A comparison between Electrically triggered thyristor (ETT) and Light-triggered thyristor (LTT) for HVDC applications.

ETT vs. LTT for HVDC

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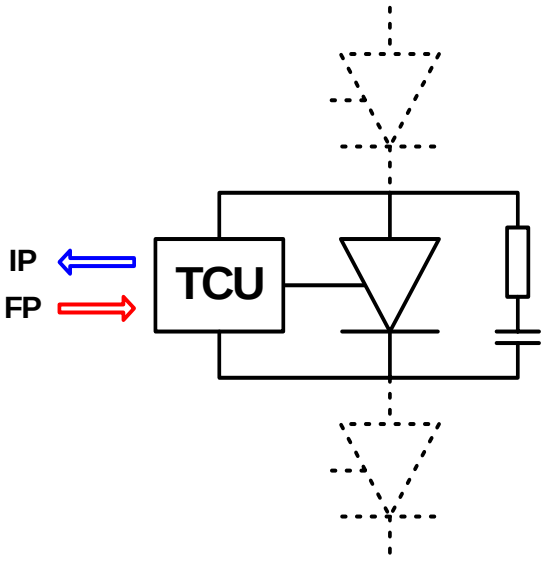
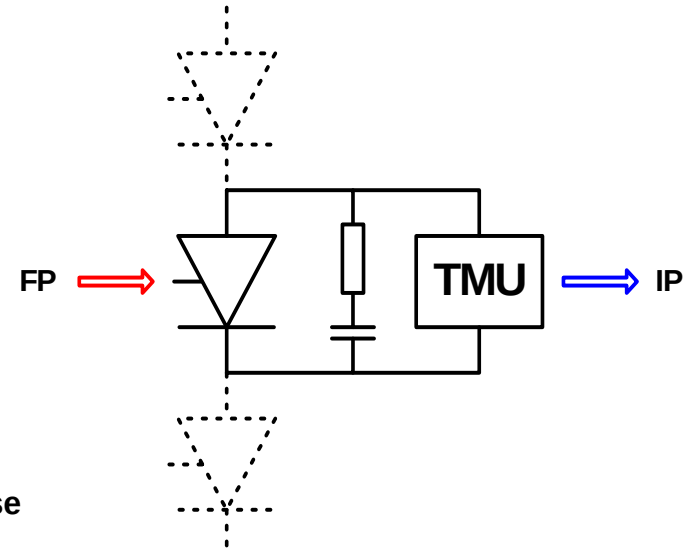
Thyristor triggering in HVDC applications





FP = Firing pulse

IP = Indicating pulse

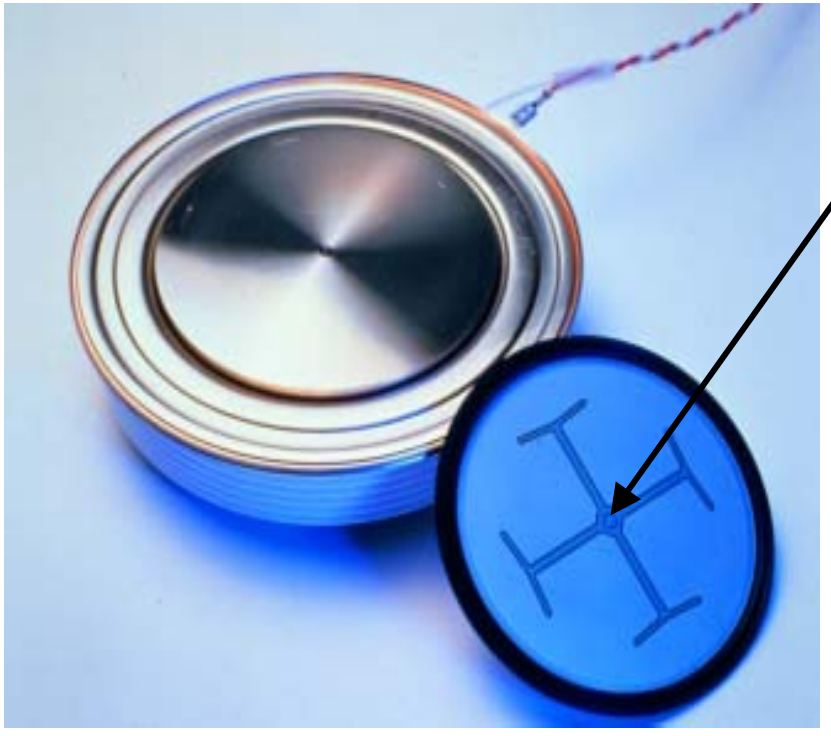
Electrically triggered thyristor (ETT)

