Power Transmission and Distribution

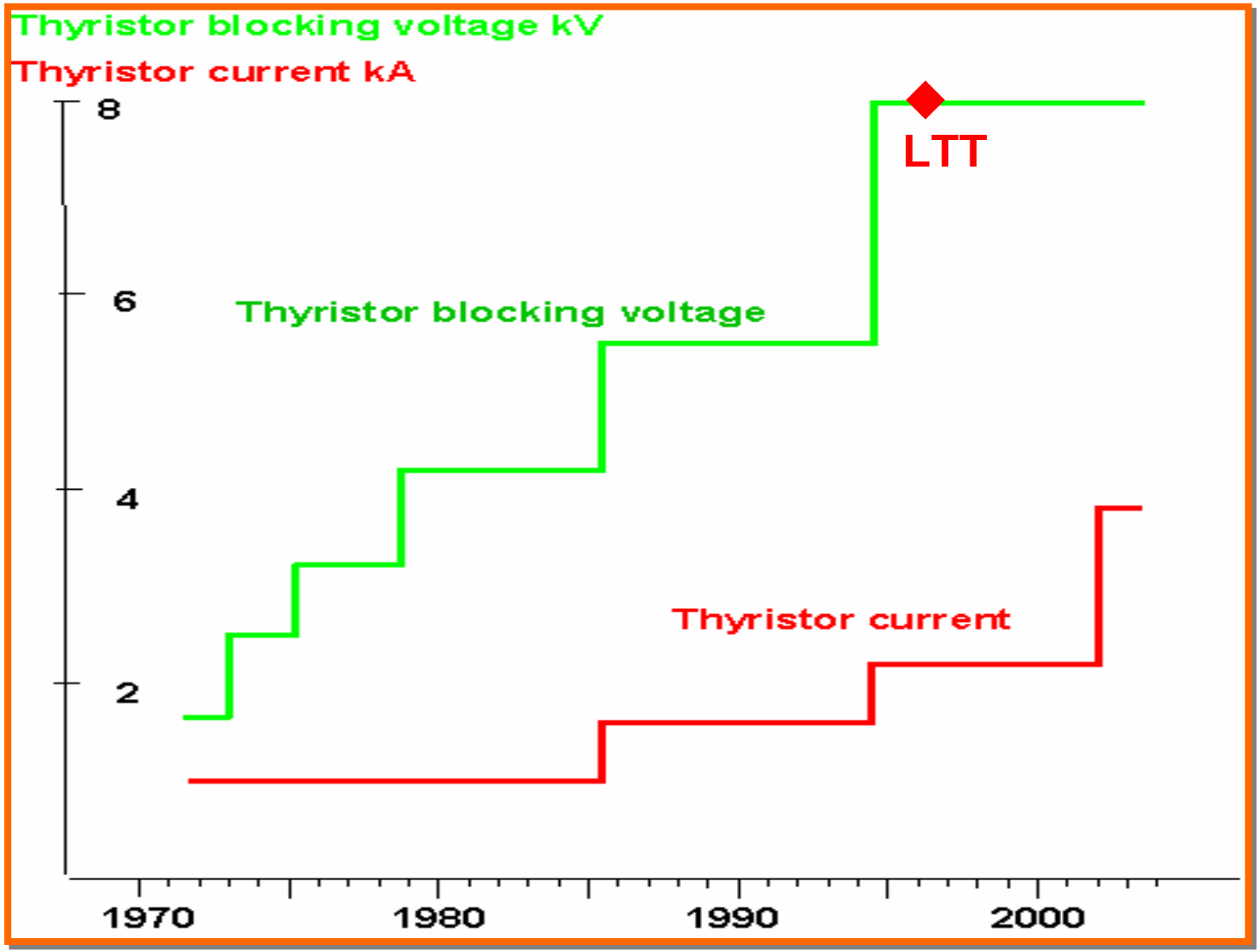
High Power Direct-Light-Triggered Thyristor Valve Technology – The Basis For Advanced Power Electronics Solutions in Transmission Systems

High Voltage

SIEMENS

Contents

30 Years Evolution of Thyristors



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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:

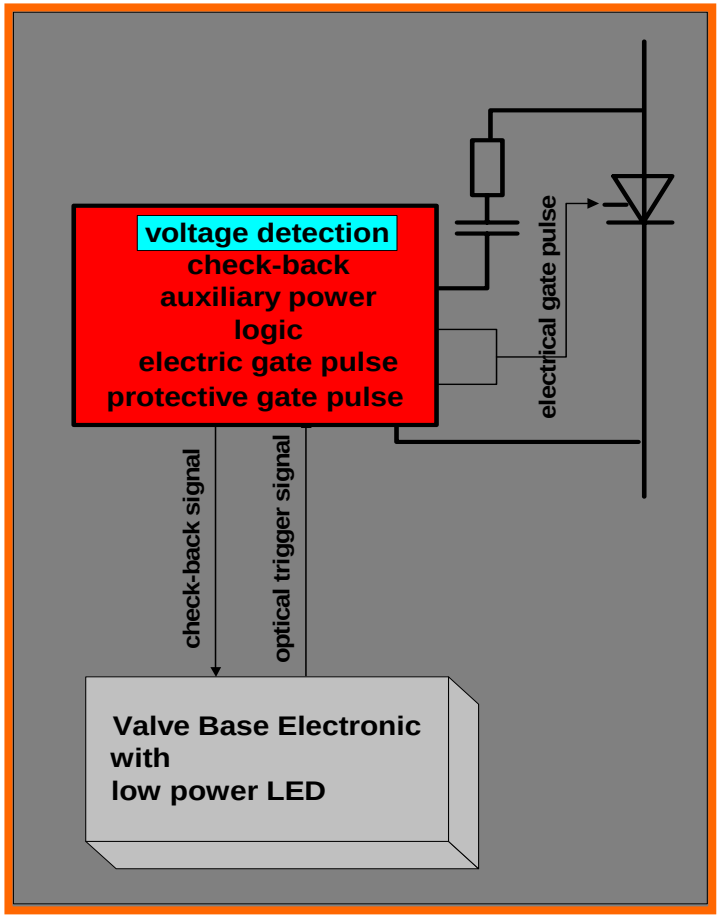
In every engineering endeavor,
anything that can fail, will fail

Siemens HVDC thyristor valve design philosophy:

