SC B4. PS 1 / HV DC systems and their applications.
Service and operating experience of converter stations including off shore platforms

Operating experience and ways to improve reliability of Vyborg back-to-back HVDC link (in connection with the 35th anniversary of the commissioning of the first converter unit)

K.B. Gusakovsky[1], N.G. Lozinova[1], O.V. Suslova[2], E.U. Zmaznov [1]

[1]JSC «NIIPT»
Russia

[2]JSC «STC UPS»
Russia

suslova@ntcees.ru

December 2016 marked 35 years since the first converter unit of Vyborg converter station was commissioned. Vyborg back-to-back HVDC link is part of reverse cross-border electrical power transmission Russia - Finland.

Power transmission includes Vyborg back-to-back HVDC link, one 400/330 kV 3x167 (501) MVA autotransformer (AT) with reserve phase, Unit-1 and Unit-2 of North West Power Plant with nominal capacity of 450 (3*150) MW each.

Vyborg back-to-back HVDC link includes four identical High Voltage Converter Units (HVCUs) rated at 355 MW each, the total specified power being 1420 MW. The circuit diagram of Russia - Finland cross-border connection is shown in Fig.1.

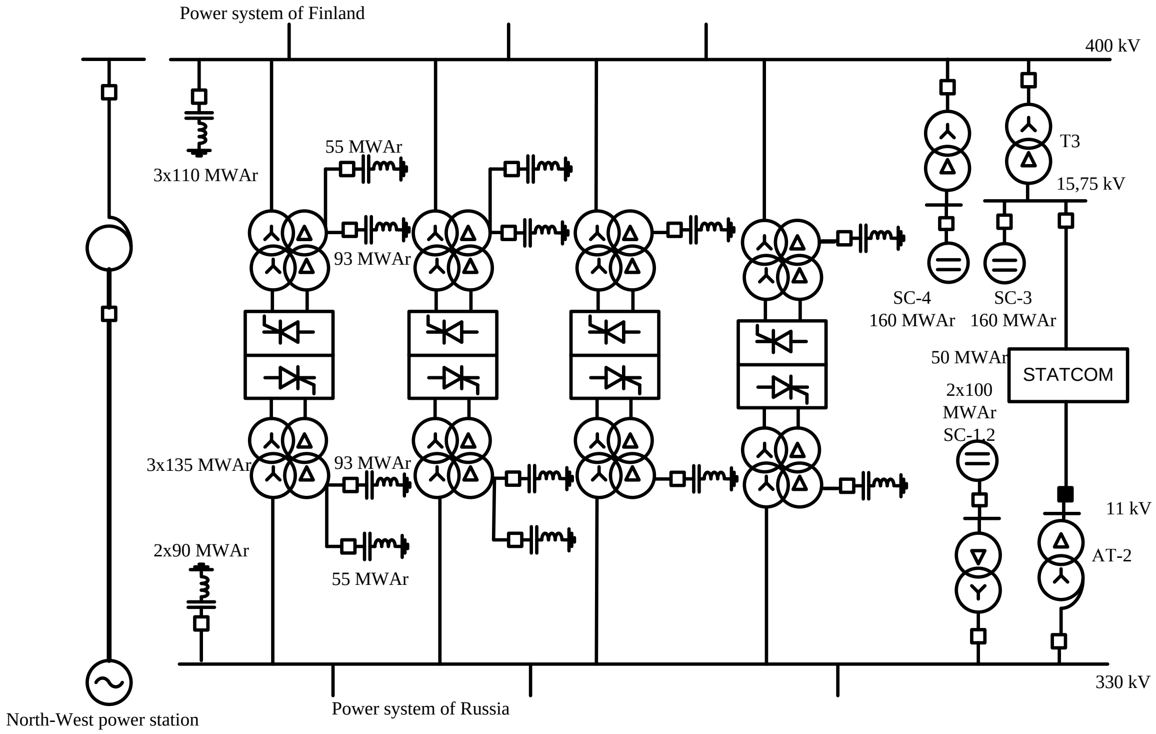

Fig. 1. Circuit diagram of Russia - Finland cross-border connection

Three of the four HVCUs were commissioned in the eighties, the fourth unit was put into operation in 2001.

Development and operating experience of Vyborg back-to-back HVDC link equipment is of key importance both for the development of HVDC technology in Russian Federation and for planning refurbishment of HVDC back-to-back.

