# 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

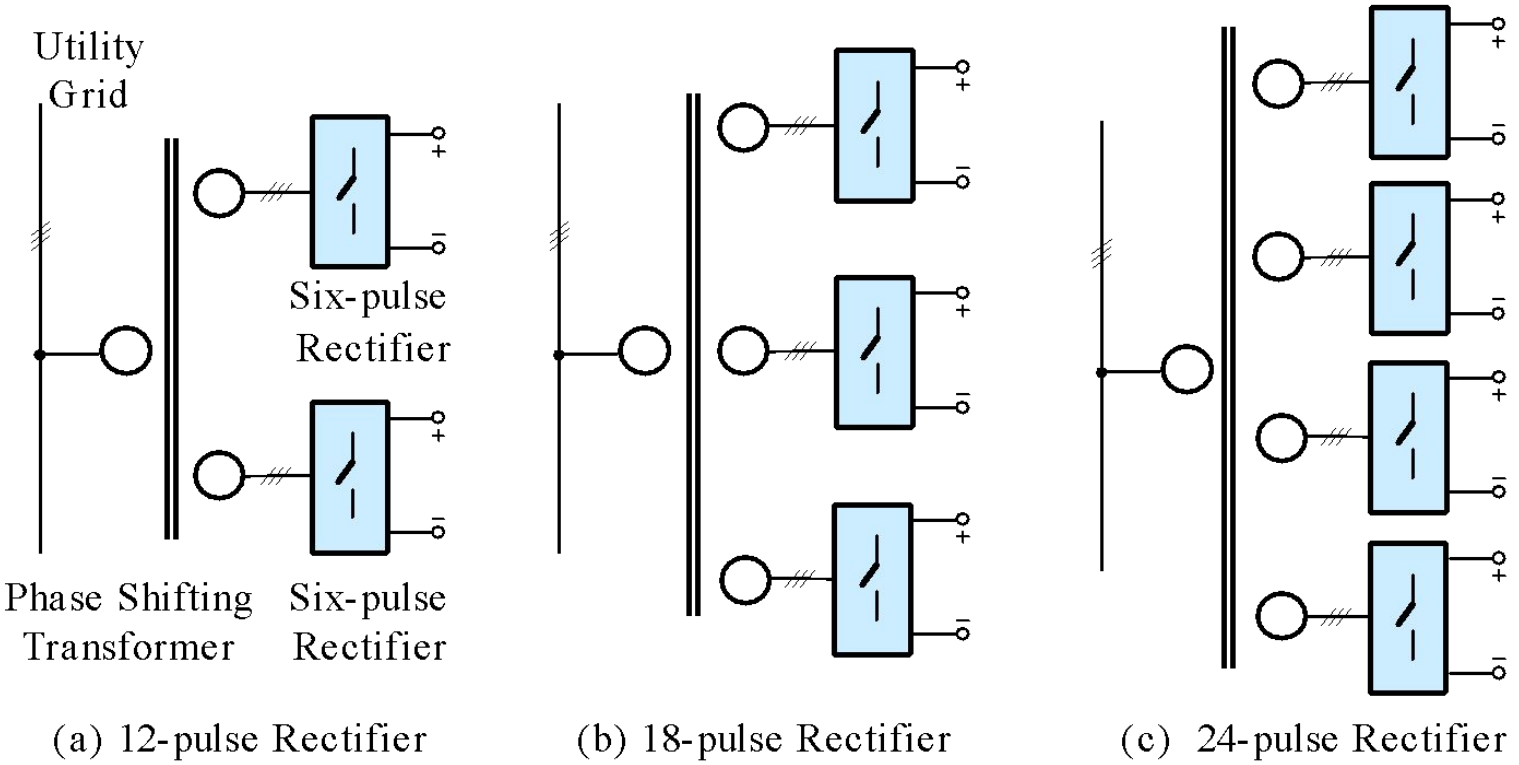
# Course Outline

- 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% |

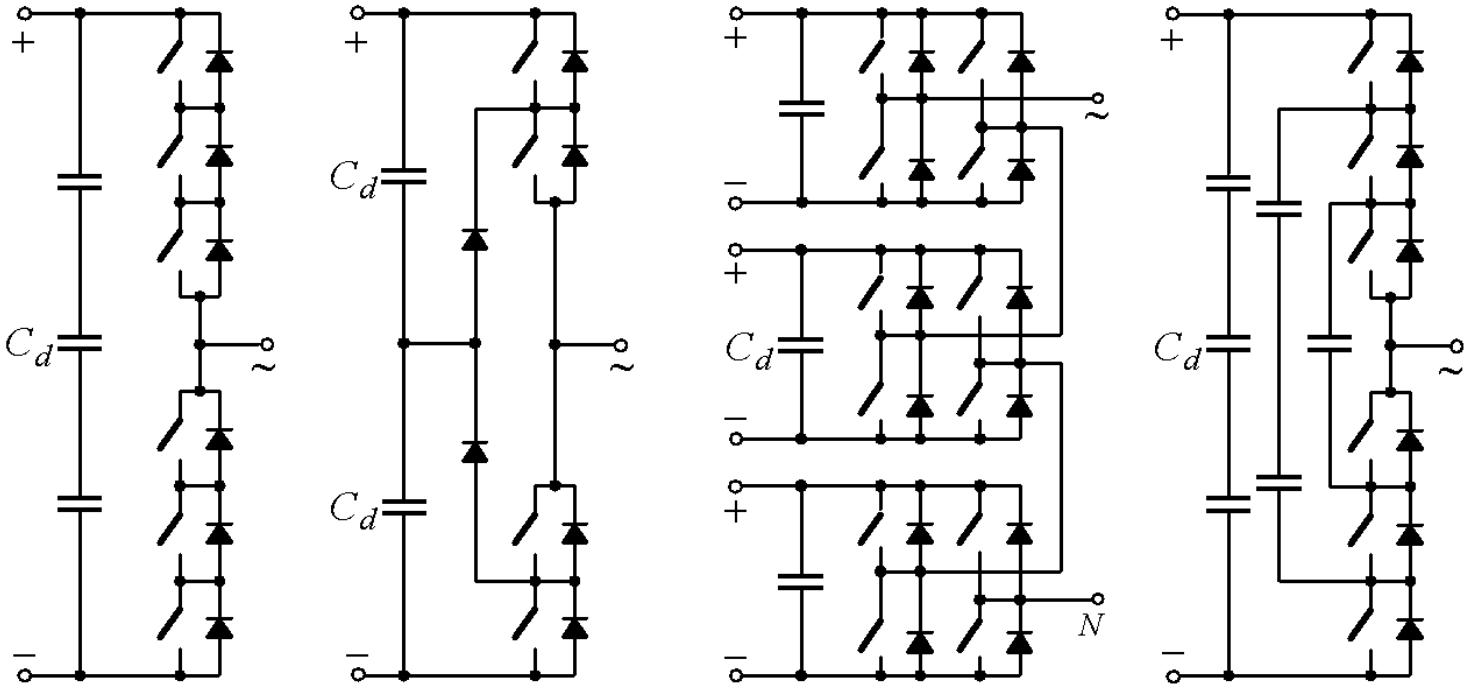