Everything that does not exist, cannot fail

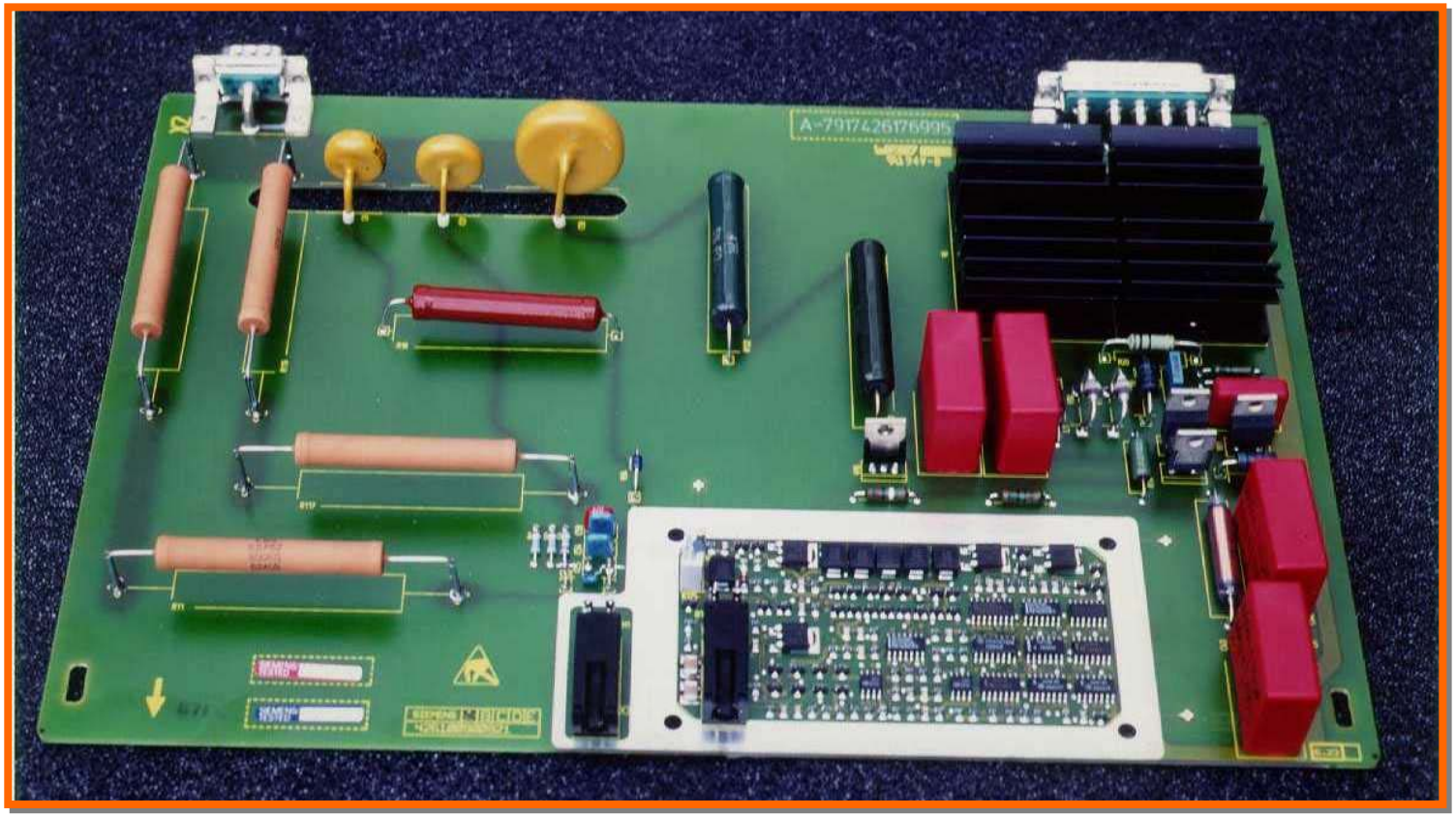
(Inverted Murphy)

