

Power Converter Systems

Graduate Course EE8407

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Ryerson Campus

Topic 1 Introduction

1. Course Outline

- Lecture Topics
- Course Organization
- Design Projects

2. High-Power Converter Topologies

- Multipulse Diode and SCR Rectifiers
- Multilevel Voltage Source Converters
- PWM Current Source Converters

3. High-Power Converter Applications

- Electric Drive Applications
- Power Systems Applications

Course Outline

- **Lecture Topics**

1. **Introduction**
2. **High-Power Semiconductor Devices**
3. **Multipulse Diode Rectifiers**
4. **Multipulse SCR Rectifiers**
5. **Two-level Voltage Source Inverter**
6. **Multilevel Cascaded H-Bridge Converters**
7. **Multilevel Diode-Clamped Inverter**
8. **Other Multilevel Voltage Source Converters**
9. **Current Source Inverters**
10. **Current Source Rectifiers**

Course Outline

- **Course Organization**

Lecture 2 hours per week

Laboratory 1 hour per week (simulation)

Textbook

Bin Wu, 'High-Power Converters and AC Drives'

Wiley - IEEE Press, 2006

Lecture Slides

Download from

<http://www.ee.ryerson.ca/~bwu/courses.html>

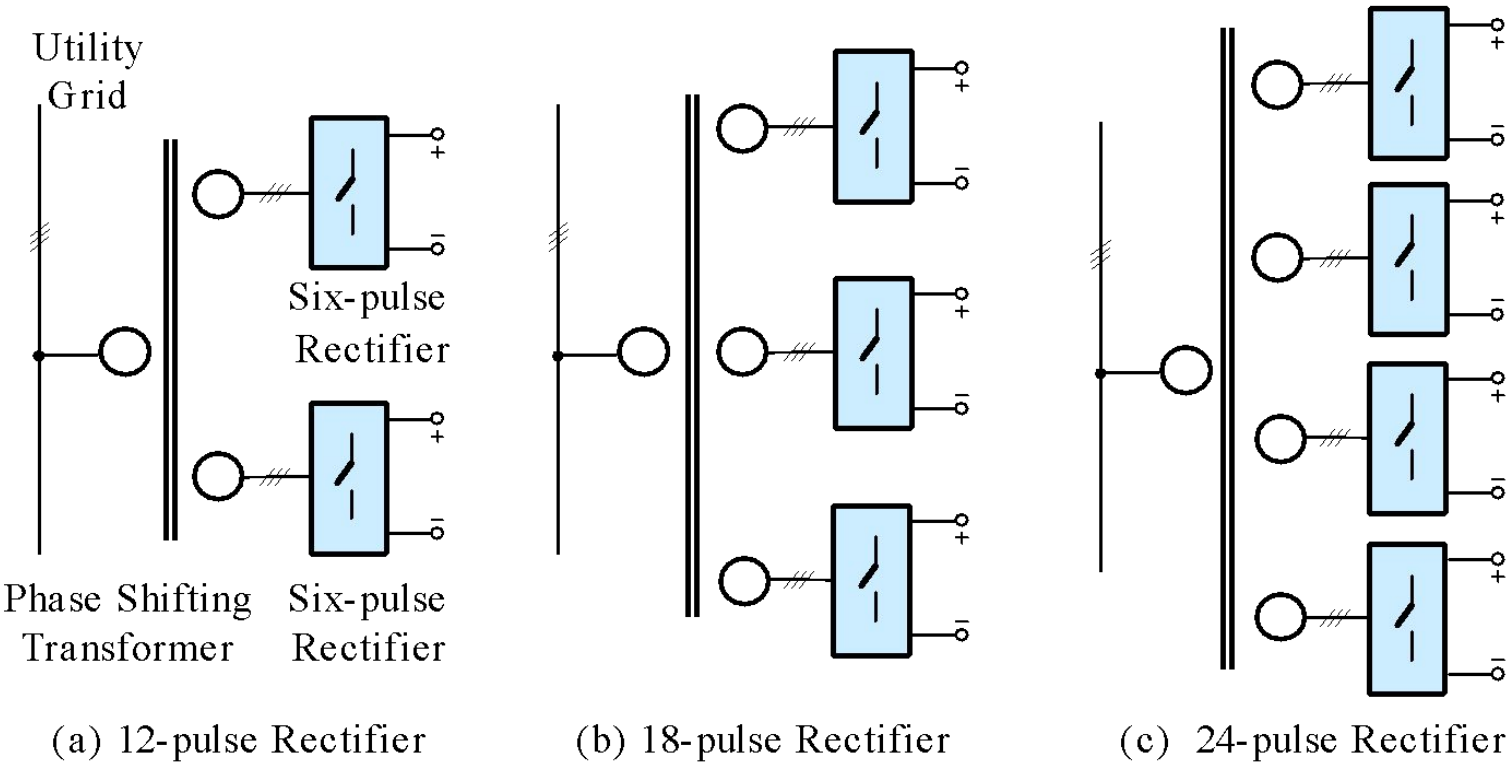
Course Outline

- **Design Projects**

1. Series-type 12-pulse Diode Rectifier	15%	
2. Space Vector Modulation Technique	30%	
3. Control of Multilevel Cascaded H-Bridge Inverters		20%
4. Multilevel diode Clamped Inverters	15%	
5. PWM Techniques for Current Source Converters		20%
Total	100%	