# High-Power Converter Topologies

## Multipulse Diode/SCR Rectifiers



# High-Power Converter Topologies

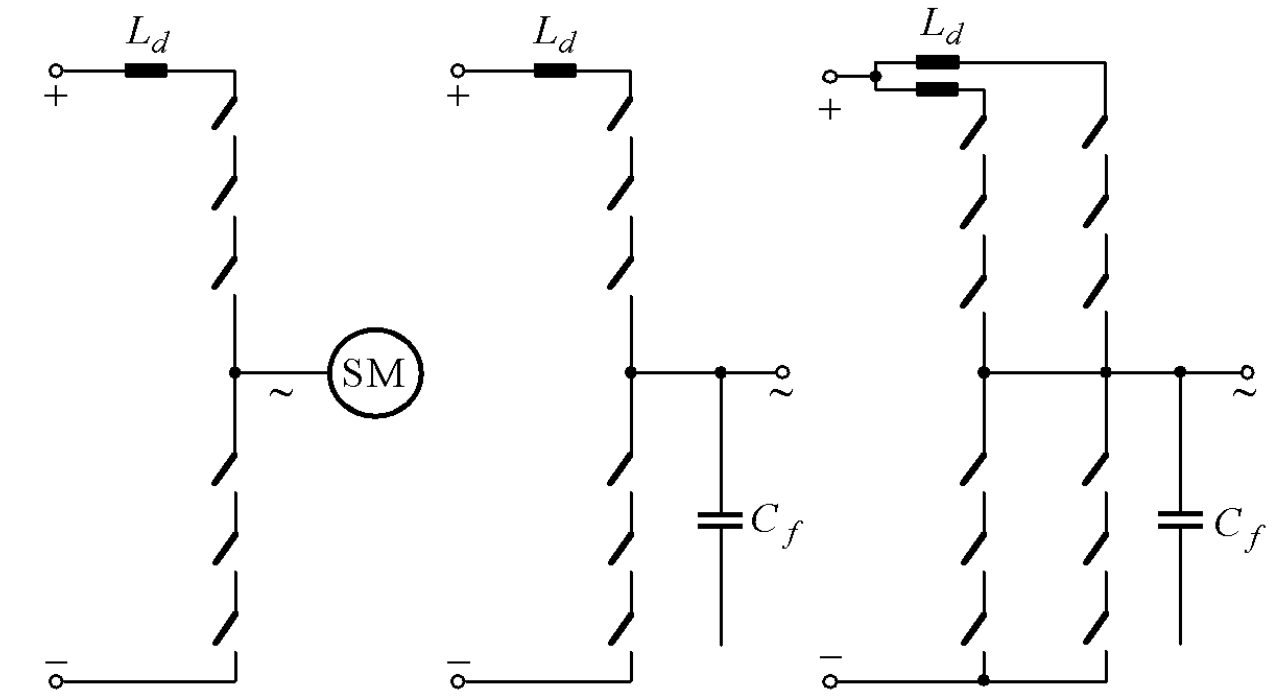
- Multilevel Voltage Source Converters




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

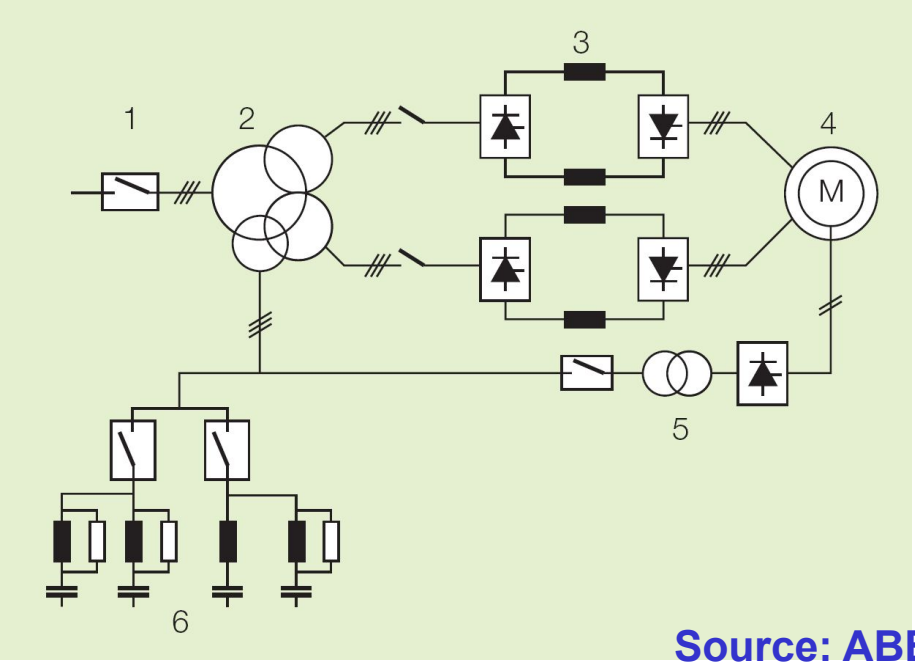