Thyristor Triggering & Monitoring

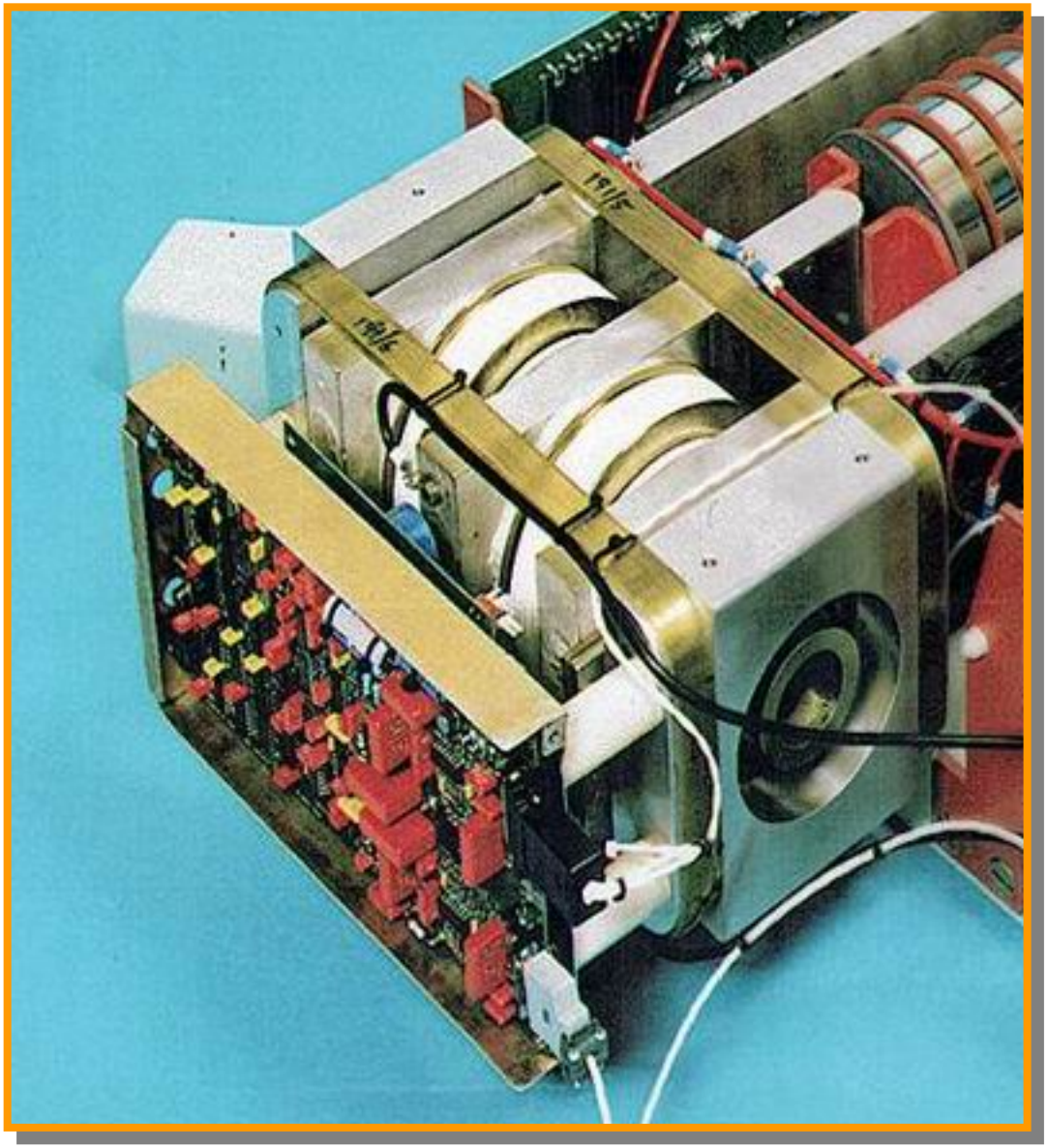


ETT
Triggering and Monitoring
Functions

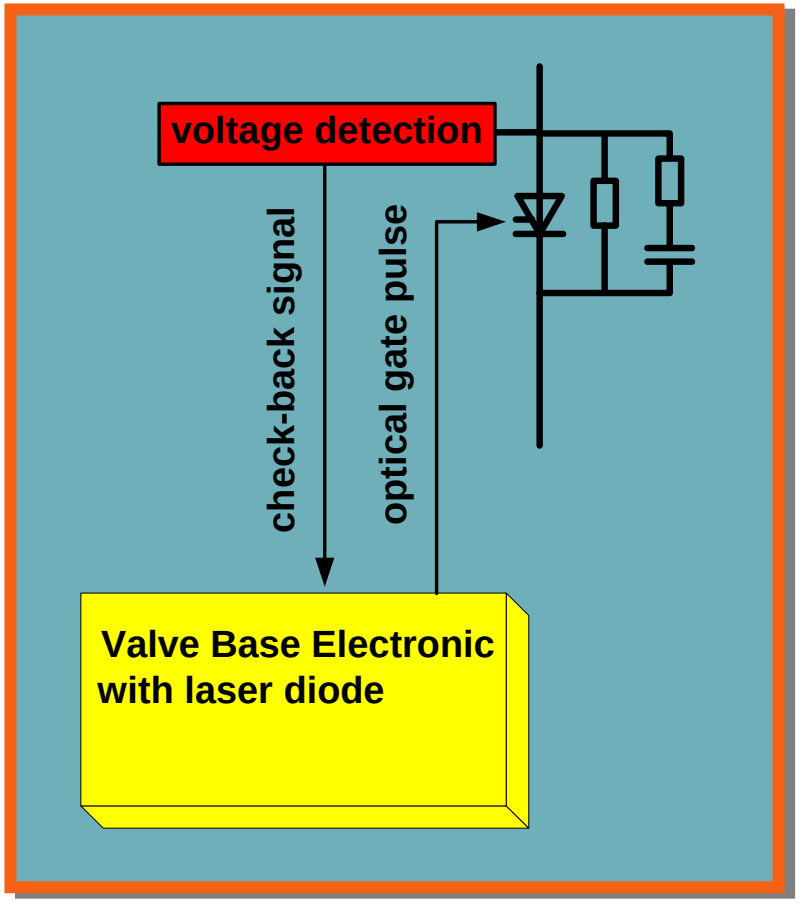
Typical Thyristor Electronic for 8kV Thyristor



An Other Design is Even More Elaborate

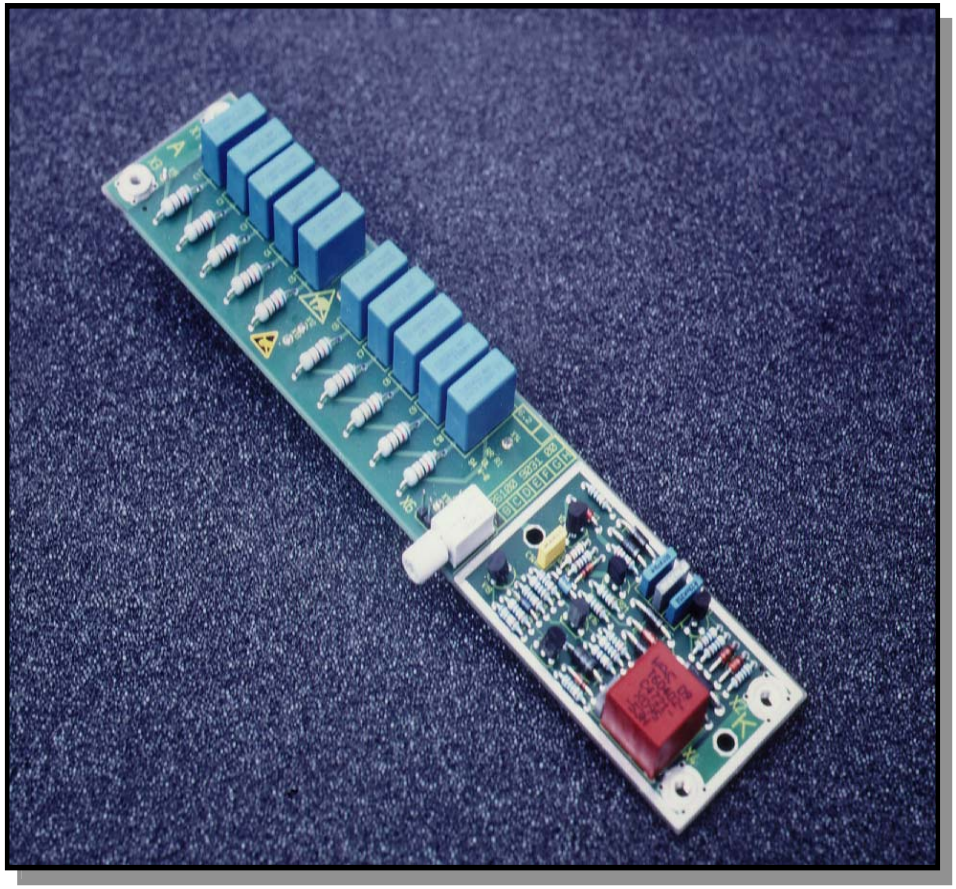


Thyristor Triggering & Monitoring: The LTT Approach



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

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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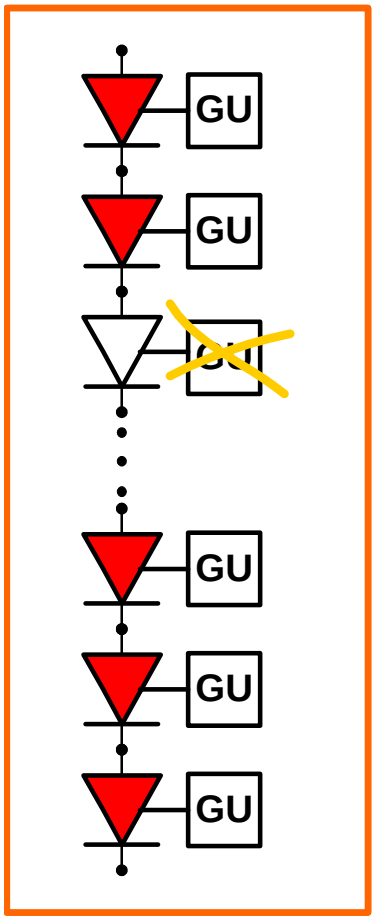
Forward overvoltage protection

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

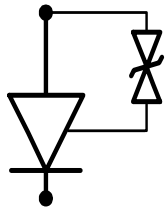
Forward overvoltage protection turns the thyristor on if the forward voltage exceeds the withstand level

