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NELSON RIVER POLE 2 MERCURY ARC VALVE REPLACEMENT

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Abstract

In 2000 Manitoba Hydro decided to replace the mercury arc valves with thyristor valves in Pole 2 of Bipole 1 to improve the reliability. In order to minimize the outage time only the valves were replaced and the existing analog control system was retained. The mercury arc valves were replaced with direct light triggered (LTT) thyristor valves. This paper describes the justification for replacement, project schedule, the valves, the control and protection changes and the actual system test results.

Keywords
HVDC, Light-Triggered-Thyristor, Reliability, Mercury-Arc-Valves

1. INTRODUCTION

The Nelson River HVDC transmission system consists of two bipoles (Fig 1). Bipole 1 is rated at +/- 463.5 kV, 1800MW. Each pole has three 6-pulse valve groups in series each rated at 154.5 kV and 2000A. Bipole 2 is rated at +/- 500 kV, 2000MW, each pole has two twelve pulse thyristor valve groups in series. The HVDC system is supplied from three generating stations on the Nelson River collector system which is isolated from the rest of Manitoba Hydro ac system. The NelsonRiver HVDC system represents 75% of Manitoba Hydro's total power generation.

Bipole 1 was originally built using mercury arc valves. In early 1990s, Pole 1 mercury arc valves were replaced with thyristors valves. Pole 2 continued to operate with mercury arc valves. In 2000 it was decided to replace Pole 2 mercury arc valves with thyristor valves to improve the reliability and availability of Bipole 1. In order to allow a future upgrade to a total dc system voltage of 500 kV, the new replacement six-pulse groups are rated for 166.7 kV and 2000 Amps.

2. JUSTIFICATION FOR REPLACEMENT

Over the last 5 years the performance of the pole 2 mercury arc valves has been deteriorating. Even though the outage time is often small but the interruption of power in today's de-regulated market is

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not acceptable. It has become difficult to refurbish these valves due to loss of expertise and unavailability of components. The large number of blocks and deblocks also had a detrimental effect on the AC and DC switchgear. In early 2000, Manitoba Hydro decided to investigate the possibility of replacing the pole 2 mercury arc valves with thyristor valves.

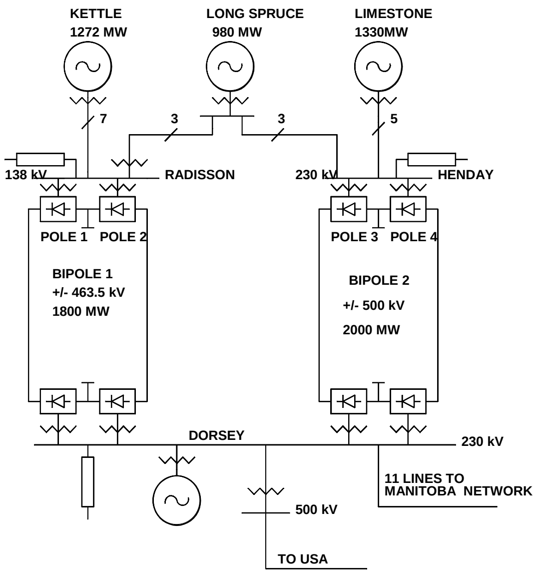

Figure 1: Nelson River HVDC System

The evaluation revealed the following technical advantages to justify the project from an operational perspective;

- Reduced number valve group outages (both forced and scheduled).
- Improved availability at a time when utilization of the HVDC facilities is increasing.
- Improved power quality due to elimination of arc-backs and consequential arc-backs.
- Significantly reduced maintenance requirements.
- Less deterioration of converter transformers and other station equipment due to elimination of arc-backs and consequential arc-backs.
- Elimination of environmentally undesirable products from the workplace such as mercury, cleaning solvents and PCB filled equipment.
- Increased availability and fewer outages during parallel operation.
- Reduction in the number of Pole and Bipole outages.

The specification for thyristors valve upgrade was issued in Feb. 2002. The contract was awarded in May 2002. The starting date for each valve group is as follows:

VG21	October	2003
VG22	April	2004
VG23	September	2004

Each valve group is planned to be completed during one month outage. This includes removing the old equipment, installing new equipment and commissioning. VG21 was completed in October 2003 as planned in 30 days.