Water / waste water

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

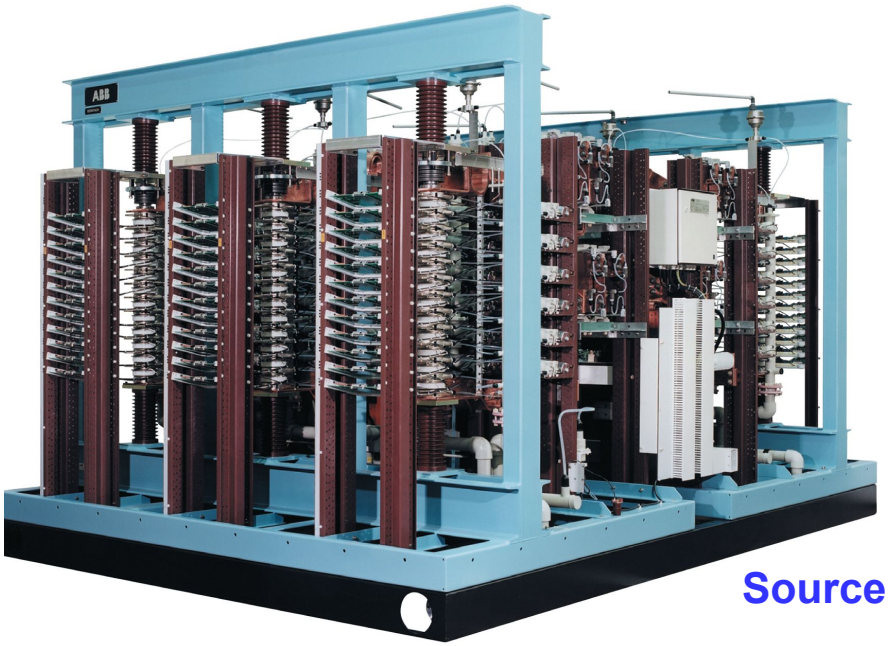



Source: ABB

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

# 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 x 6) x 4 = 288
- Converter efficiency: > 99%