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

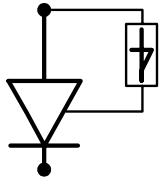


Evolution of forward overvoltage protection

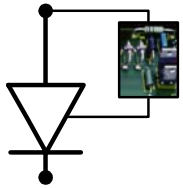
1970: **1650V ETT with external controlled avalanche diode (CAD) element between anode and gate**



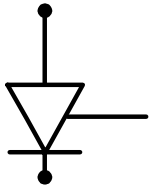
1975: **3200V ETT with external Breakover diode BOD) between anode and gate**



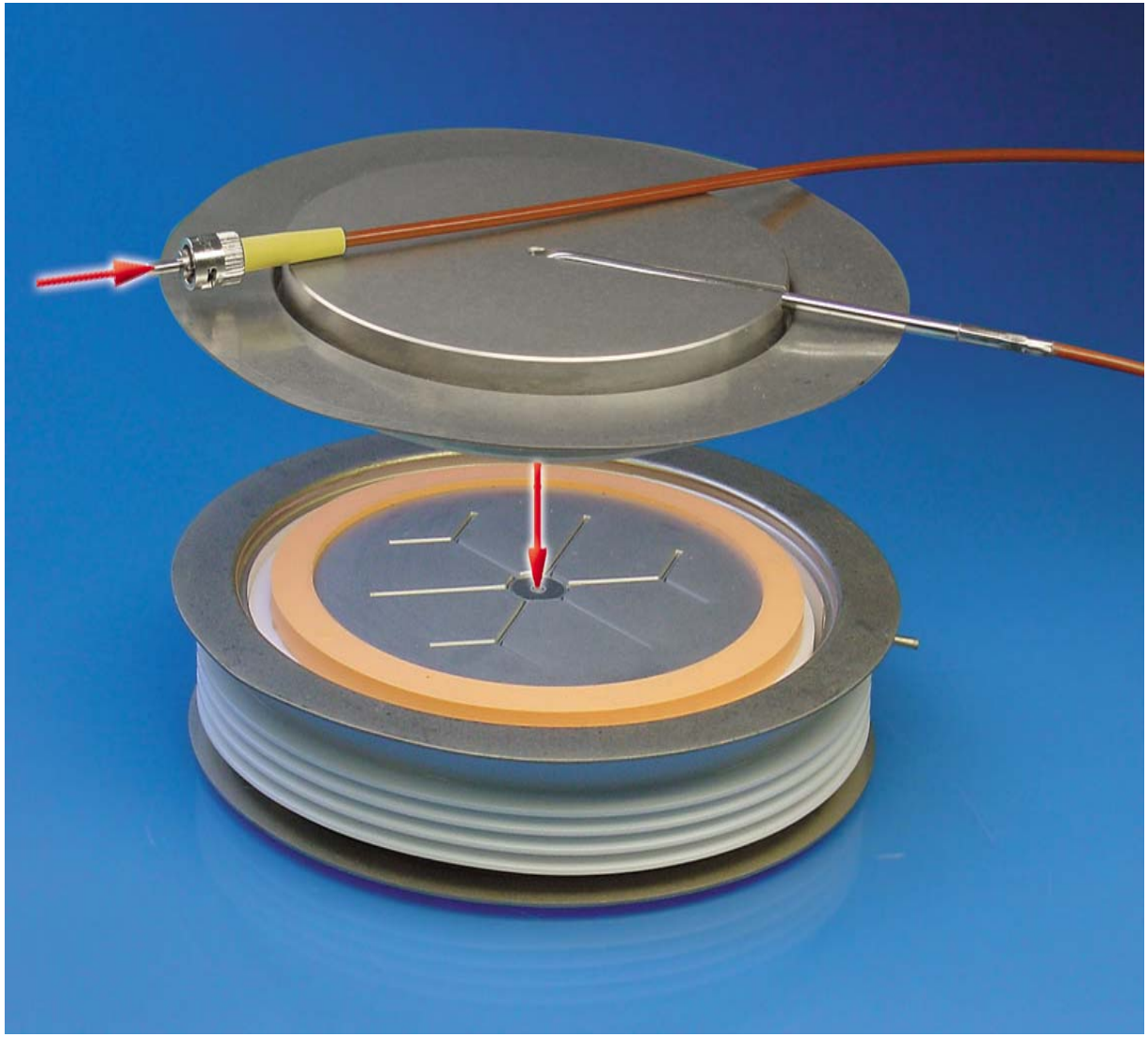
1990: **5500V ETT with external active electronic switching circuit**



1997: **8000V LTT with integrated forward overvoltage protection**



LTT Light Path



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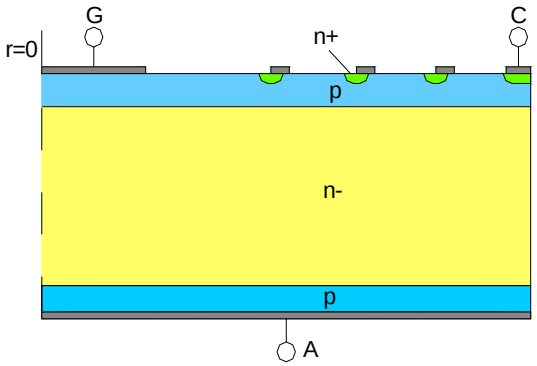
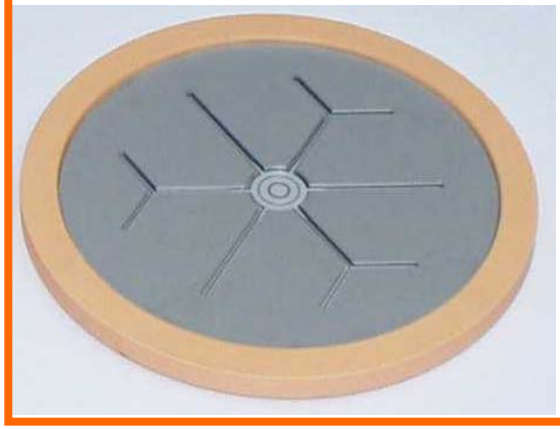
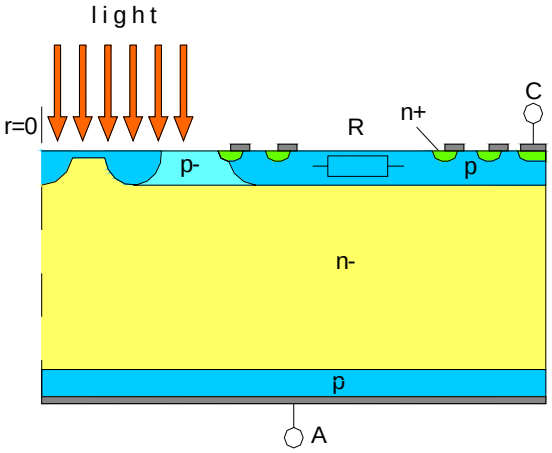
Comparison of Gate Structure ETT vs. LTT