- The ETT is triggered by the thyristor control unit (TCU).
- The TCU is energized by the main circuit, and triggering is initiated by an optical pulse
- The TCU protects and monitors the ETT

Light-triggered thyristor (LTT)

- The LTT is triggered directly by an optical pulse
- The LTT is self-protected against overvoltage
- Separate recovery protection is provided
- The TMU monitors the LTT

Thyristor and wafer

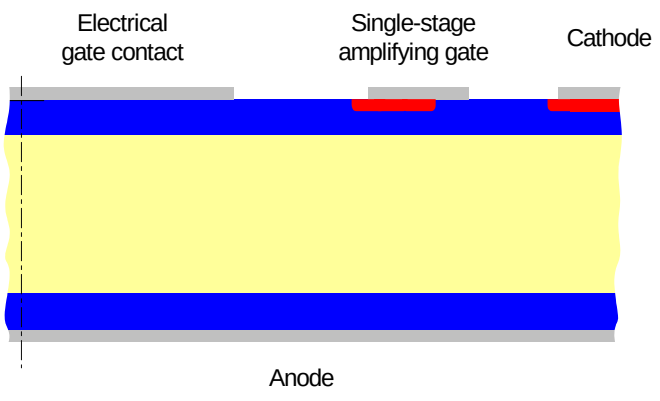


The thyristor gate is located in the center of the wafer

- The gate is designed for either electrical control (ETTs) or optical control (LTTs)
- The ETT gate connects to the outer control cable via a simple electrical cable and a hermetic feed-through
- The LTT gate needs an internal light-guide of glass and an external optical connector in order to connect to the external light-guide
- Electrical triggering is main stream for thyristors, and is necessary for advanced components like GTOs and IGBTs

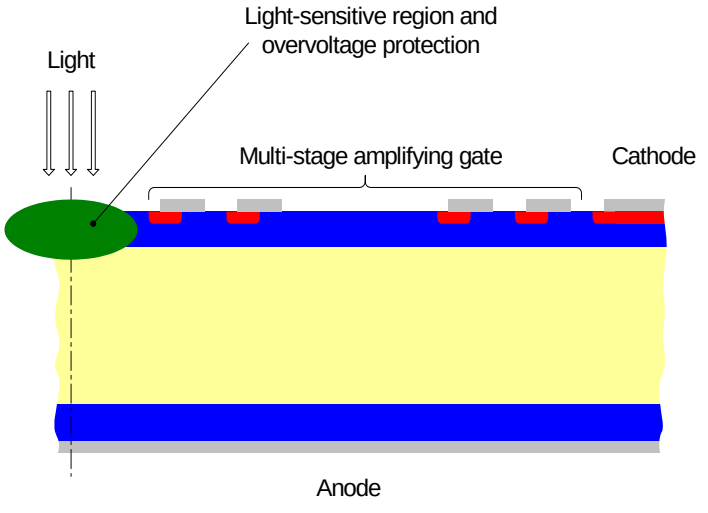
ETT vs LTT in commercial HVDC installations

ETT



- Simple gate design because of powerful gate signal
- 10 major wafer processing steps. Standard encapsulation and testing. High production yield
- Precise external overvoltage protection in TCU
- Highest voltage rating 8.8 kV

LTT



- Complicated gate design due to low optical power
- 16 major wafer processing steps. More complex encapsulation and testing. Reduced production yield
- Temperature dependent internal overvoltage protection with large production spread
- Highest voltage rating 8 kV

Thyristor Control Unit (TCU) for ETT

*)

Old type of TCU

- Discrete components design
- High voltage/high power components included in circuit board electronics
- Pre-charging needed for firing
- Not encapsulated - prone to disturbances

*)

