

Study Committee B4 "HVDC and Power Electronics".
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**Operation experience of back-to-back HVDC station
based on voltage source converters for interconnection non-synchronous
power systems with significant voltage distortion.**

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The electrical connection between united power systems (UPS) of Siberia and Far East is carried out by double-circuit 220 kV lines from each side. These lines serve mainly as power supply for electrified railways, oil/gas transmission systems. The parallel operation of the UPS was impossible due to the large lines length which is about 600km from each side. This did not allow reliable power supply of railway substations and oil/gas pumping stations. It was decided to connect the energy systems of Siberia and Far East via the existing 220 kV lines by construction of 200MW back-to-back HVDC converter station to improve the reliability and quality of power supply to consumers located on the border of two power grids.

Mogocha back-to-back (BTB) includes two parallel blocks of voltage source converters (VSC) each of 100 MW capacities, connected through transformers 38.5/220kV to 220 kV switchgear. VSC on Mogocha substation is based on 3-level NPC converter design with series IGBT connection. In addition to HVDC mode each VSC can operate as STATCOM for fast reactive power compensation within ± 66.7 MVar. The total rated power of generation and consumption of reactive power is 4×66.7 MVar. This makes it possible to use back-to-back as a stabilizer of voltage levels with a total power of ± 266 MVar, when power system interconnection is impossible or AC lines under maintenance. The change of active power in HVDC mode during the operation of the emergency control system is performed in 150ms.

A significant factor affecting the VSC HVDC operation is the power quality in AC lines, which is significantly exceed the required values mainly due to the draft load of the railway. The voltage unbalance of the negative sequence K_{2U} at the point of installation before the commissioning of the HVDC was more than 17%. Voltage deviations reached 19%. The values of the total coefficients of the voltage harmonic components of the K_U reached 20%. The increase in freight traffic and doubling rated power of electric locomotives further significantly degraded the power quality. During the pilot operation of the HVDC it was detected long-term operation modes when the harmonic distortion exceeding in one phase 30%. In addition quite frequently voltage dips occurs, which are associated with the operation of the railway and thunderstorm activity in the spring-summer period.

During pilot period the operation of the HVDC in normal and emergency operation modes of the network was analyzed, changes were made to the VSC control algorithms in the static and dynamic modes of operation, the settings of the HVDC equipment protection and the automatic re-inclusion algorithms were corrected. Algorithms of voltage balancing DC capacitor were adjusted taking into account the existing power quality factors, transit scheme configuration and short-circuit capacity. A specific «zero» cycle of automatic re-inclusion was introduced taking into account heavy electric locomotives power consumption during start and acceleration. Current protection and additional levels of voltage protection for the DC capacitor bank were added. Both active and reactive power control regulators was supplemented with algorithms for limiting the current amplitude values, which takes into account the asymmetry and high harmonics of the current. These changes in control algorithms confirmed reliable operation of the back-to-back and the HVDC station were put into commercial operation.

Operation of Mogocha HVDC tie increased the reliability and improved power quality from both sides of back-to-back tie. This allowed for a railroad substations disconnect modular power stations that supply auxiliaries and railroad automatic interlock devices. The number of failures in the locomotive signaling devices significantly decreased and the voltage levels were stabilized within the nominal values.