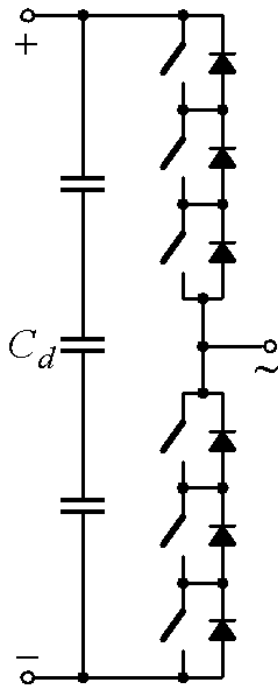
High-Power Converter Topologies

Multipulse Diode/SCR Rectifiers

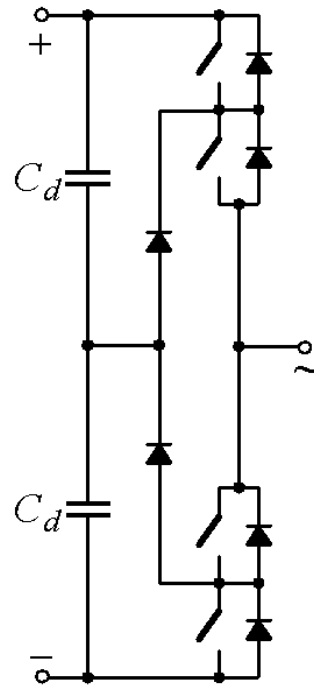


High-Power Converter Topologies

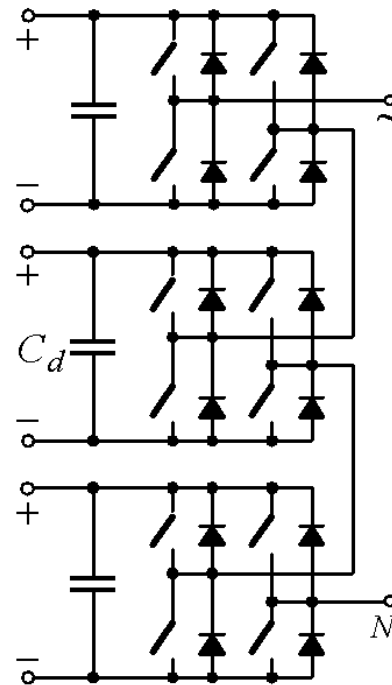
- Multilevel Voltage Source Converters



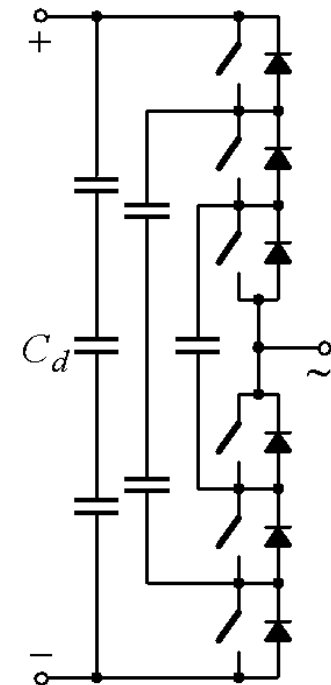
Two Level
Inverter



Neutral Point
Clamped Inverter



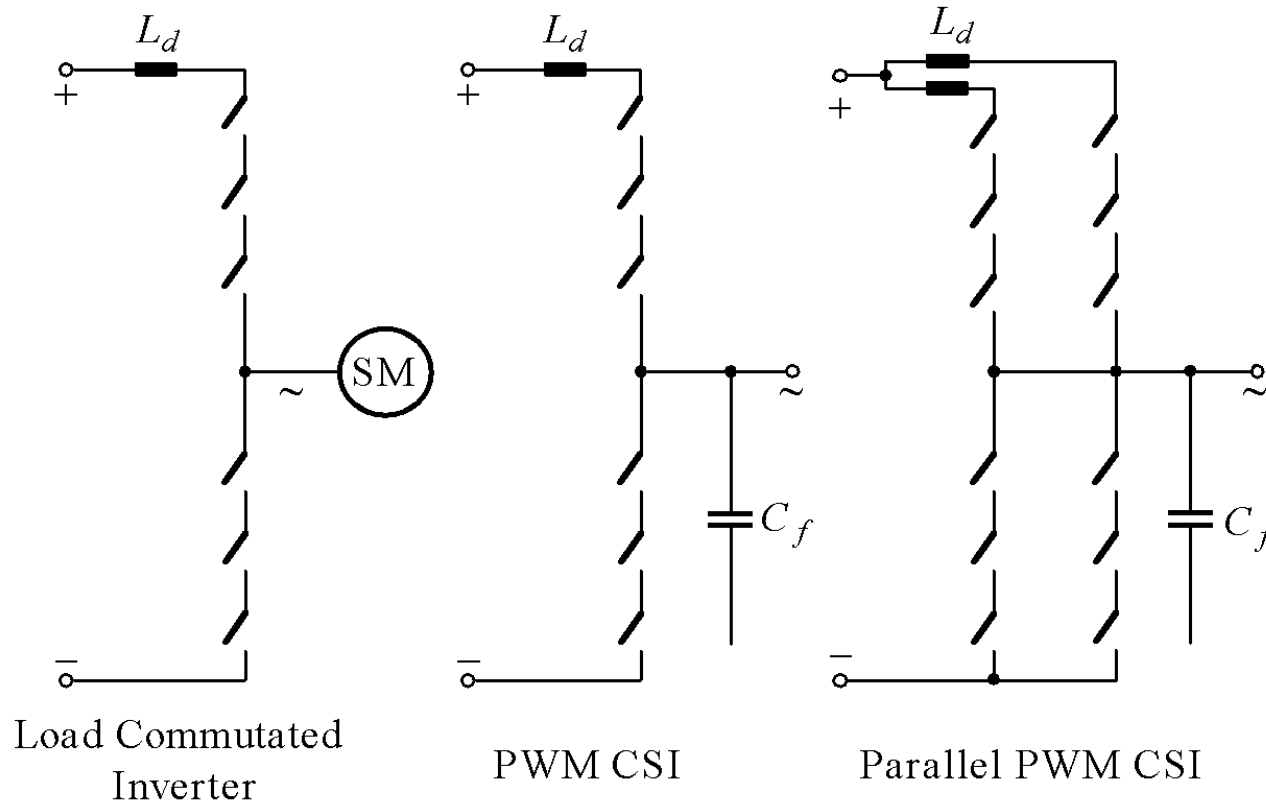
Cascaded
H-bridge Inverter



Flying Capacitor
Inverter

High-Power Converter Topologies

- PWM Current Source Converters



High-Power Converter Applications

- **Converter Power Rating**

- **Electric Drive Systems: 100MW**
- **Wind Energy Systems: 6MW**
- **Power Systems FACTS: 300MVA**
 HVDC: 3000MW

FACTS - Flexible AC Transmission System

HVDC - High Voltage DC Transmission

Variable Speed Drive Applications

- Application Areas



Mining / cement



Petrochemical



Metals



Paper / pulp



Marine



Oil / gas



Power generation



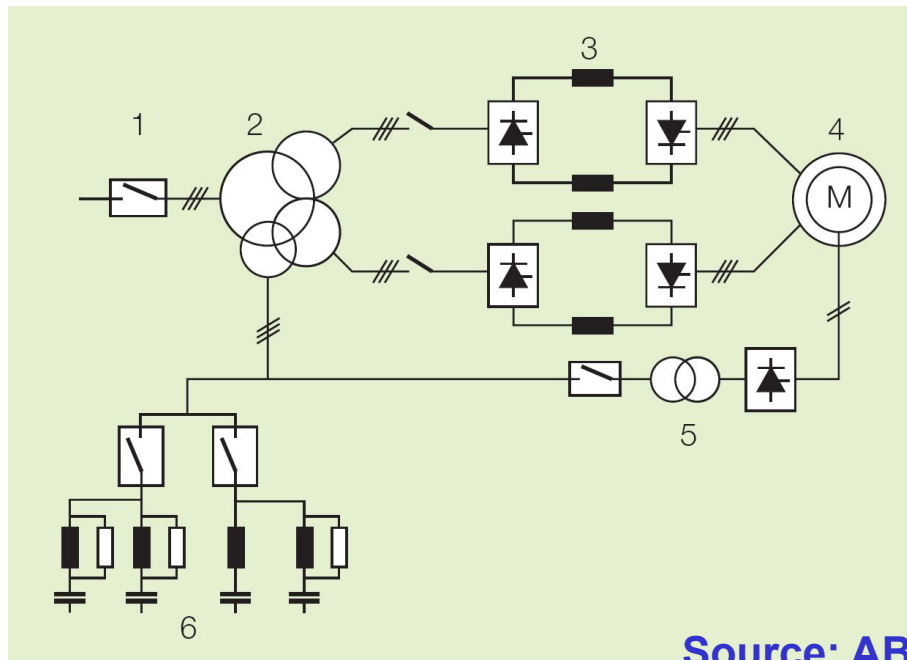
Water / waste water

Source: Robicon

Variable Speed Drive Applications

- 100MW Wind Tunnel Drive

- Application: NASA wind tunnel
- Motor: Six-phase, synchronous
- Load: High power fan
- Speed Range: 360 - 600rpm

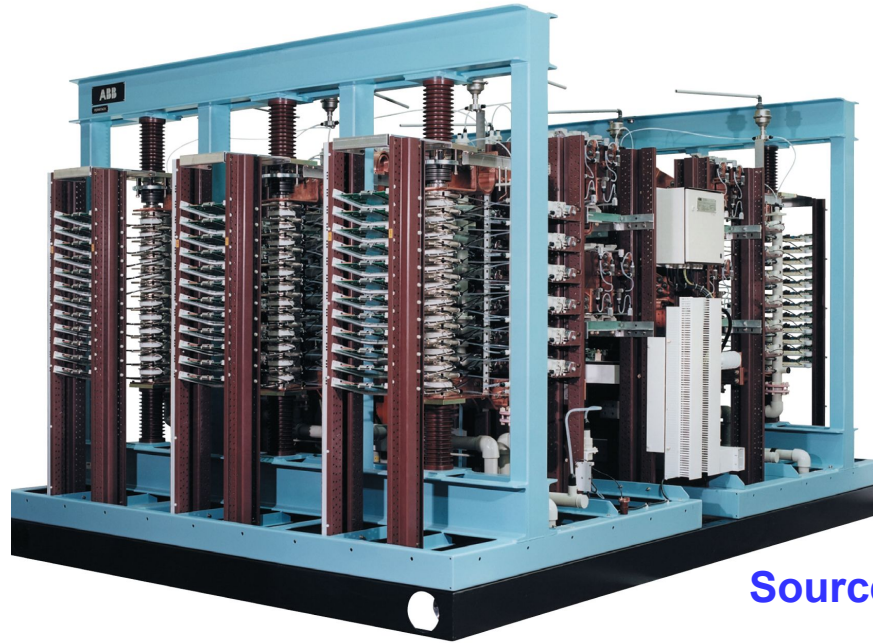


1. Supply system
2. Transformer
3. Converters
4. Motor
5. Excitation system
6. Filter

Source: ABB

Variable Speed Drive Applications

- 100MW Wind Tunnel Drive



Source: ABB

One of the 4 converters used in the drive

- Inverter type: current source
- Switching device: SCR thyristor
- # of devices in series: 12
- Total # of devices: $(12 \times 6) \times 4 = 288$
- Converter efficiency: $> 99\%$

