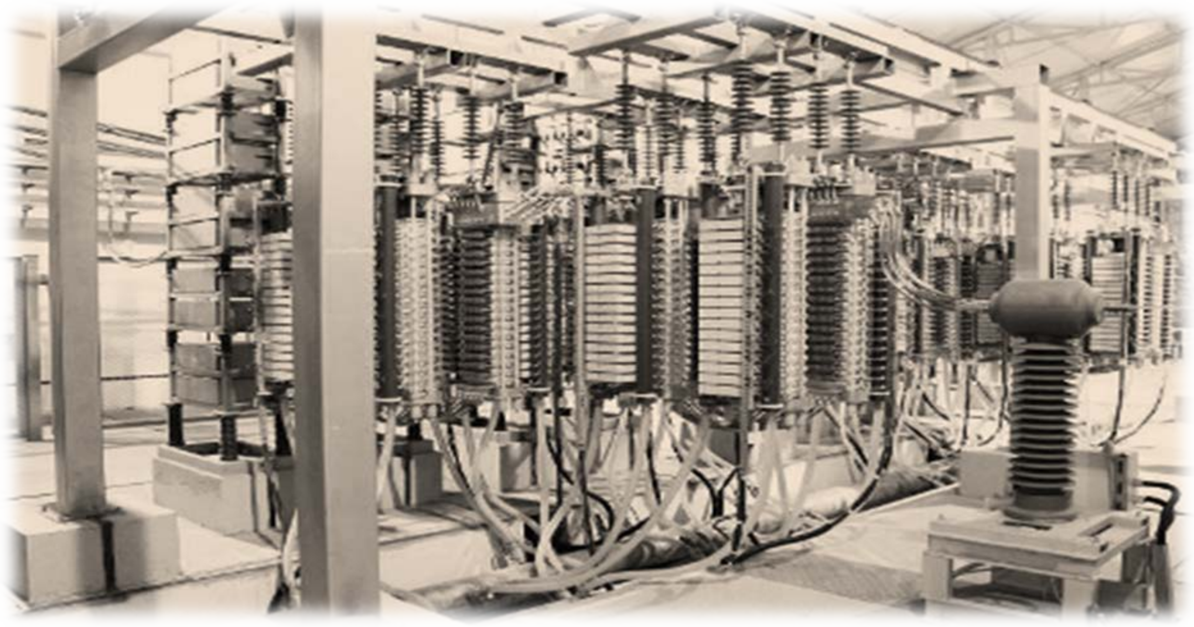


- Proposed locations of HVDC(VSC) Back-to-back in Moscow power grid 220 kV*
- Promising and effective mean to limit short-circuit currents
- Sectionalizing of power grid 220 kV with use of VSC back-to-backs

*Data from the research project "Strategic directions of development of the Moscow energy system taking into account the increase in short-circuit levels" by "Institute" Energosetproject ",2011.

Thank you!

Q&A



Andrey Drozdov
R&D Director
SPC «SAURUS ENERGO»
A.Drozdov@saurus.ru