3. CONVERTER DESIGN

3.1 Valves

Pole 2 of the Nelson River Bipole 1 Scheme is arranged in three series connected six-pulse groups . Each valve is mounted on a valve stand, which provides the necessary insulation to ground. They are equipped with wheels allowing their transfer via rails to the maintenance rooms. Replacing the mercury arc valves by thyristor valves using the existing infrastructure as far as possible was a challenging task. However, the valve manufacturer had gained good experience from a very similar mercury arc valve replacement project (Pacific Intertie, Celilo Station). Hence, major benefits could be offered to the owner in terms of the investment costs and the outage time required for installation.

The design of the new HVDC valves uses direct light-triggered thyristors (LTTs) with a maximum blocking voltage of 8kV and integrated overvoltage protection. This state-of-the-art technology has been used in several HVDC projects as well as in Static Var Compensators worldwide, proving its tendency to become industry standard. The details of this technology were described previously in [1]

Each thyristor valve consists of two series connected thyristor valve modules (Fig. 2) mounted on top of each other. These two units are placed on an empty module frame which serves as a mechanical base and is equipped with wheels for roll-in (Fig. 3). Each valve module consists of two valve sections. A valve section is the smallest part of a valve that have the same electrical characteristics as the complete valve but only a part of its voltage withstand capability. Each valve section incorporates 12 thyristor levels, yielding in total 48 thyristor levels per valve, two of which are redundant.

Figure 2: Typical Valve Module

Figure 3: Fully Assembled Valves

Furthermore, each valve section comprises a grading capacitor connected in parallel to the complete valve section, RC snubber circuits associated with each thyristor level as well as saturable reactors connected in series to the thyristor stack. Due to an increased di/dt capability of the LTTs compared to electrically triggered thyristors (ETTs), the number of reactors per valve section was reduced from four to three.

3.2 Valve Cooling

Each valve group has its own cooling system. A double circuit closed loop system with de-ionized water in the primary circuit and water/glycol mixture for the secondary circuit was installed. Heat transfer to the ambient is provided by dry coolers.

The key data are:

Ambient temperature outdoor 40°C/-50°C

Thyristor heat removal without redundancy

Radisson (rectifier)	1098 kW
Dorsey (inverter)	924 kW
Nominal de-ionized water flow	1386 l/min

In order to avoid system outages due to a single component failure or maintenance, a system with a high degree of redundancy was installed.

The cooling of the valve components is realized by using well-proven parallel water cooling circuits. Main advantages of this type of cooling arrangement are a better utilization of the thyristor capability as well as prevention of electrolytic currents through the heat sinks.

3.3 Valve base electronic (VBE)

The VBE cubicle comprises the central functional elements for one valve group. It consists of two redundant microprocessor based systems "Thyristor Control and Monitoring" (TC&M) A and B, light emitter printed circuit boards (PCBs) and light receiver PCBs, power supply and interfaces to valve group control (Fig. 4). To guarantee high availability and reliability parallel redundant hardware components are used wherever possible. Only one of the TC&M systems is active at a time, the other one running in "hot" stand-by mode. In case of a failure of the active system an automatic changeover to the other system is performed without causing any interruption of operation. The failed system then can be replaced during operation of the second system.

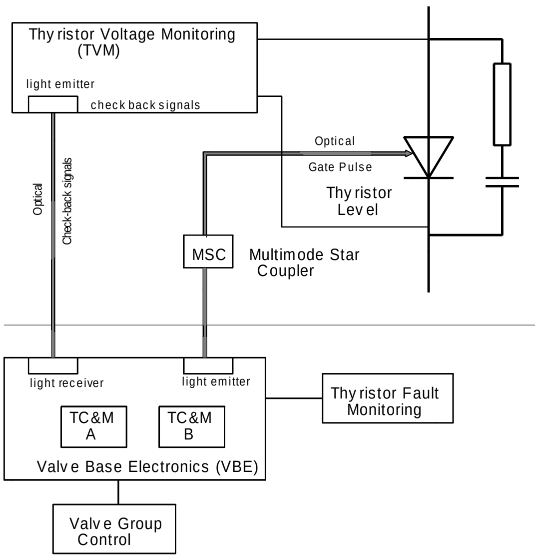

Figure 4: Block diagram of the valve control for LTT valves

Both TC&M systems receive signals from the valve group control independently, e.g. firing control signals. The active TC&M converts these signals into electrical firing impulses for the thyristors (which then are converted into light impulses by the light emitter boards and sent to the individual valve sections). The TC&M also receives the check-back signals of all thyristor voltage monitoring boards (TVMs) via the light receiver boards. The thyristor monitoring function in the TC&M evaluates the status of the valves and sends appropriate messages to the thyristor fault monitoring. Failure of the voltage grading circuit always results in a thyristor failure. Hence it is included in the monitoring scheme. An alarm signal is issued in case redundancy is used up in a valve. A trip signal is sent to the converter if the redundancy is exceeded.