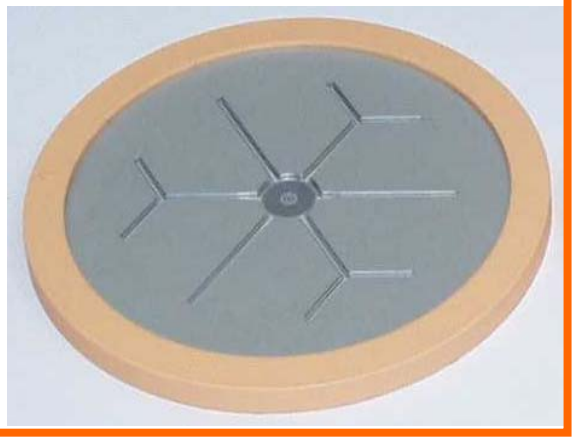
Electrically Triggered





Direct-Light-Triggered





Forward overvoltage and dv/dt protection

The issue:

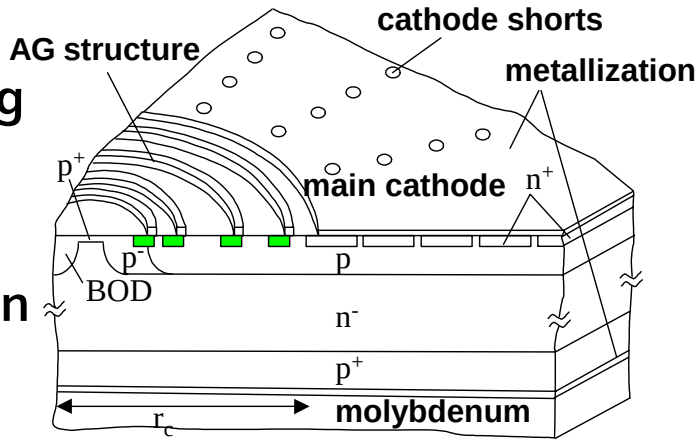
- **dv/dt in off state results in displacement current (space charge near main blocking junction similar to capacitance)**
- **High displacement current may turn thyristor on locally resulting in destruction**

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

Device	4" - LTT	5" - LTT
	(with integrated overvoltage protection)	
forward protection voltage	min. 7500 V	
repetitive peak reverse voltage	8000 V	
non-repetitive peak reverse voltage	8300 V	
on-state voltage (I T = 3000 A)	max. 2.6 V	max. 2.3 V
di/dt capability	300 A/µs	
dv/dt capability (V D = 7.5 kV)	3500 V/µs	
surge on-state current (10 ms)	35 kA	63 kA
turn-off time	max. 350 µs	max. 350 µs
min. light trigger power	10 mW	

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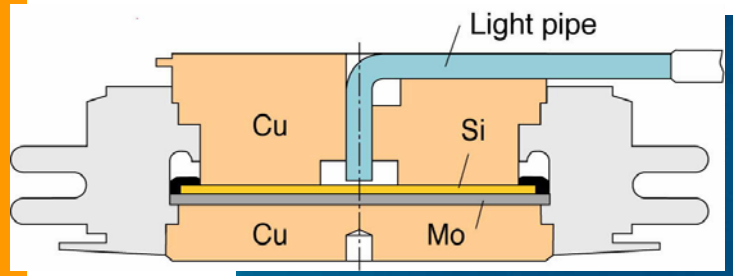
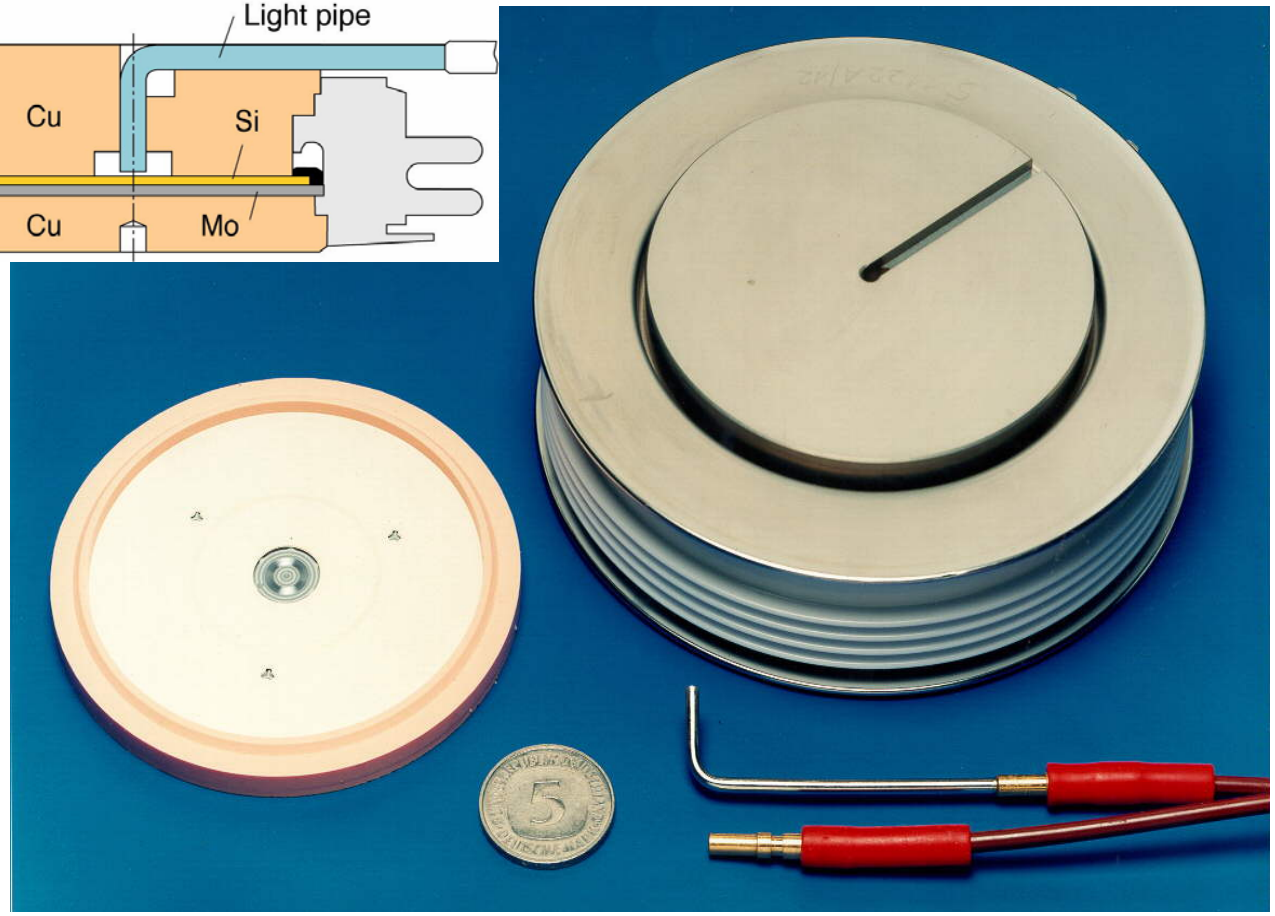
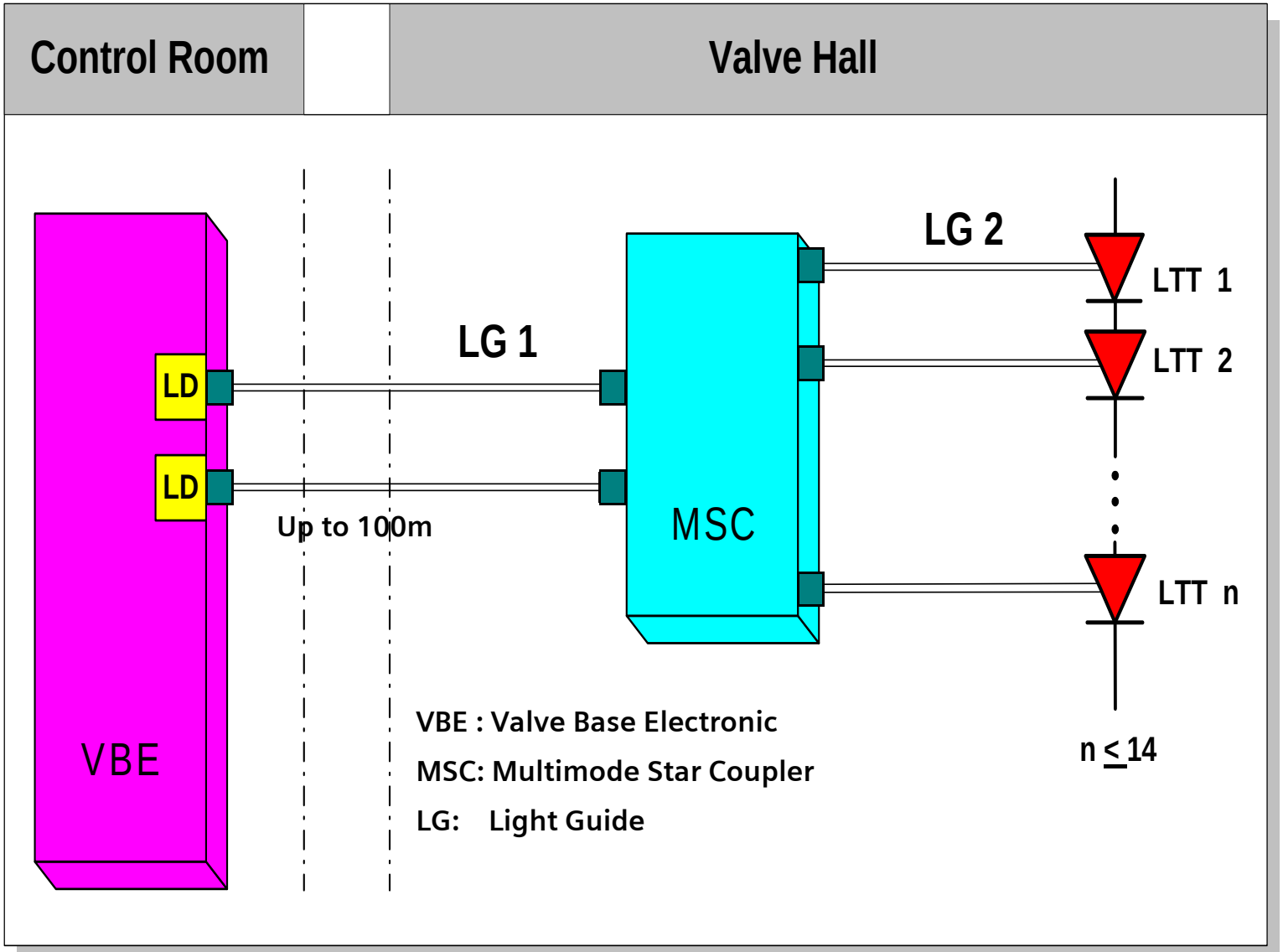
The LTT thyristor valve: LTT Housing and Trigger Cable