Variable Speed Drive Applications

- 100MW Wind Tunnel Drive



Source: ABB

**Six-phase synchronous motor
(100MW, 12.5KV, 2.8KA)**

Variable Speed Drive Applications

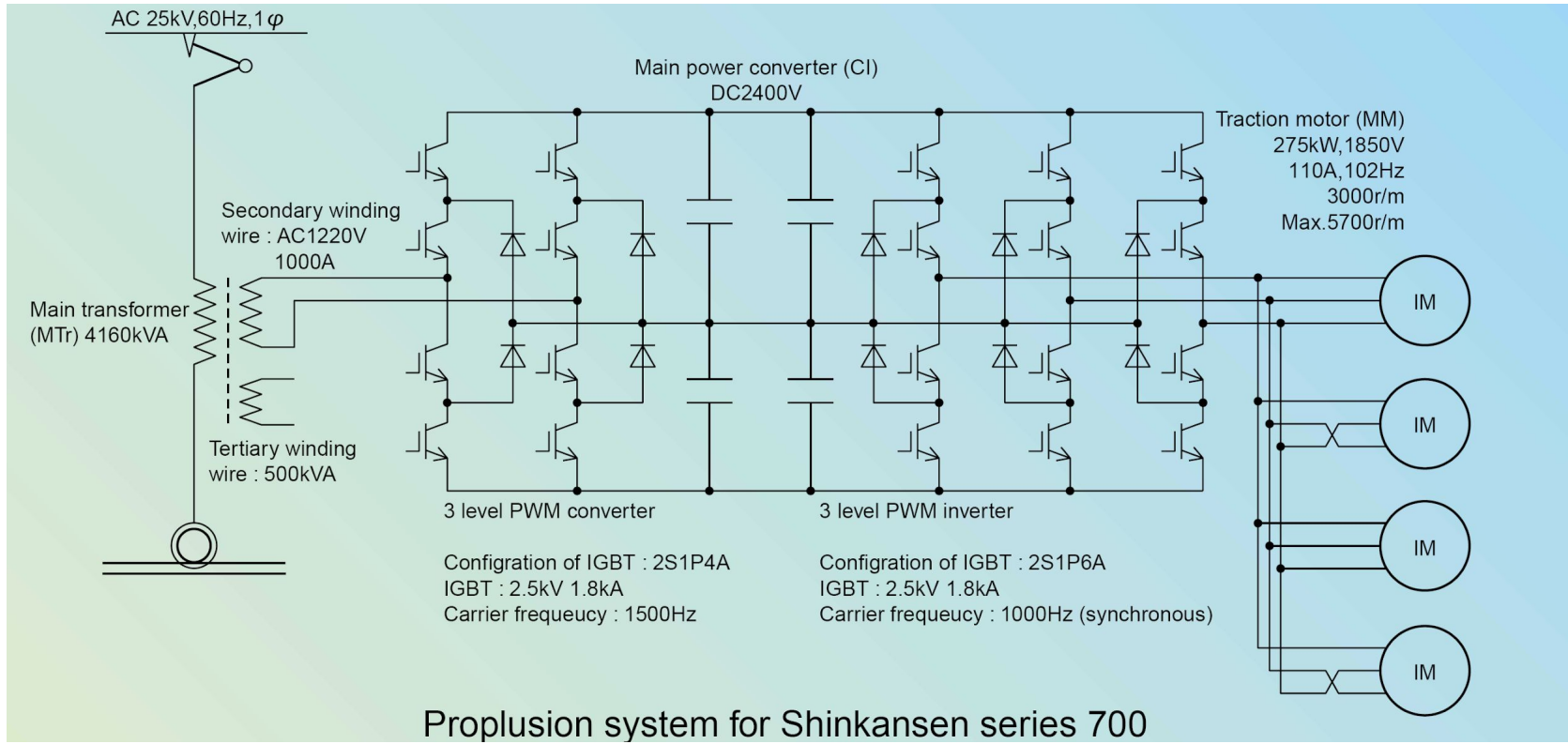
- High Speed Train



Source: Fuji Electric

Variable Speed Drive Applications

- High Speed Train

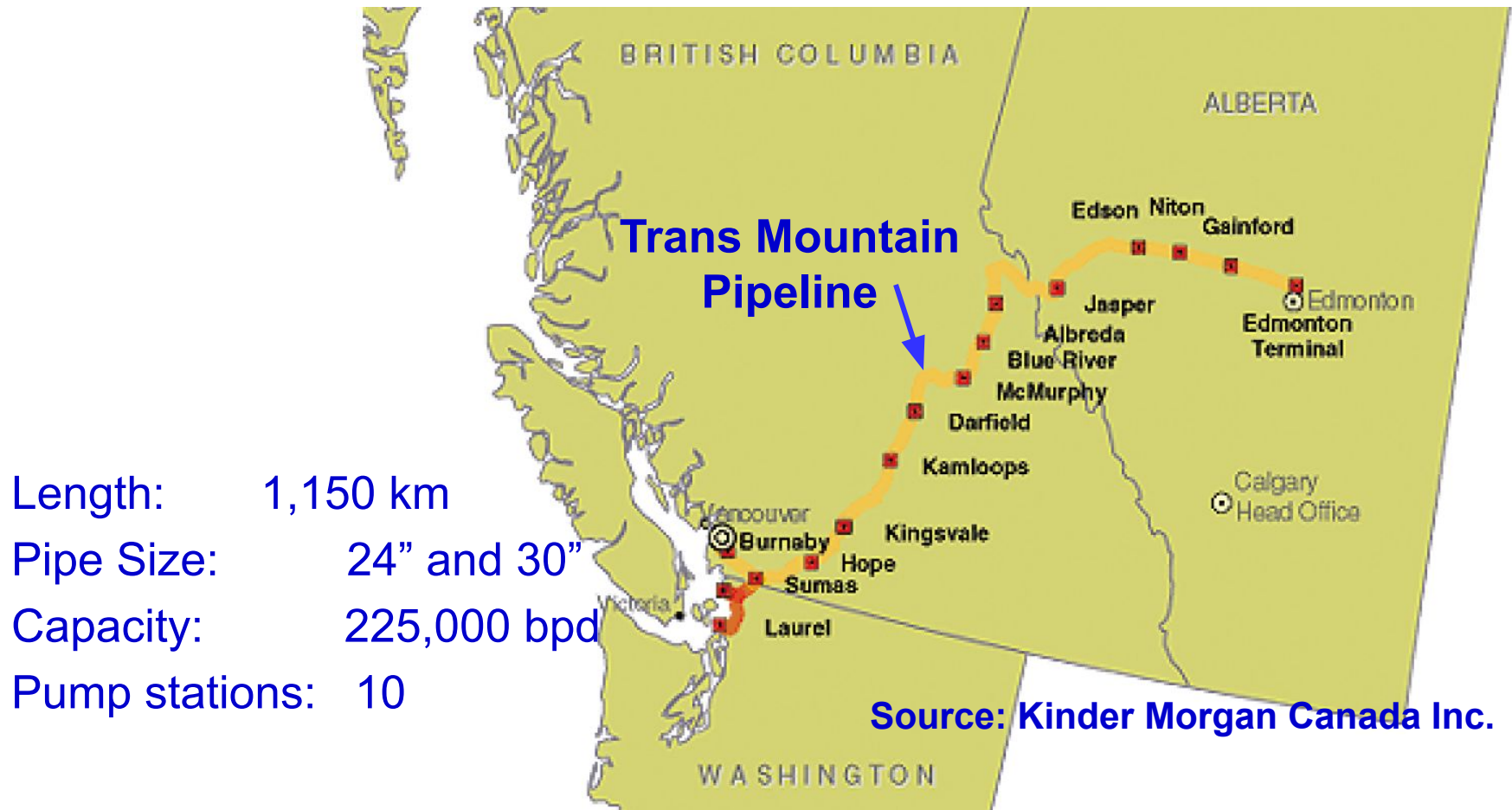


Source: Fuji Electric

Rectifier: Single-phase three-level diode clamped
Inverter: Three-phase three-level diode clamped
Ratings: 1.1MW, 1850V