ABB design

- Hybrid components technique:
  - Compact layout
  - High reliability
- Only low voltage electronics
- Ready for firing in all operating conditions
- Totally encapsulated in metallic housing

*) The photographs are of the same scale

Features of the ABB type TCU

Optional:

On-line supervision of specific thyristor level conditions such as

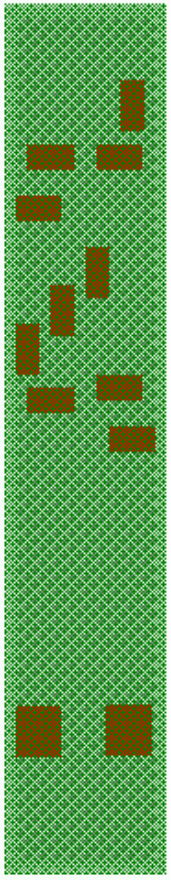
- Thyristor temperature
- Snubber circuit impedance
- Optical performance

Standard features:

- Quickly energized from the main circuit, even by a lightning impulse
- Ready for triggering in all operational conditions due to the very fast energization, even directly after a network fault
- Protective triggering against thyristor overvoltages:
  - Overvoltage in forward blocking state
  - Very fast rate-of-rise of the voltage in forward blocking state
  - Transient forward overvoltage during reverse recovery
- Low light power requirement for control. Light emitting diodes are sufficient
- On-line monitoring of thyristor level blocking ability
- On-line indication in case of protective firing

Thyristor level electronics

ABB ETT vs. LTT



The circuit boards are approximately of the same scale.

The ABB Thyristor Control Unit :

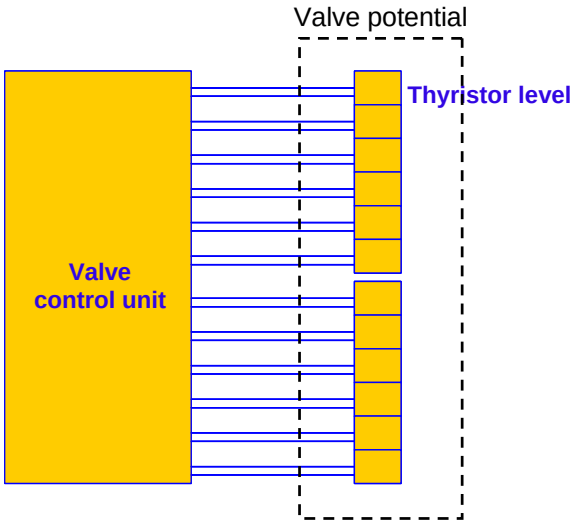
- Normal and protective firing
- Thyristor performance monitoring
- Approximately 40 components and 100 solder joints
- Estimated commercial operation experience (end of 2004): 350 000 unit years (45 000 units)

LTT Monitoring Unit :

- Thyristor voltage monitoring
- DC voltage grading
- Approximately 130 components and 280 solder joints
- Recovery protection not included ➔ additional module electronics needed
- Estimated commercial operation experience (end of 2004): 8 100 unit years