The LTT thyristor valve: Light Transmission from Ground to Thyristors

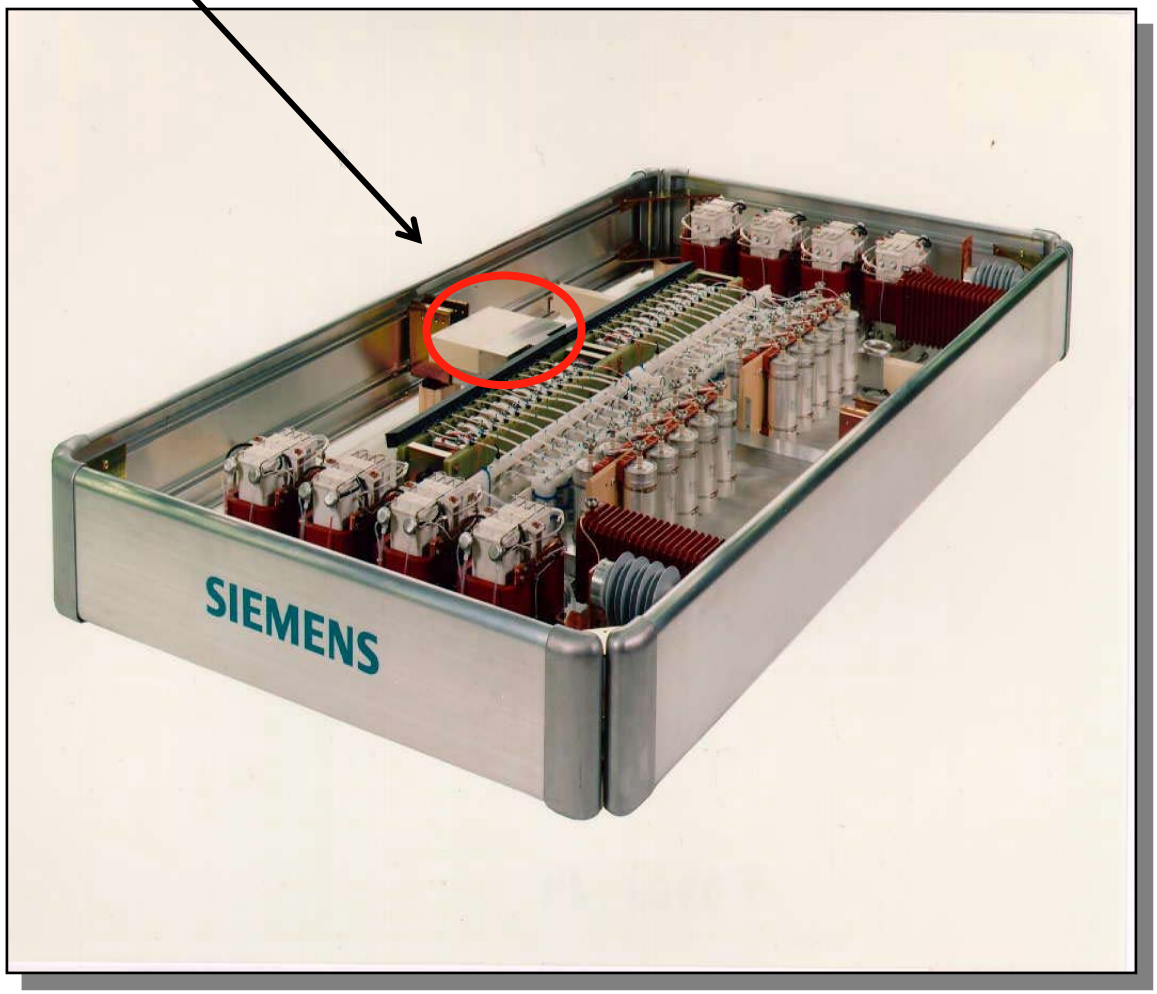


Multimode Star Coupler (MSC)