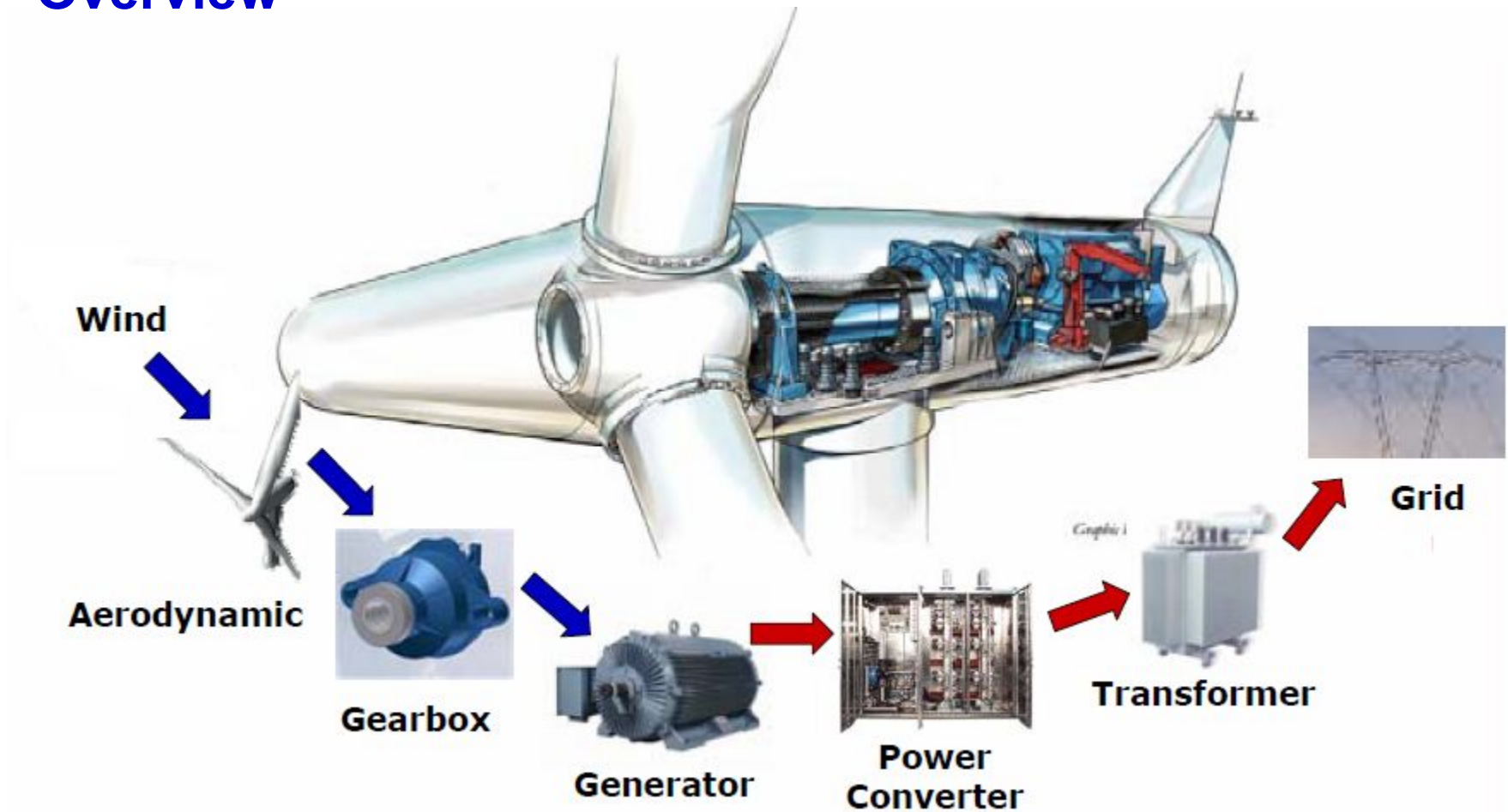
Variable Speed Drive Applications

- Megawatt Drive for Pipeline Pumps



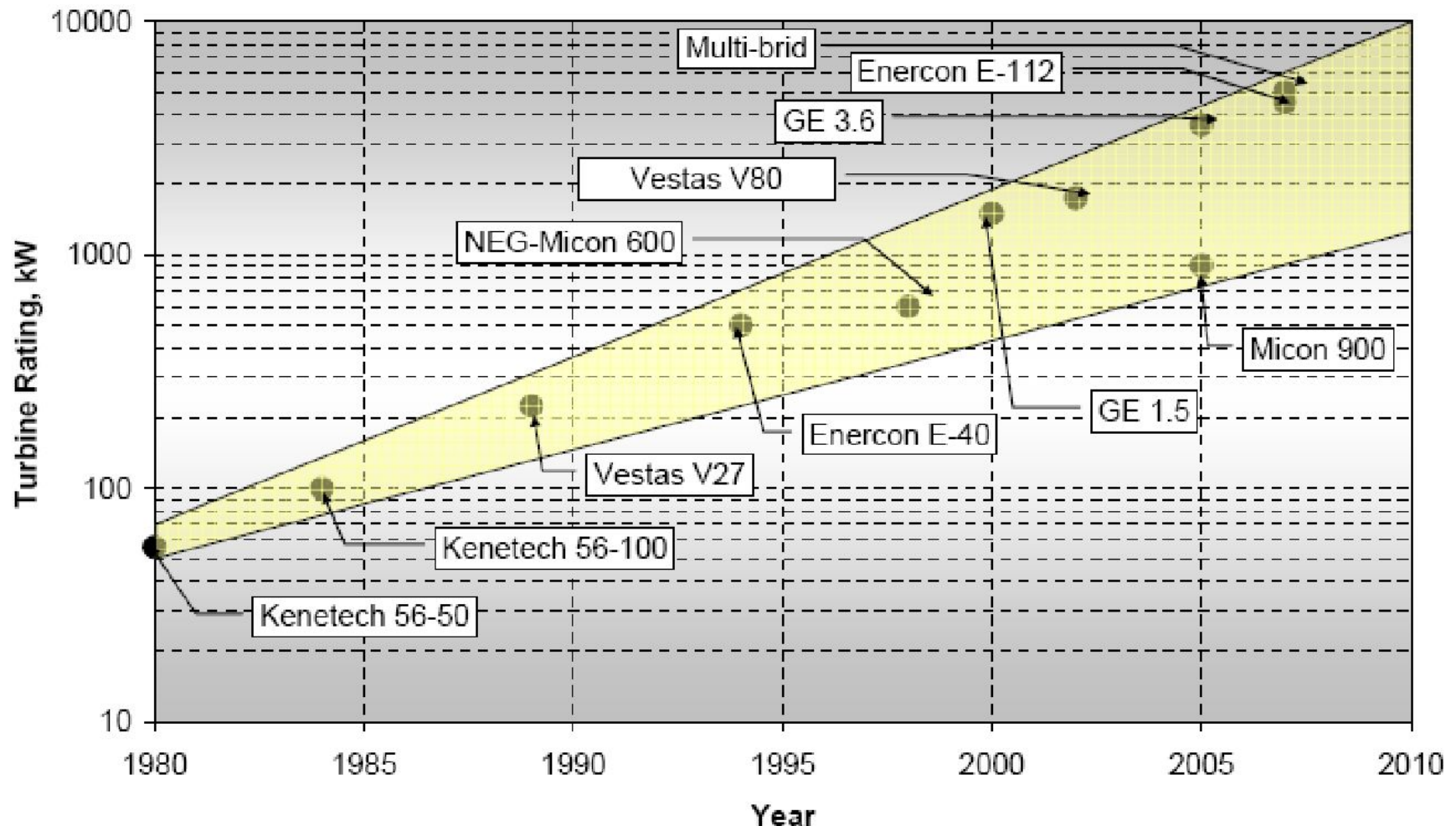
Applications In Wind Energy Systems

- Overview



Applications In Wind Energy Systems

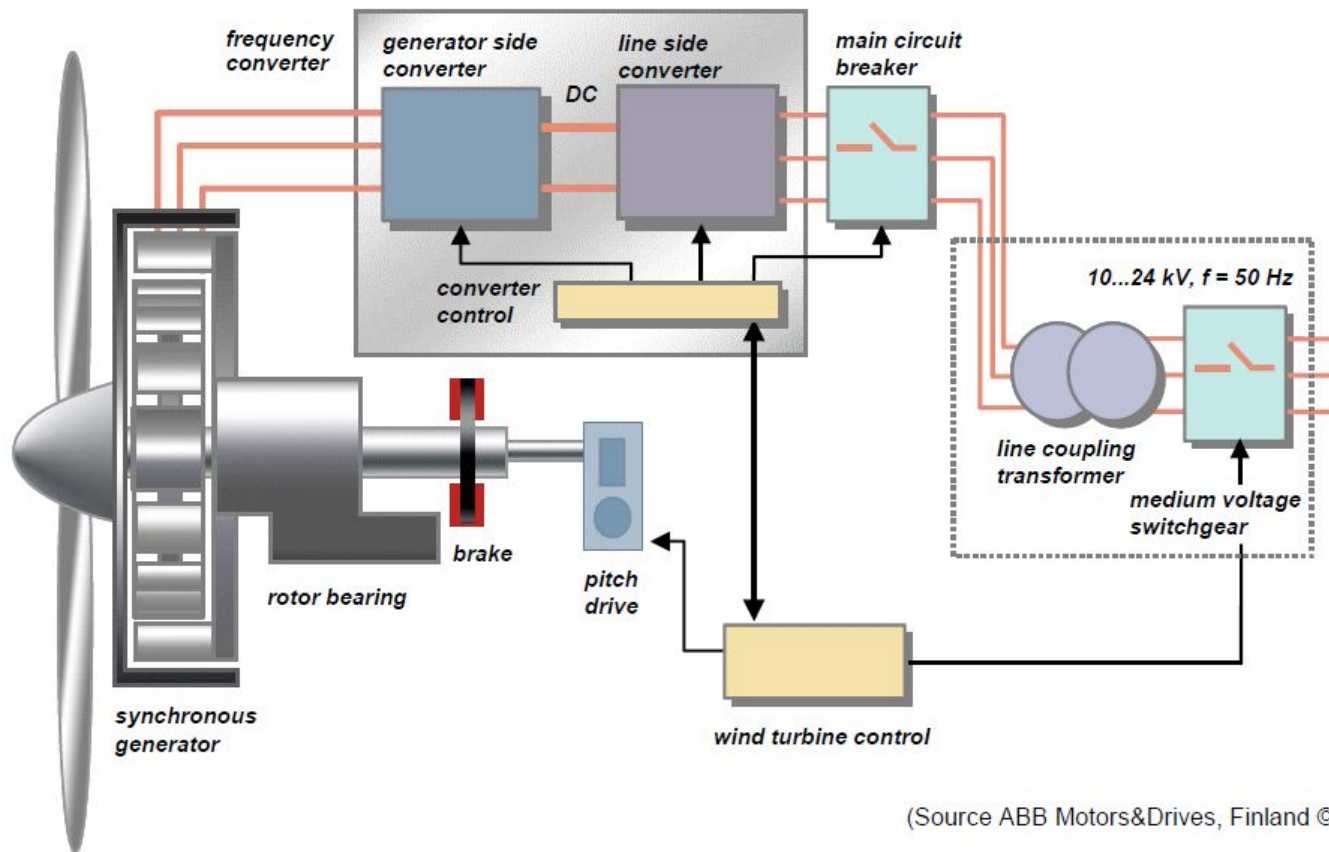
• Wind Generator Power Rating



Source: National Renewable Energy Laboratory

Applications In Wind Energy Systems

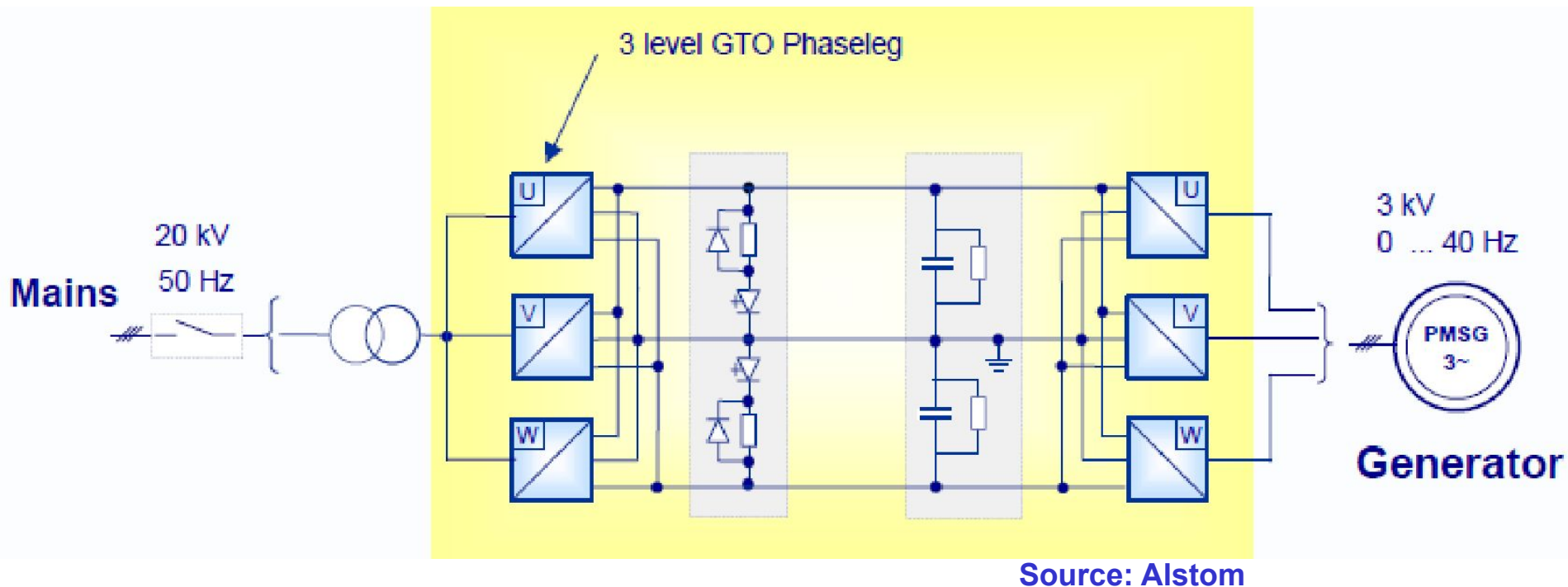
• Permanent Magnet SG



- ✓ Direct driven, no gear box
- ✓ Completely decoupled from grid

Applications In Wind Energy Systems

- Examples - Multibrid M5000 (5MW PMSG)

