The New Standard in HVDC & RPC: Thyristor Valves with Direct-Light-Triggered Thyristors

Contents

Introduction
Why direct-light-triggering of thyristors?
Thyristor protection issues
Self protecting LTT features
The LTT thyristor valve
30 Years Evolution of Thyristors

Thyristor blocking voltage (kV)
Thyristor current (kA)

- 1970
- 1980
- 1990
- 2000

LTT
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Why direct-light-triggering of thyristors?

Because it is the better engineering solution for high voltage applications with multiple series connection of thyristors.

The reason is Murphy's Law:

In every engineering endeavor, anything that can fail, will fail

Siemens HVDC thyristor valve design philosophy:
Everything that does not exist, cannot fail
(Inverted Murphy)
Thyristor Triggering & Monitoring

ETT
Triggering and Monitoring Functions

Valve Base Electronic with low power LED

Voltage detection
Check-back
Auxiliary power logic
Electric gate pulse
Protective gate pulse

Check-back signal
Optical trigger signal
Electrical gate pulse
Typical Thyristor Electronic for 8kV Thyristor
An Other Design is Even More Elaborate
Thyristor Triggering & Monitoring: The LTT Approach

The LTT offers the same monitoring capability as the ETT - the logic is just located more conveniently at ground potential.

- Voltage detection
- Check-back signal
- Optical gate pulse

Valve Base Electronic with laser diode
Thyristor Triggering & Monitoring

Thyristor Voltage Monitoring Board in the Celilo Valve
Advantages of the LTT for operation

😊 Number of electrical components in the valves reduced substantially, statistic failure rate reduced, eliminates possibility of electromagnetic interference (EMI), providing inherently higher reliability

😊 Firing pulses available independent of AC system voltage, no auxiliary energy required within the valve

😊 Voltage divider at the thyristor level with simple standard components instead of specialized circuits, simplifies the wiring in the module, less risk of accidental damage during maintenance, less spare parts required with over-the-counter availability resulting in lower operating cost

😊 Eliminates a potential source of partial discharges, providing inherently longer life
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Forward overvoltage protection

In a multiple series connection, all thyristors need to be turned on simultaneously.

Forward overvoltage protection turns the thyristor on if the forward voltage exceeds the withstand level.

Forward overvoltage protection was originally devised for ETT as a backup for failed gate circuits in the multiple series connection.
Evolution of forward overvoltage protection

1970: 1650V ETT with external controlled avalanche diode (CAD) element between anode and gate

1975: 3200V ETT with external Breakover diode (BOD) between anode and gate

1990: 5500V ETT with external active electronic switching circuit

1997: 8000V LTT with integrated forward overvoltage protection
LTT Light Path
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Comparison of Gate Structure ETT vs. LTT

Electrically Triggered

Direct-Light-Triggered

Comparison of Gate Structure ETT vs. LTT
Forward overvoltage and dv/dt protection

The issue:
- dv/dt in off state results in displacement current (space charge near main blocking junction similar to capacitance)
- High displacement current may turn thyristor on locally resulting in destruction

The solution for ETT:
- external sensor activated turn on pulse

The solution for LTT:
- integrated protective turn on by coordinated sensitivity of AG
### Characteristic Data of LTT for Power Transmission

<table>
<thead>
<tr>
<th>Device</th>
<th>4'' - LTT</th>
<th>5'' - LTT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(with integrated overvoltage protection)</td>
<td></td>
</tr>
<tr>
<td>forward protection voltage</td>
<td>min. 7500 V</td>
<td></td>
</tr>
<tr>
<td>repetitive peak reverse voltage</td>
<td>8000 V</td>
<td></td>
</tr>
<tr>
<td>non-repetitive peak reverse voltage</td>
<td>8300 V</td>
<td></td>
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<tr>
<td>on-state voltage (I_T = 3000 A)</td>
<td>max. 2.6 V</td>
<td>max. 2.3 V</td>
</tr>
<tr>
<td>di/dt capability</td>
<td>300 A/µs</td>
<td></td>
</tr>
<tr>
<td>dv/dt capability (V_D = 7.5 kV)</td>
<td>3500 V/µs</td>
<td></td>
</tr>
<tr>
<td>surge on-state current (10 ms)</td>
<td>35 kA</td>
<td>63 kA</td>
</tr>
<tr>
<td>turn-off time</td>
<td>max. 350 µs</td>
<td>max. 350 µs</td>
</tr>
<tr>
<td>min. light trigger power</td>
<td>10 mW</td>
<td></td>
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The LTT thyristor valve:
LTT Housing and Trigger Cable
The LTT thyristor valve: Light Transmission from Ground to Thyristors

Control Room | Valve Hall
---|---

VBE: Valve Base Electronic
MSC: Multimode Star Coupler
LG: Light Guide

Up to 100m

n ≤ 14
Multimode Star Coupler (MSC)

Standard box from communications industry with cover removed up to 12 inputs (lower left) and up to 28 outputs (lower right)
The LTT thyristor valve:
Typical HVDC LTT Valve Module

Multimode Star Coupler
### LTT Thyristors - the Future is Now

These latest HVDC contracts use Siemens LTT:

- **Moyle Interconnector (September 1999)**
  - 500MW, 250kV, 64km submarine cable

- **Basslink (February 2000, NTP Nov 2002)**
  - 480MW, 400kV, 278km submarine cable

- **Celilo MARP (April 2001)**
  - 1600MW, 400kV

- **Guizhou-Guangdong (October 2001)**
  - 3000MW, 500kV

- **Nelson River BP1 MARP (June 2002)**
  - 1000MW, 500kV
The LTT thyristor valve: Moyle Interconnector

250 MW Converter (250kV, 1000A) with 8 kV LTT including integrated overvoltage protection at Moyle HVDC Converter Station (July 2001)
The LTT Thyristor Valve:  
Pacific Intertie, Celilo Converter Station

Bonneville Power Administration (BPA):  
Replace all mercury arc valves rated 133kV, 2000A  
with 36 roll-in LTT valves
Guizhou - Guangdong LTT Thyristor Valve Group

500kV, 3000A Thyristor Valve Group including 5" LTT with integrated overvoltage protection for Guizhou-Guangdong (under construction)

looks identical to

500kV, 1800A Thyristor Valve Group including 4" ETT in Tian-Guang as shown
In Reactive Power Compensation the LTT also has become the standard: LTT Thyristor Stacks for SVC Valve

The active portion of the valve becomes a straightforward assembly of thyristors, heat sinks, and cooling water piping.
LTT Thyristor Module for SVC Valve

The module is a mechanical building block for the three phase valve setup
Thyristor Valve Structures:
Three-Phase SVC Valve - Kemps Creek
TCR Arrangement for Containerized Installation
Computer Model of Container Assembly – Two TCR
Summary

The introduction of direct-light-triggered thyristors simplifies the thyristor valve by

- substantially reducing the electrical parts count
- reducing the electric wiring and number of fiber optic cables
- reducing the spare parts requirements

Direct-light-triggered thyristors with integrated overvoltage protection are the technology of the 21st century. They pave the way towards the maintenance-free high voltage thyristor valve

Thank you for your attention