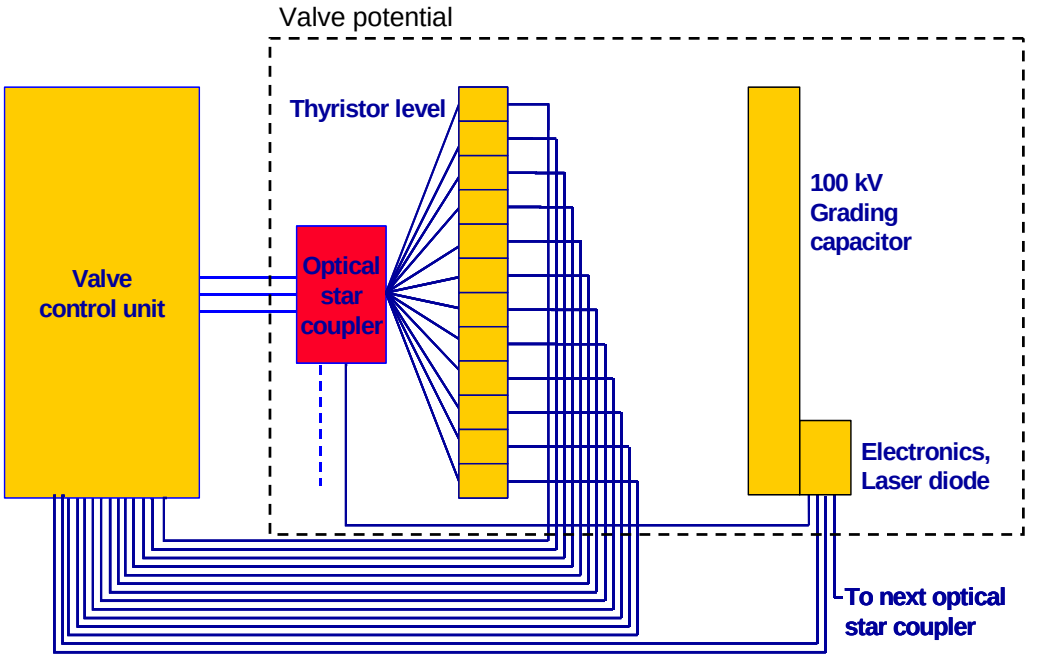
ETT and LTT optical systems

ETT system



- For 12 thyristors:
  - 24 light guides
  - 24 optical connectors at ground level
  - 24 optical connectors at valve potential

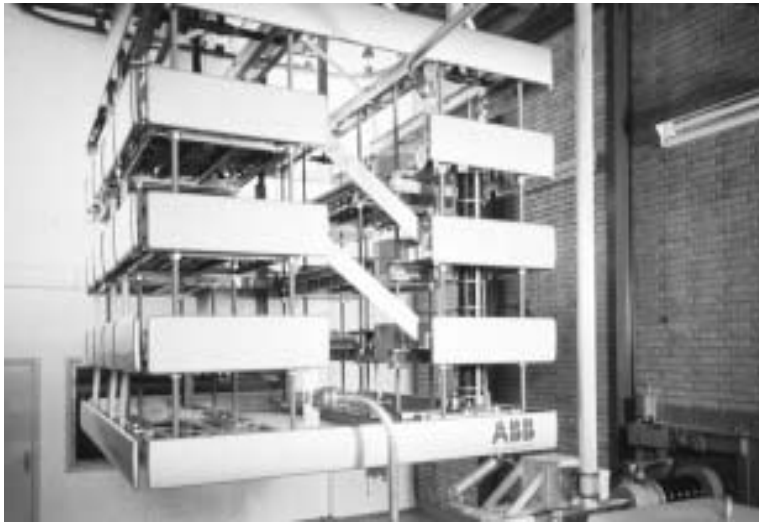
LTT system with external recovery protection



- For 12 thyristors:
  - 31 light guides
  - 17 optical connectors at ground level
  - 45 optical connectors at valve potential

Non-redundant component

The ABB Konti-Skan test valve with LTTs



The 125 kV, 1050 A test valve

- In commercial operation since May 1988, replacing a mercury arc valve
- 48 LTTs in series
- Two types of light sources tested:
  - Light-emitting diodes, one per thyristor
  - Powerful laser diodes serving groups of thyristors via optical star couplers
- Technically functioning, but no advantage in comparison with ABB's ETT concept

The 7 kV, 45 cm² thyristor

- Directly light-triggered
- Built-in overvoltage protection during off-state and recovery

ABB converter valves for HVDC transmission

ABB has selected the ETT approach for superior performance

Converter valves in the Three Gorges-Changzhou transmission

Characteristics of the ABB solution with ETTs

- Proven high reliability
  - 14 000 ETTs with 5” wafers installed (end 2004). No thyristor failure during commercial operation reported.
- Low maintenance requirements. Scheduled maintenance interval 5 years for modern installations.
- Full redundancy in case of a component failure (optical system, electronics, or thyristor)
- Low risk of commutation failures
- Robust thyristor design
- High-tech solution for thyristor triggering and protection

Conclusions

- The LTT concept is a technological dead-end
- The ETT concept is a robust and reliable design with lower complexity
- ABB has
  - used ETTs for HVDC since 1967
  - tested LTTs for HVDC during 17 years since 1988

Electrically triggered thyristors are superior!

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