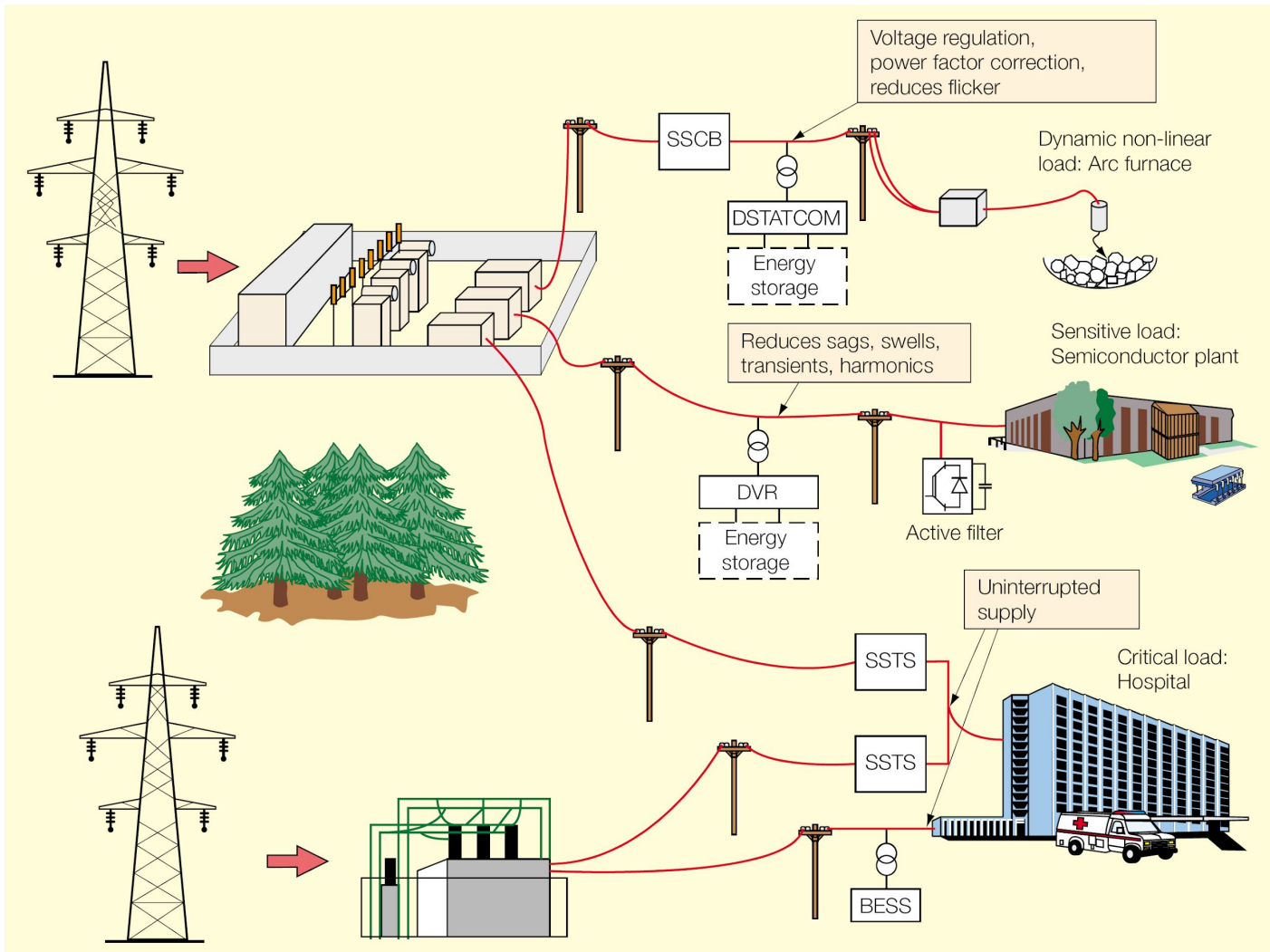


Converter: ALSPA VDM7000

Applications In Power/Utility Industry

- **FACTS - Flexible AC Transmission Systems**
 - Static Synchronous Compensator (STATCOM)
 - Static Synchronous Series Compensator (SSSC)
 - Unified Power Flow Controller (UPFC)
- **Custom Power Devices**
 - Dynamic Voltage Restorer (DVR)
 - Distribution Static Synchronous Compensator (D-STATCOM)
 - Active Power Filter (APF)
- **HVDC – High Voltage DC Transmission**

Applications In Power/Utility Industry



STATCOM:
Static Synchronous Compensator

DVR:
Dynamic Voltage Restorer

Active Filters

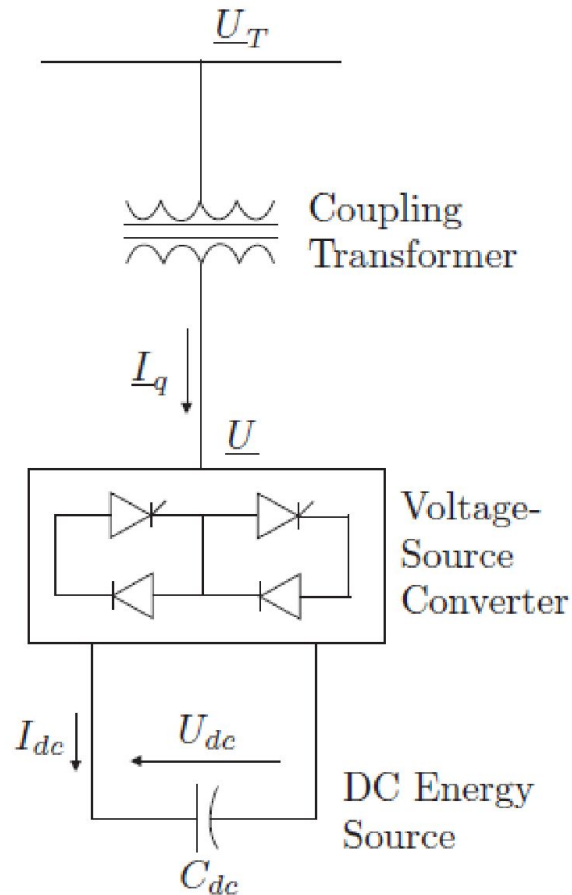
SSTS:
Solid-State Transfer Switch

SSCB:
Solid-State Circuit Breaker

BESS:
Battery Energy Storage System

Applications In Power/Utility Industry

• STATCOM

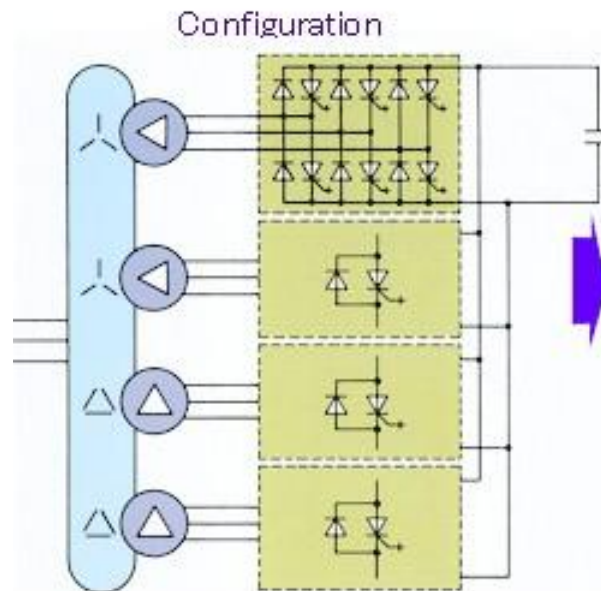


Source: Toshiba Electric

Purpose: To provide reactive power for voltage regulation

Applications In Power/Utility Industry

- 50 MVA STATCOM



GTO valves



↓ Converter transformer



Rating of STATCOM

Capacity 50MVA
(12.5MVA x4)