For many years JSC «NIIPT» has been working on analyzing the outages of the equipment of Vyborg converter station and developing recommendations to improve its operation reliability. The results of this study make possible to assess the operation reliability and availability of Vyborg converter station, both current and retrospective and compare the values of these indicators with reliability performance of HVDC systems in operation worldwide, take measures to improve the reliability characteristics of the equipment.

Technical solutions implemented in the high-voltage thyristor valve (HVTV) of Vyborg converter station meet the basic world tendencies: modular design, light pulse control system, auxiliary power supply from high valve potential, cooling with de-ionized water.

The valves had been put into operation at first stage with thyristors T-630 connected 3 in parallel. Parallel connection of thyristors was applied due to the fact that I_{TAV} of one thyristor was less than the rated steady-state current unit. Six modules formed one valve block, which represented a phase of a 6-pulse bridge. One VBE was provided for each HVTV block. Completely new thyristor modules had been developed in the mid-90s when new thyristors of type T273-1250 became available. Module consists of 4 series-connected thyristors, the valve contains 16 modules. One VBE is used for the entire valve bridge.

Operating experience showed that one of the main disadvantages of the valves were leakages of the de-ionized water out of the water supplying pipes.

First industrial model of the integrated control, protection and automation system was successfully tested and put into operation on the new fourth HVCU - 4 in August 2003. Control system is implemented on the basis of processor CPC 102.01 with a clock rate of 200 MHz. Old C&P systems were replaced at the remaining HVCU-1,2,3 step by step in 2004.

During the commissioning of the C&P system for the next HVCU, software was upgraded to take into account the operating experience of already commissioned C&P systems. The exact copy of control and protection system of HVCU (replica) is installed at Vyborg converter station. Replica is connected to physical model and intended to testing and validation of the upgraded algorithms and hardware before field implementation.

For example, the developer proposed to make a desensitization of the backup circuit of commutation failure protection (CFP) to reduce the probability of false protection triggering when the rectifier operates with small firing angles. After implementation of this improvement, there were no false triggering of CFP at all HVCU.

Inverter short-term ccommutation failures in some cases caused by interference (induced "false" impulses in control circuits). To protect the control circuits from interference it is necessary to replace the conductor circuits with fiber optics.

Software for implementing power reversal was created and system tests of HVCU-4 reverse mode were completed in 2010.

In 2007 there were three cases of avalanche voltage collapse at 400 and 330 kV buses. One failure caused by short circuit in adjacent 330 kV AC system resulted in 850 MW power loss. In two other cases the development of the accident was prevented due to HVDC link power decrease. In this connection study was conducted to determine the sufficiency of reactive power sources and to develop measures to prevent avalanche voltage collapse. Study was conducted to determine the permissible transmission limit of HVDC link when the short-circuit ratio at 400 kV AC system is reduced.

Appropriate adjustments were made to power control system to implement the frequency load shedding algorithm in accordance with the demand of System Operator.

Power control system was adjusted in connection with the introduction of STATCOM equipment with a capacity of 50 MWAr. STATCOM was commissioned in December 2011.

In 2013 there were two emergency shutdown of the HVCU when unloaded converter transformers were energized. It is known that the energizing of power transformers is accompanied by slowly decaying inrush current magnitude of which depends on many factors. Inrush current can cause huge voltage distortion, which result in large firing angles and even commutation failures. To improve the reliability of the HVDC link at energizing of unloaded converter transformers some recommendations were developed. Recommended measures are significantly different in feasibility and cost. Some of them can be implemented during the day-to-day operation and maintenance, some of them can be performed during the reconstruction of the substation.

According to the outage statistics for 2007-2016 HVCU average forced outage rate is 4.9 per year.

It should be noted that since 2012 Vyborg HVDC back-to-back link has been working with an uneven load schedule, which leads to daily multiple HVCU tripping operation. In 2013 there were 1377 HVCU tripping operation, in 2014 - 1374. This operation mode makes the equipment operation conditions heavier.

Reconstruction of Vyborg HVDC back-to-back link is scheduled for the near future. Thyristor valves, reactive power compensation equipment are scheduled for replacement. Improving the protection of filter capacitor banks is planned. It is also planned to carry out a comprehensive reconstruction of the cooling system.