HVDC Development at Toshiba and Its Outlook

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World’s 10th largest electronics & electrical equipment manufacturer

Corporate profile (As of April 1, 2015)

Established: July 1875
Net Sales: US$ 62 Billion
Employee: Approx. 206,087
Subsidiaries: 554 Companies

Social Infrastructure

Electronic Devices

Digital Products

Home Appliances

Home Appliances

Electronic Devices

Digital Products

Social Infrastructure
Provide

- Low-carbon & high-efficiency infrastructure for the electrical industry and society
- high quality systems at a competitive price
### History of Toshiba HVDC Technology

#### Basic Developments
- **Electrical machine Laboratory**
  - 100kV Air-Cooling Valve (1969)
- **Sakuma Thyristor Testing Center**
  - 37.5MW Converter field tests (1970)
  - 125kV Oil-Cooling Valve (1972)

#### Applications
- **Sakuma Frequency Converter**
  - 125kV Water-Cooling Valve (1981)
  - 125kV Light-Triggered Valve (1983)

#### Projects
- **First Generation**
  - **Shin - Shinano FC No.1** 300MW, (1977); it was replaced in 2009
  - **Hokkaido - Honshu HVDC Link Pole - 1** 300MW (1979/80)

- **Second Generation**
  - **Shin - Shinano FC No.2** 300MW (1992)
  - **Hokkaido - Honshu HVDC Link Pole - 2** 300MW (1993)
  - **Sakuma FC** 300MW (1993)

- **Third Generation**
  - **Kii Channel HVDC** 1400MW (2000)

#### Thyristor Valve
- **ETT**
  - (Electrically-Triggered Thyristor)
  - Oil/Air Cooling
- **LTT**
  - (Light-Triggered Thyristor)
  - Water Cooling
- **LTT**
  - 6 inch thyristors
Experience of HVDC System in Japan

Shin-Shinano Frequency Converter Station
300MW – Year 1977/2009
600MW – Year 1992
DC voltage: 125kV
DC current: 2,400A
Thyristor: LTT (7.5kV-2,440A)
Cooling: Water
Insulation: Air

Minami-Fukumitsu Back to Back Converter Station
300MW – Year 1999

Sakuma Frequency Converter Station
300MW – Year 1965 / 1993

Higashi-Shimizu Converter Station
300MW – Year 2006

Hokkaido-Honshu DC Transmission Line
150MW – Year 1979
300MW - 1980
600MW - 1993

Kii-Channel DC Transmission Line
700MW x 2 pole - Year 2000
(2800MW in the future)
DC voltage : 250kV
DC current: 2800A
Thyristor : LTT (8kV-3500A)
Cooling : Water
Insulation: Air
Triggering: Direct Light
Quadruple valve size: 6.7W-3.7D-8.75H
Submarine cable: 50km
Overhead line: 50km

*Year: Commissioning year
Montenegro-Italy HVDC Link

- Link power grids of Italy and Montenegro across the Adriatic Sea
- Part of EU power grids integration project
- Tap into the hydro power in the Balkans and mitigate energy shortage in Italy
- Toshiba’s second overseas HVDC project

PROJECT OVERVIEW:
LCC type with rapid power reversal cap
Power: 1,000MW with 20% continuous overload
DC voltage: 500kV
Length of sea cable: 415km
Commissioning in progress
Completion: End of 2019
Voltage Sourced Converter Development

GTO

1991
50Mvar STATCOM Shin-Shinano

1992
20Mvar 3-Teminal FC Shin-Shinano

1997
53MW 3-Teminal FC Shinkansen

IEGT

2004
60MW FC Tsunashima Shinkansen

2007
90Mvar STATCOM Electricity

2009
60MW FC Numazu Shinkansen

2012
60MW FC Ooi Shinkansen

IEGT: Injection Enhanced Gate Transistor
GTO: Gate Turn Off Transistor
SVC: Static Var Compensator
STATCOM: STATic COMPensator
FC: Frequency Converter
New Hokkaido-Honshu HVDC Link

Commissioning: March 2019
Converter type: MMC-VSC
Rated Capacity: 300 MW ± 100 Mvar
DC circuit configuration: Monopole (asymmetrical)
DC voltage and current: +250 kV, 1200 A
AC voltage: 275 kV (both converter stations)
Transmission distance: 122 km (overhead line: 98 km, cable: 24 km)

Source: The voltage source converter applied to new Hokkaido-Honshu HVDC Link, Cigre-IEC 2019 Conf, April 2019
LCC HVDC

• Many of its traditional applications have been taken over by the VSC
• Its robustness, high reliability, ample experience and strong supply can be attractive
• It is inherently immune to the DC fault
• Much cheaper than the MMC for high power applications
• Extra powerful systems have been built and are working well
• uHVDCs reach to 3 – 12 GW, $V_{DC}$ at 800/1100 kV for bulk power transmission over extra-long distances
• Working together with SC, SVC or STATCOM can be a valid and economic solution
• To be further developed into hybrid HVDC systems and multi-terminal HVDC
VSC HVDC Applications

• The MMC technology is a focus point in VSC systems
• The right technology for offshore wind and solar power plants
• Other features like controllability, lower harmonics, reduced space, connection ability etc. are increasingly appreciated
• Move to transmission systems with even higher power capability
• New systems like multiple-terminal, hybrid HVDC and DC grid are starting to emerge
Outlook of the HVDC Industry in the Future

VSC Technology Development

• System development at pace
• Systems get very complicated with a lot of uncertainties
• Raise the power level
• Reduce the losses
• Improve the reliability
• Reduce the cost
Conclusions

• HVDC system has been bringing many benefits to modern power systems, but it also brings in many challenges, making the power grid very complicated.

• This are the reasons why we need modelling, analysis and studies in order to fully understand such a complicated network.

• This is one of the tasks why we are here today
Thank you for your attention