DC voltage 16.8kV

Converter type 3phase 3-PulsePWM

GTO 6kV-2.5kA

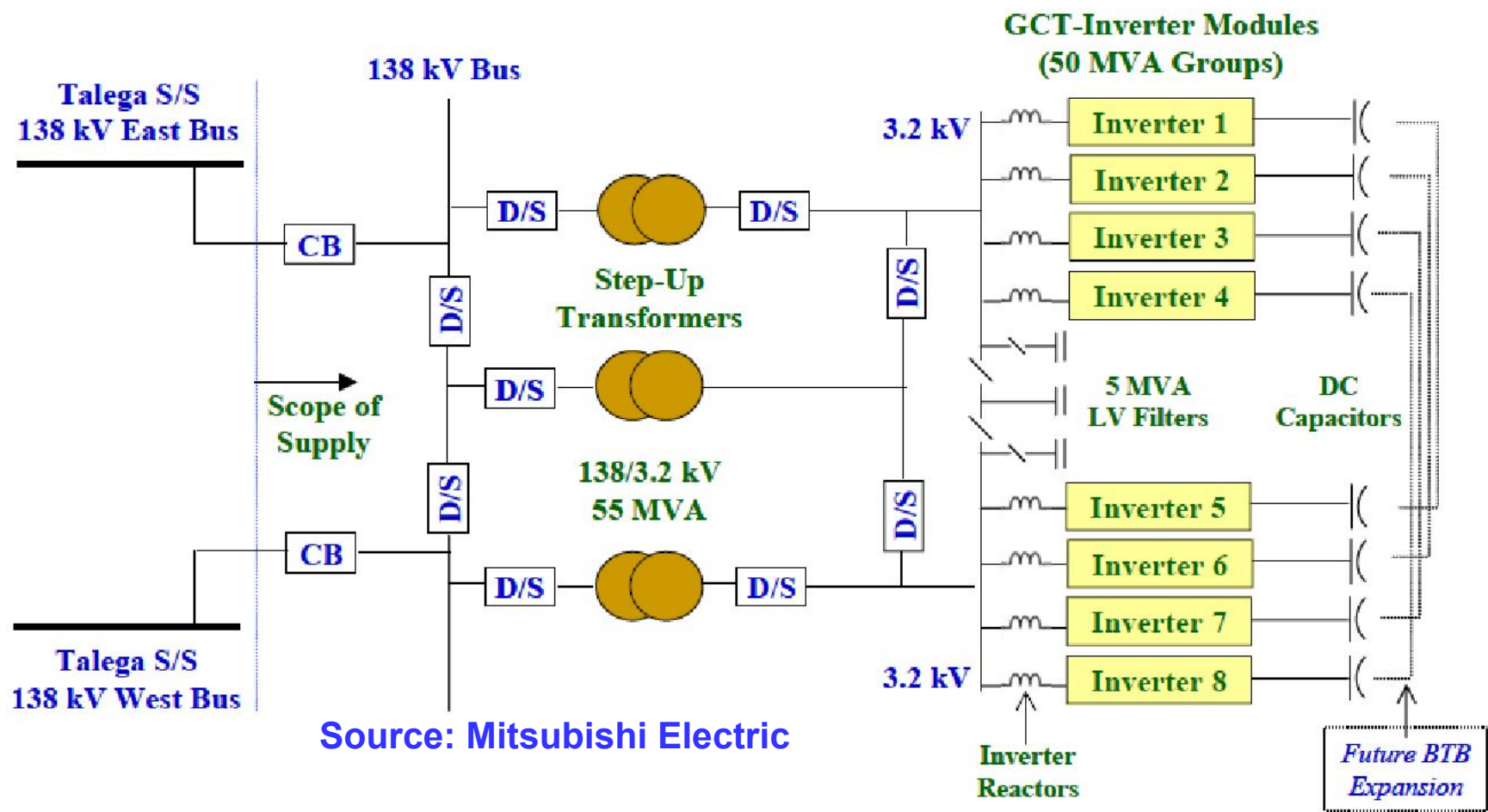
Insulating Air

Cooling Water

Source: Toshiba Electric

Applications In Power/Utility Industry

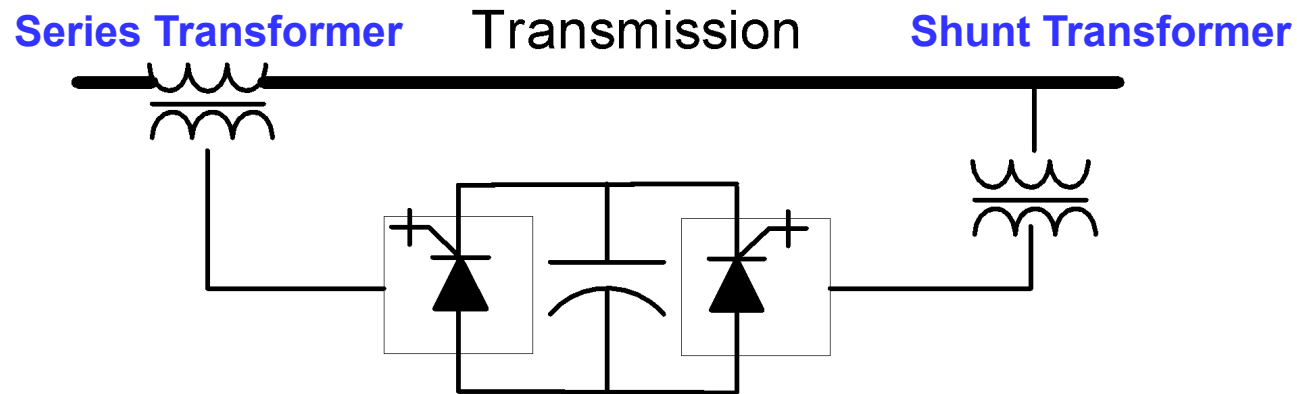
- Example – 100MVA GCT STATCOM



Talega ±100 MVA, 138 kV STATCOM system

Applications In Power/Utility Industry

- UPFC

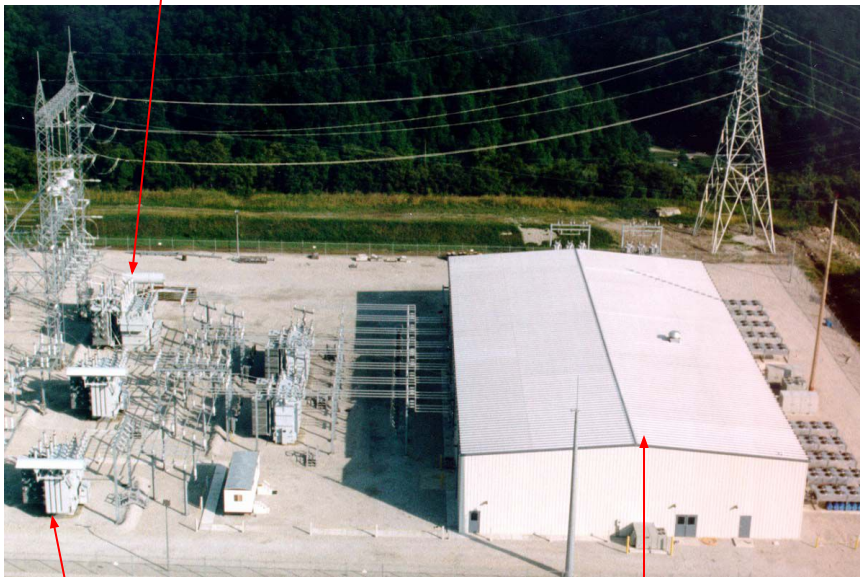


- Combines STATCOM and SSSC which are coupled via a common DC link
- Allows bi-directional flow of real power between the STATCOM and SSSC without external energy source
- Controls power flow, voltage and power factor, allowing optimal use of existing lines

Applications In Power/Utility Industry

- Example – 320MVA 138kV UPFC (GTO Based)

Series Transformer



UPFC building

UPFC Equipment

Shunt Transformer

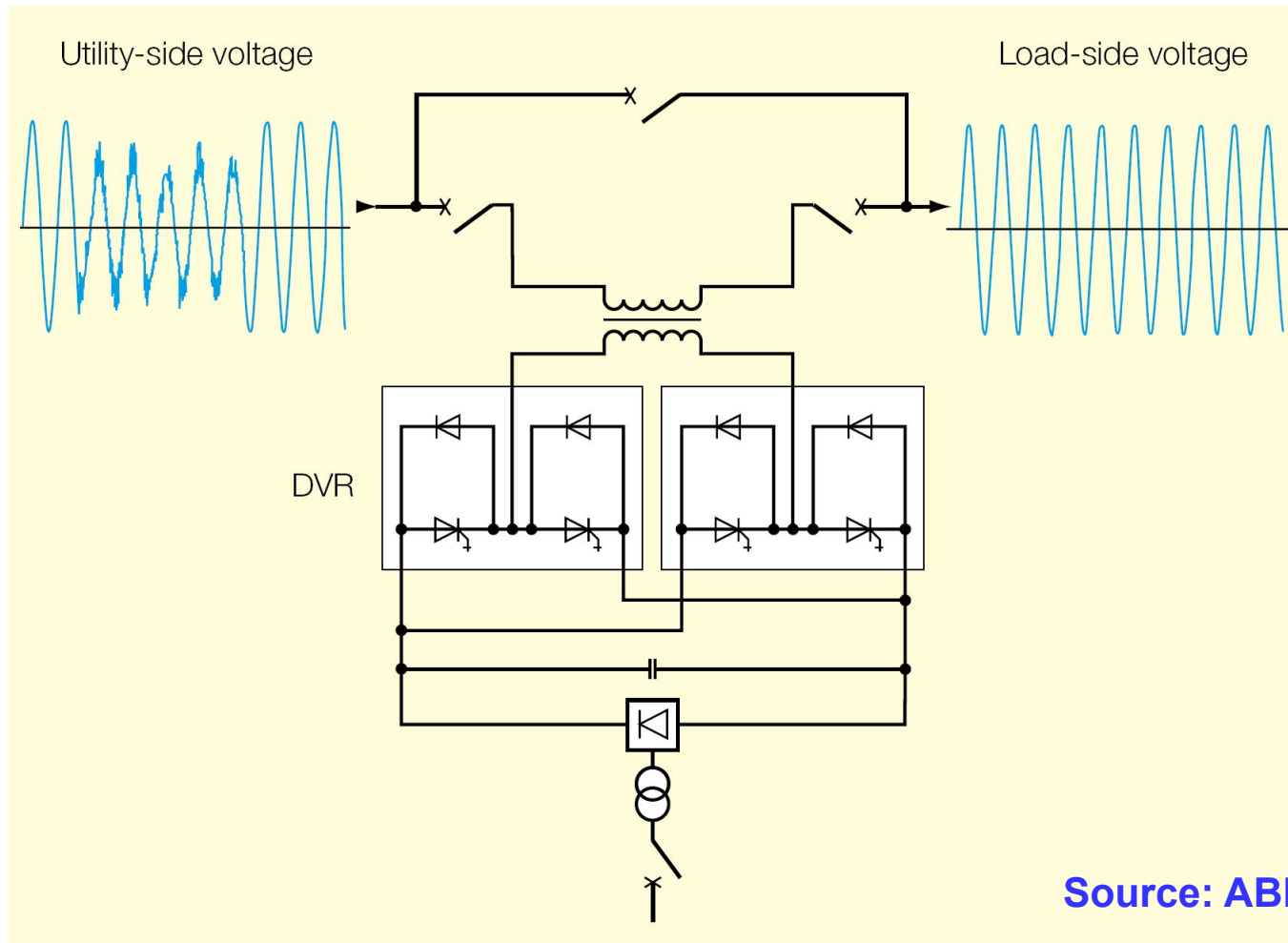


GTO valve hall

Source: AEP Inez UPFC Project

Applications In Power/Utility Industry

- Dynamic Voltage Restorer (DVR)