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



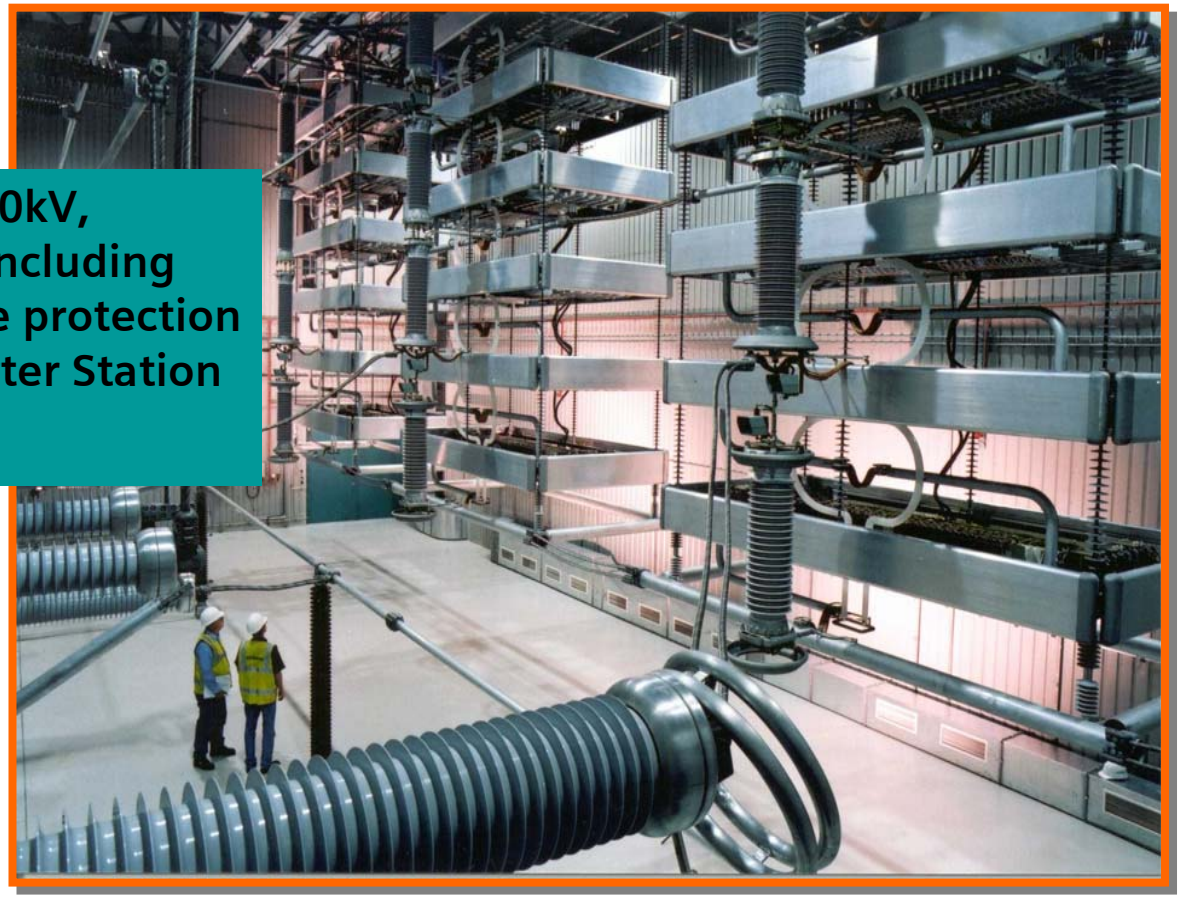
LTT Thyristors - the Future is Now

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)



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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

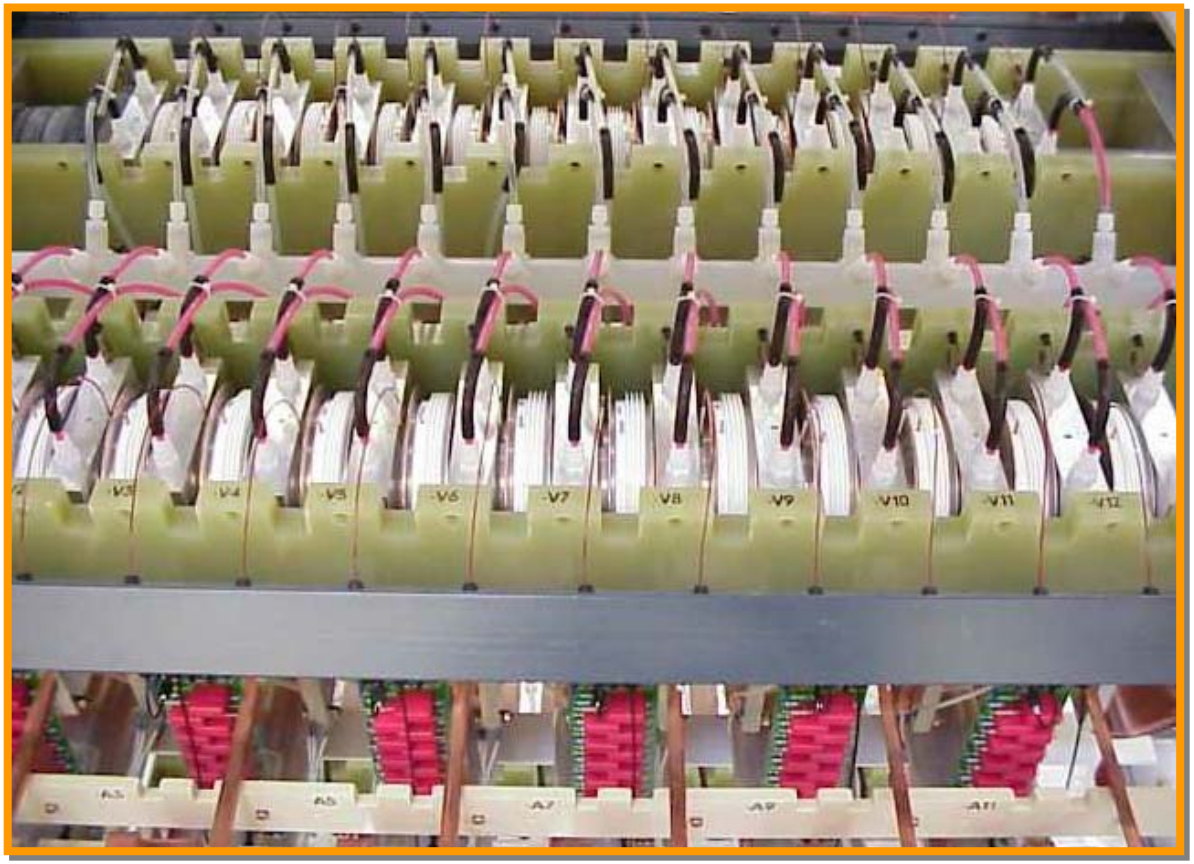
Guizhou - Guangdong LTT Thyristor Valve Group