3.4 Light Emitters and receivers

The Light Emitter PCBs convert the electrical trigger impulses into light pulses which then are sent to the individual valve sections. Three infrared laser diodes, located on different light emitter boards, are used to generate the trigger impulses for one valve section. Two of the three diodes emit enough light power to trigger the associated thyristors, one being redundant. In the valve section a Multimode Star Coupler (MSC) distributes the light pulses, fed in by three parallel mono-mode fiber optics, to the fiber optics leading directly to the gates of the individual thyristors.

The Light Receiver PCBs convert the optical check-back signals from the individual TVMs into electrical signals. These are sent to the TC&M for further processing via two parallel redundant channels. For the communication between valve group control and VBE copper cables and fiber optics are used.

All messages of the VBE are displayed in a separate cubicle located in the control room. The display gives information about faulty thyristors, laser diodes as well as alarms generated by the VBE.

4. CONTROL AND PROTECTION

Manitoba Hydro reviewed the performance of the original analog controls and decided not to replace the controls as the failure rate of the controls was less than 0.1% and surplus of spares is available. The following changes were made to the controls:

4.1 Interface with VBE

The start stop signals for the mercury arc valves were transmitted using cable, pulse transformers and light beam units. These signals were removed completely and replaced with optical signals between the controls and the VBE. The signals to the VBE consisted of firing control signals and operating signals. The specification of these signals was supplied by the manufacturer early during the project. Two interface circuit boards were designed and built in-house. The prototype circuit boards were then taken to the factory and were successfully tested with the VBE via fiber optic cables.

4.2 Deblock sequence

The valve group is deblocked at $\alpha = 45°$ at both stations. The deblock sequence was changed slightly to adapt to the thyristor valves. In the original deblock sequence the By Pass Vacuum Switch (BPVS) was opened and the valves were fired sequentially. For deblocking the new valve group the BPVS is opened and the two valves on the opposite side of the bridge are fired simultaneously a short time later.

4.3 Blocking sequences

The blocking sequence for the mercury arc valves did not include bypass pair formation. The normal blocking sequence was changed so that a bypass pair is formed. Once the Bypass switch is closed the bypass pair is reset. The only exception is the valve overcurrent condition where no bypass pair is formed. For overcurrent conditions, a trip signal is sent to the ac breaker, firing pulses to all valves are blocked and at the same time force retard (Idref = 0) is applied to the pole.

4.4 Protection changes

The protection study recommended that all of the protections used for mercury arc valves can be used as they were with the following exceptions:

- Block the valve group permanently for all protection operations
- Adjust the AC overcurrent protection as per study recommendation
- Added valve overvoltage protection.
- Added abnormal firing angle protection.
- Where necessary trip ac breakers and isolate ac and dc side.
- Force retard pole for valve overcurrent condition.

5. INSTALLATION & TESTING

Before the valve group was taken out of service for the valve change out the following installation was completed

- Cooling system except the connections to the valves
- All 6 valves were pre-assembled and ready to roll in.
- VBE & TFM cubicles were placed in their final location and pre-energized
- Fibers between the VBE, TFM and controls were installed.
- New motor control centre's were installed and tested.

The modifications to the controls and other systems were completed in 2 weeks. During this period the valves were rolled in and tested. At the same time fibers between the VBE and the valves were installed. The subsystem test between the controls and VBE were completed in two days.

The valve group was deblocked on the 24th day of the outage. No problems were encountered in the deblocking and blocking sequence. Only control problems encountered were at the inverter. The existing commutation failure protection misoperated due to a defective circuit board. Over the next 7 days the operation of the various protections was verified. The thyristor valve group was successfully blocked and deblocked and operated in series with the remaining two mercury arc valve groups in the pole.

6. CONCLUSIONS

Close cooperation between the supplier and the customer contributed to the project being completed on schedule and within the planned outage time period of 30 days.

Factory testing of the interface circuits contributed to elimination of problems during system testing.

7. REFERENCES

1. F.J. Niedernostheide, H.J. Schulze. J. Dorn, U. Kellner-Werdehausen, D. Westerholt " Light triggered thyristors with integrated protection functions" Proceedings of the 12th international symposium on power semiconductors and IC's, ISPSD 2000 (Toulouse France) pp 267-270.