Source: ABB

Applications In Power/Utility Industry

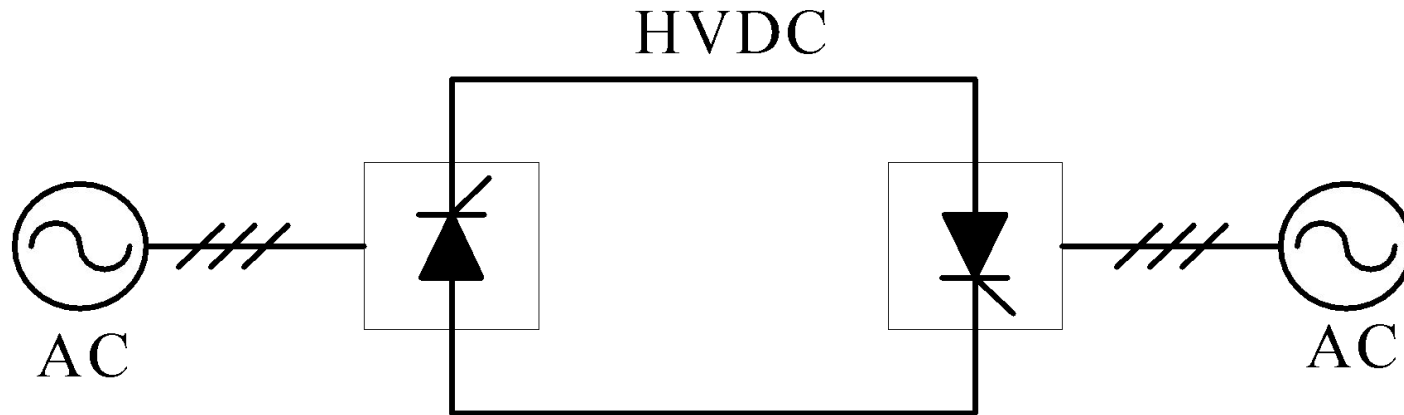
- Dynamic Voltage Restorer (DVR, 4MVA)



Source: ABB

Applications In Power/Utility Industry

- HVDC



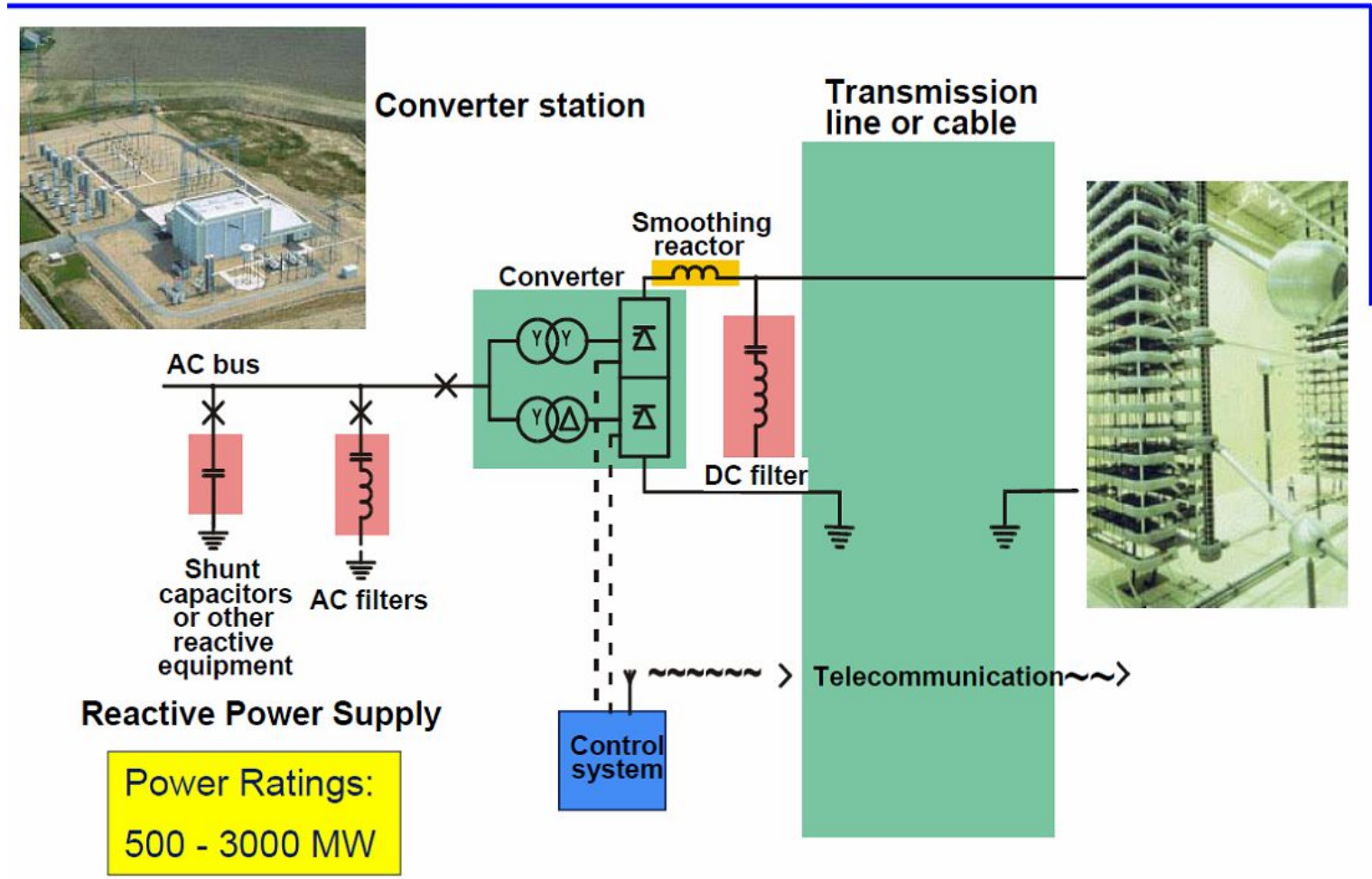
Main Benefits of HVDC

- Long distance
- Network stability
- Low losses
- Environmental concerns

Applications In Power/Utility Industry

- HVDC

HVDC Converter Station



Source: ABB

Applications In Power/Utility Industry

• HVDC Transmission Québec - New England



Source: ABB

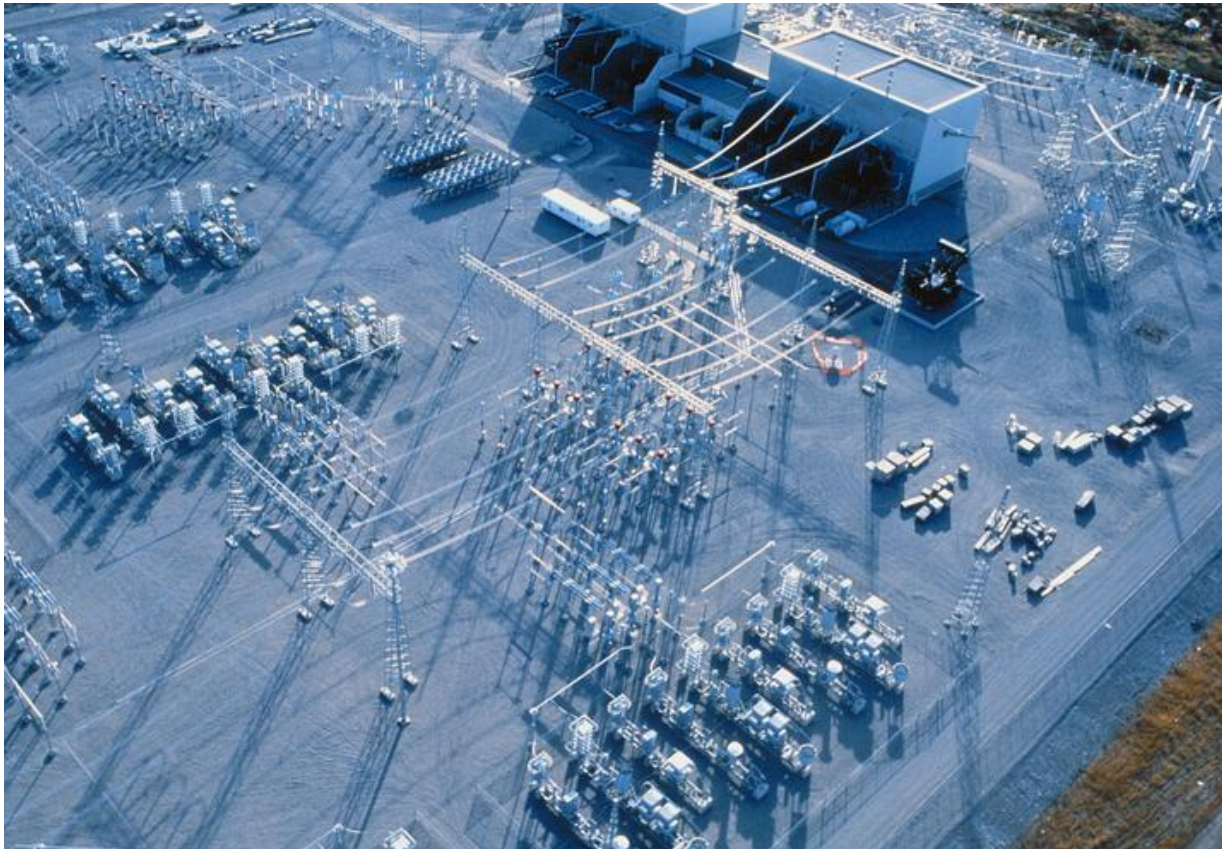
Main data

Commissioning year:	1990 - 1992
Power rating:	2000 MW
DC voltage:	± 450 kV
Length of overhead DC line:	1,480 km