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

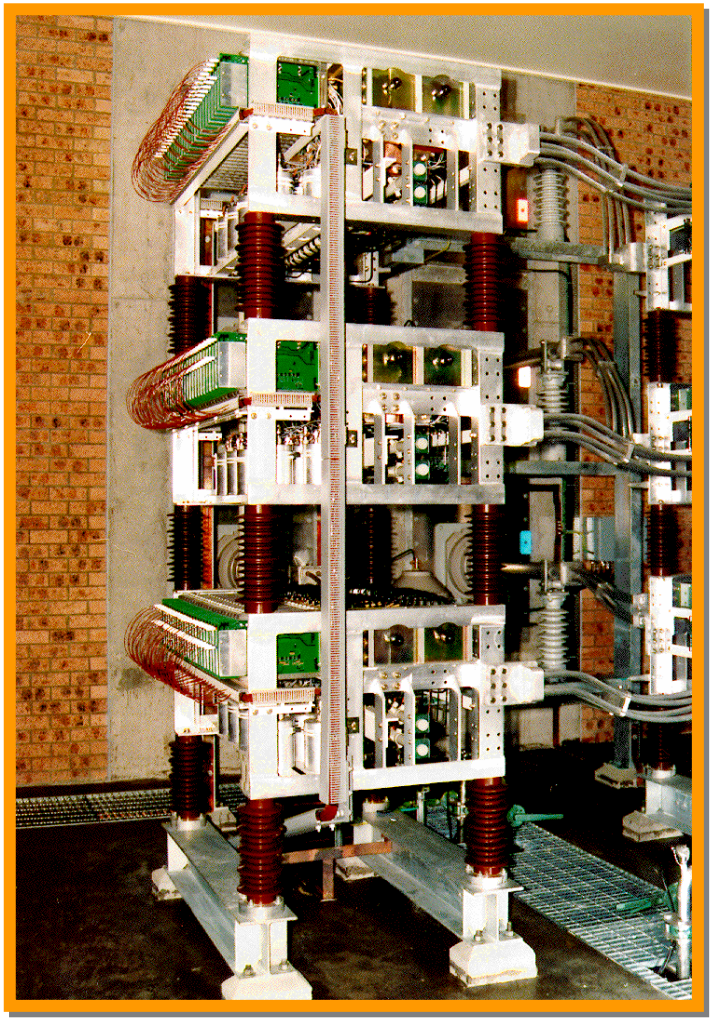


The active portion of the valve becomes a straightforward assembly of thyristors, heat sinks, and cooling water piping

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

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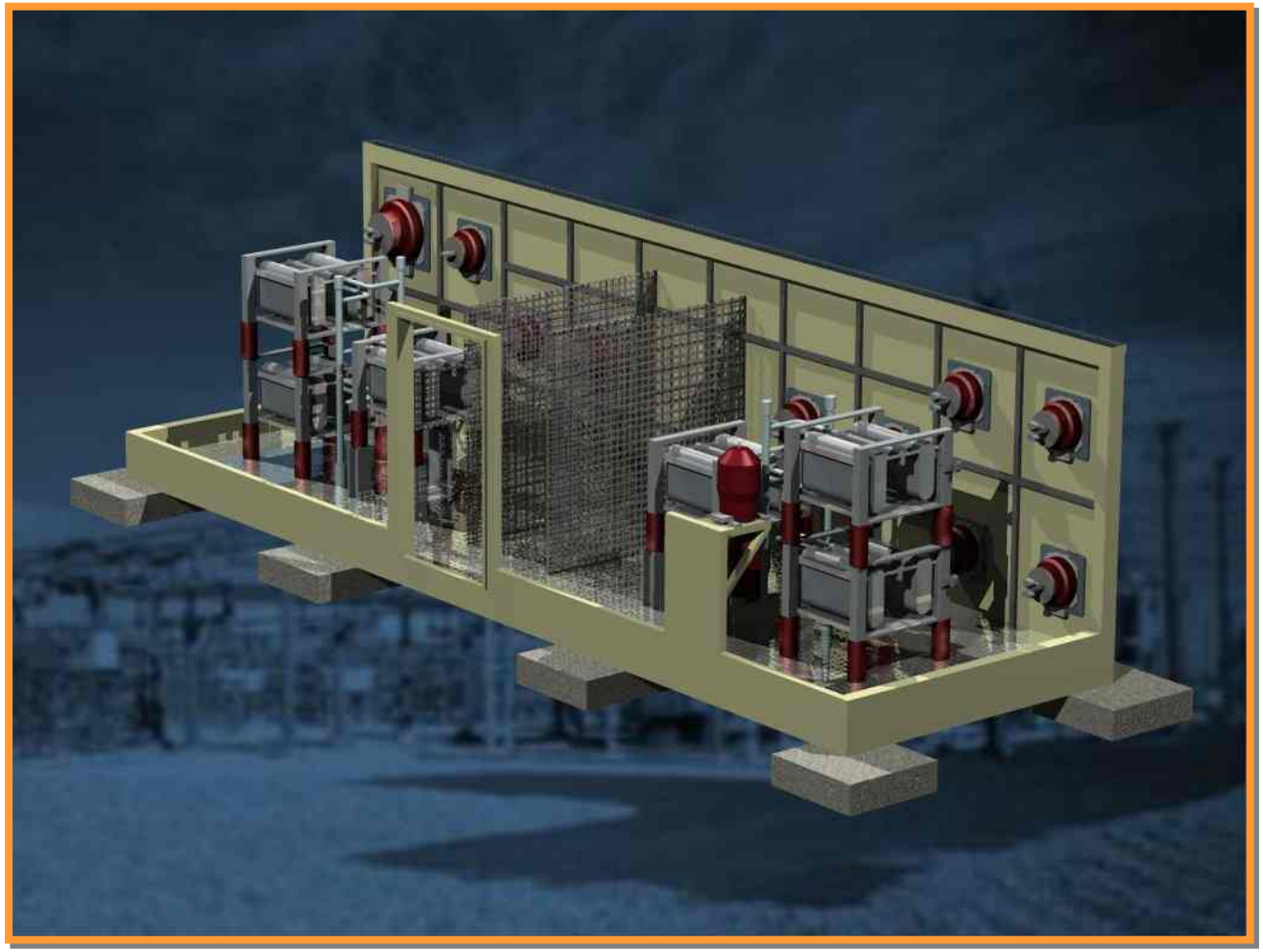
Computer Model of Container Assembly – Two TCR



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