# Variable Speed Drive Applications

- 100MW Wind Tunnel Drive


Source: ABB

**Six-phase synchronous motor**

**(100MW, 12.5KV, 2.8KA)**

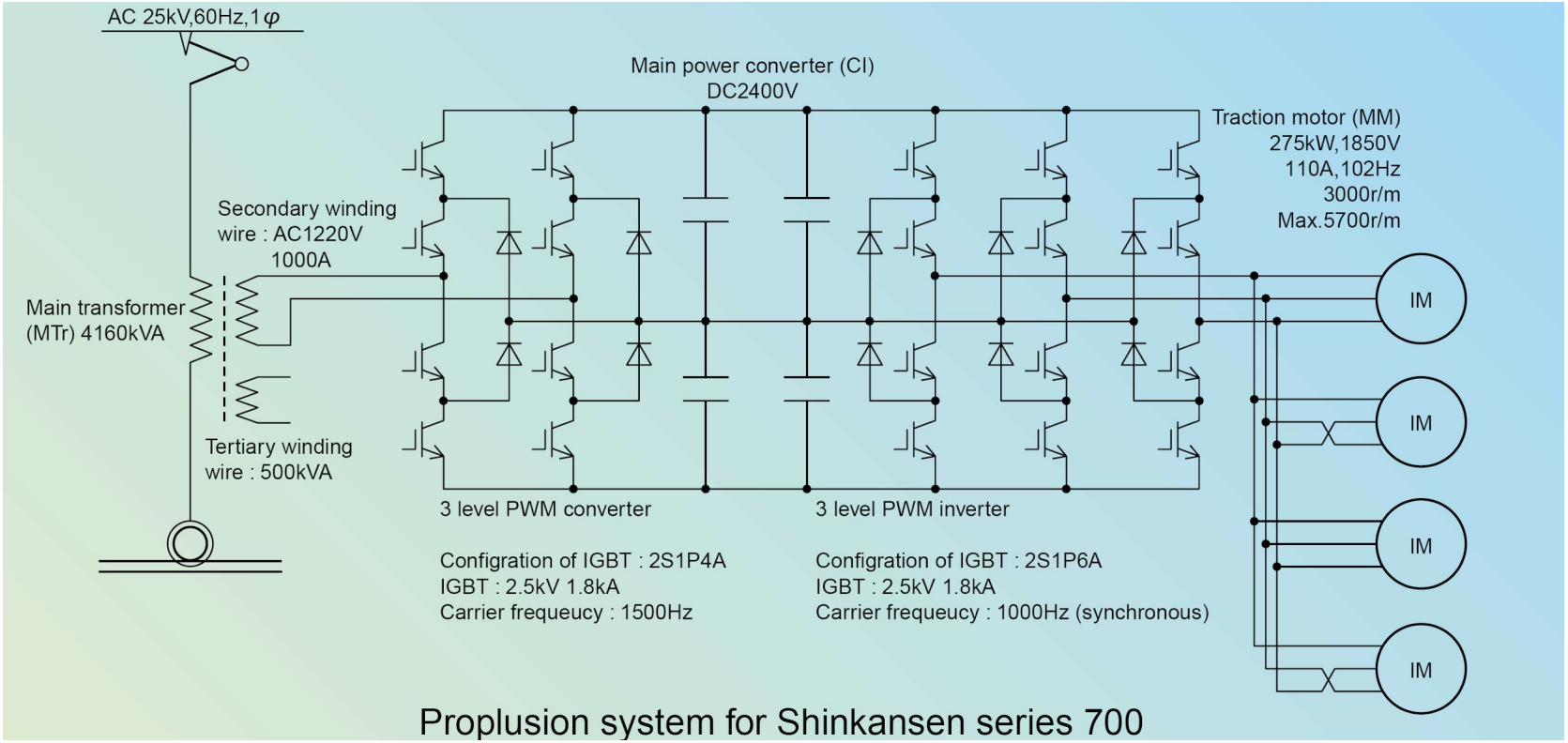
# Variable Speed Drive Applications

- High Speed Train