Main reason for choosing HVDC:
Long distance, asynchronous networks

Applications In Power/Utility Industry

- HVDC Transmission Québec - New England

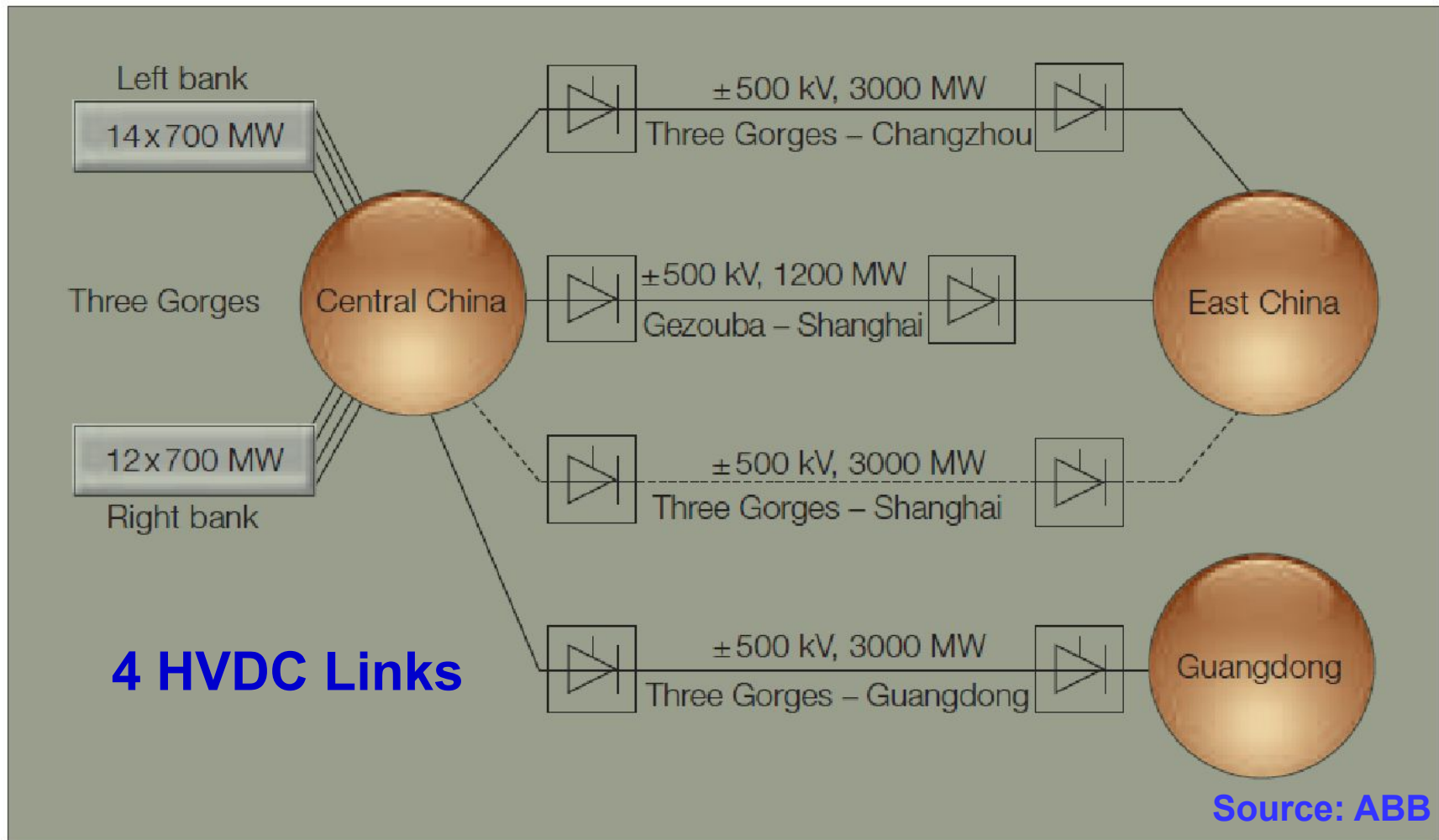


Source: ABB

Radisson Converter Station

Applications In Power/Utility Industry

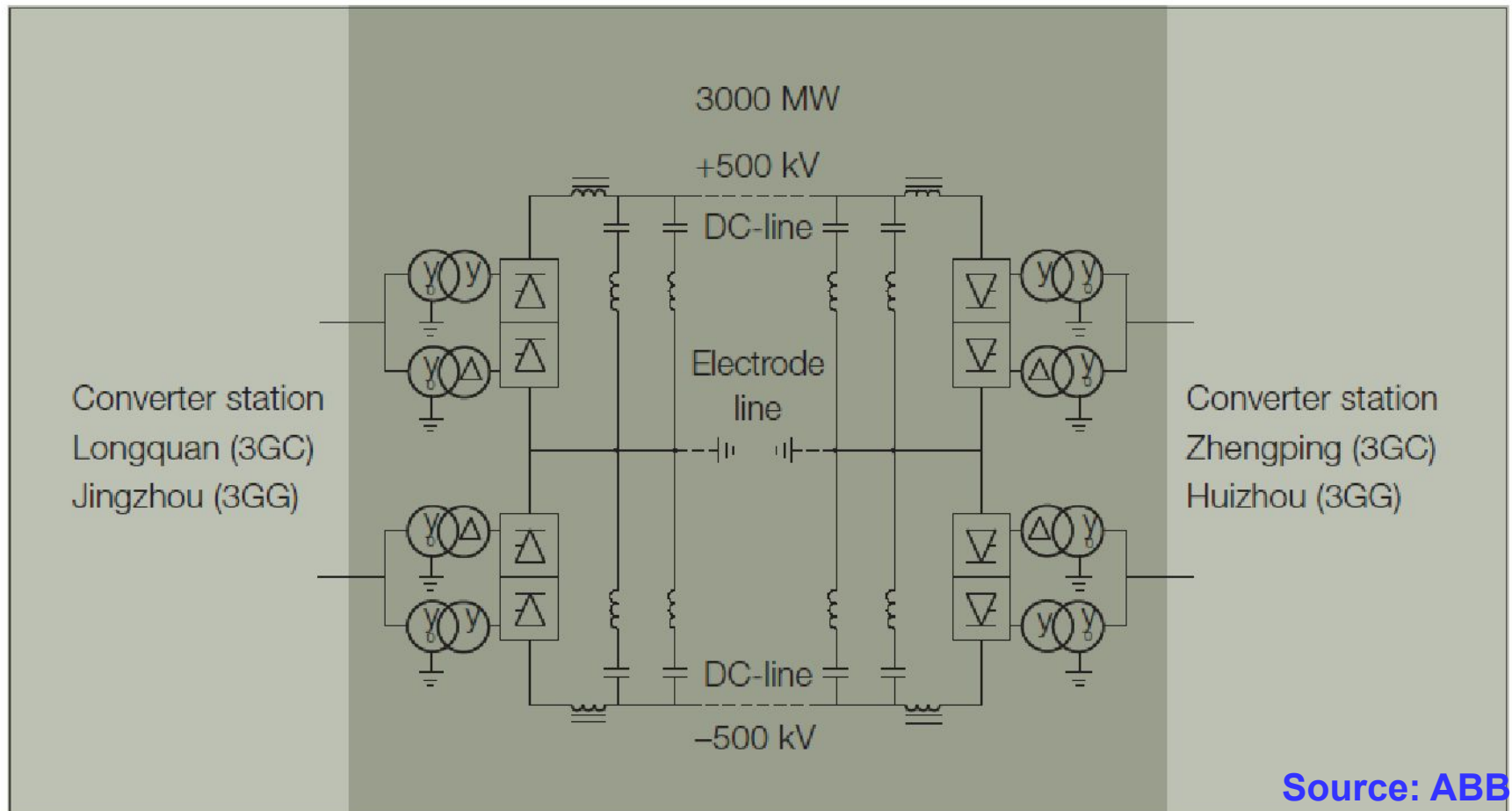
- HVDC Project in China



Applications In Power/Utility Industry

- HVDC Project in China

3000MW HVDC from Three Gorges to Guangdong



Applications In Power/Utility Industry

- HVDC Project in China

3000MW HVDC from Three Gorges to Guangdong



Overview



Source: ABB

Thyristor valve hall

Length of overhead DC line: 940 km



Thanks