Source: Fuji Electric

# Variable Speed Drive Applications

- **High Speed Train**



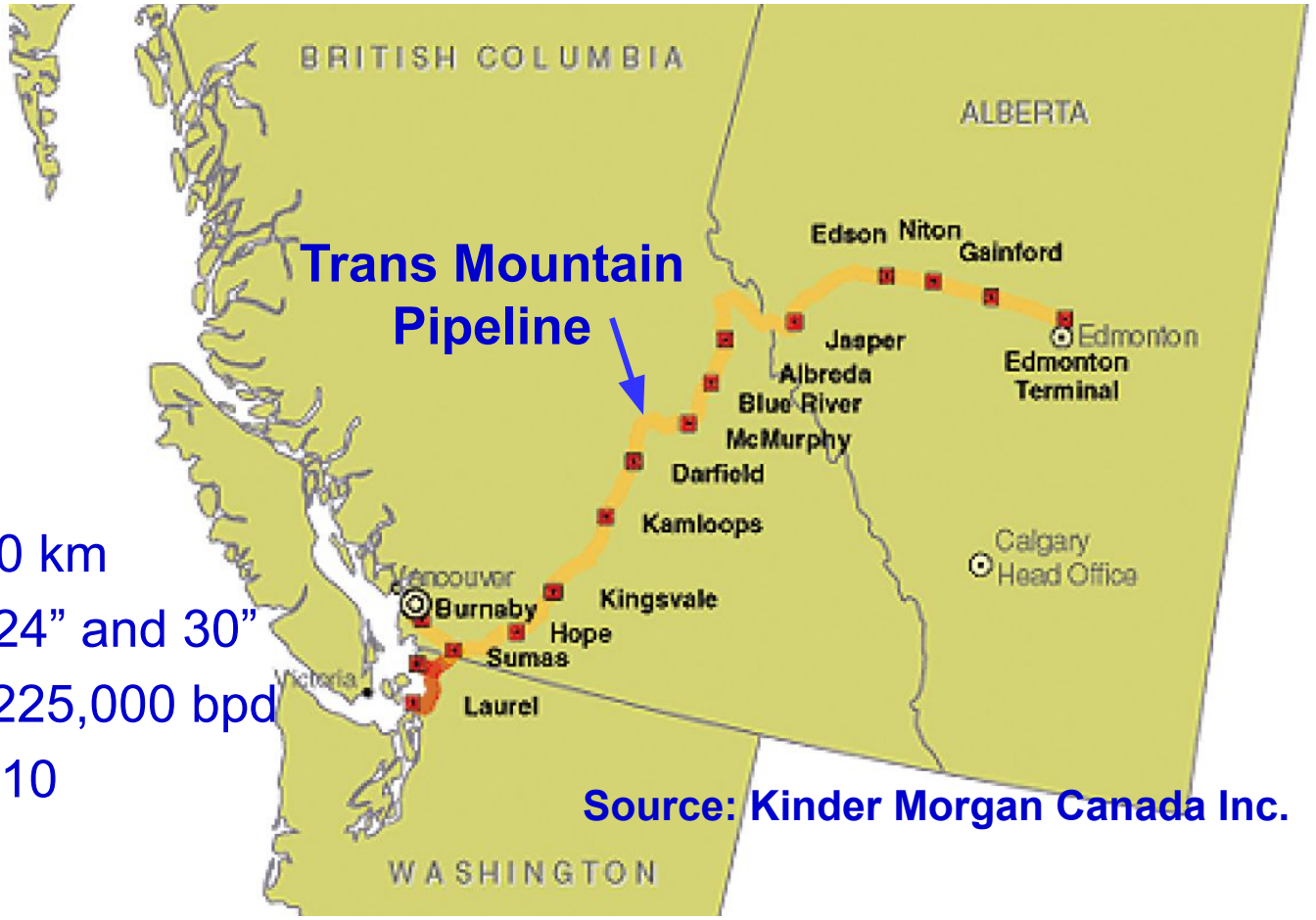

Proplusion system for Shinkansen series 700

**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**

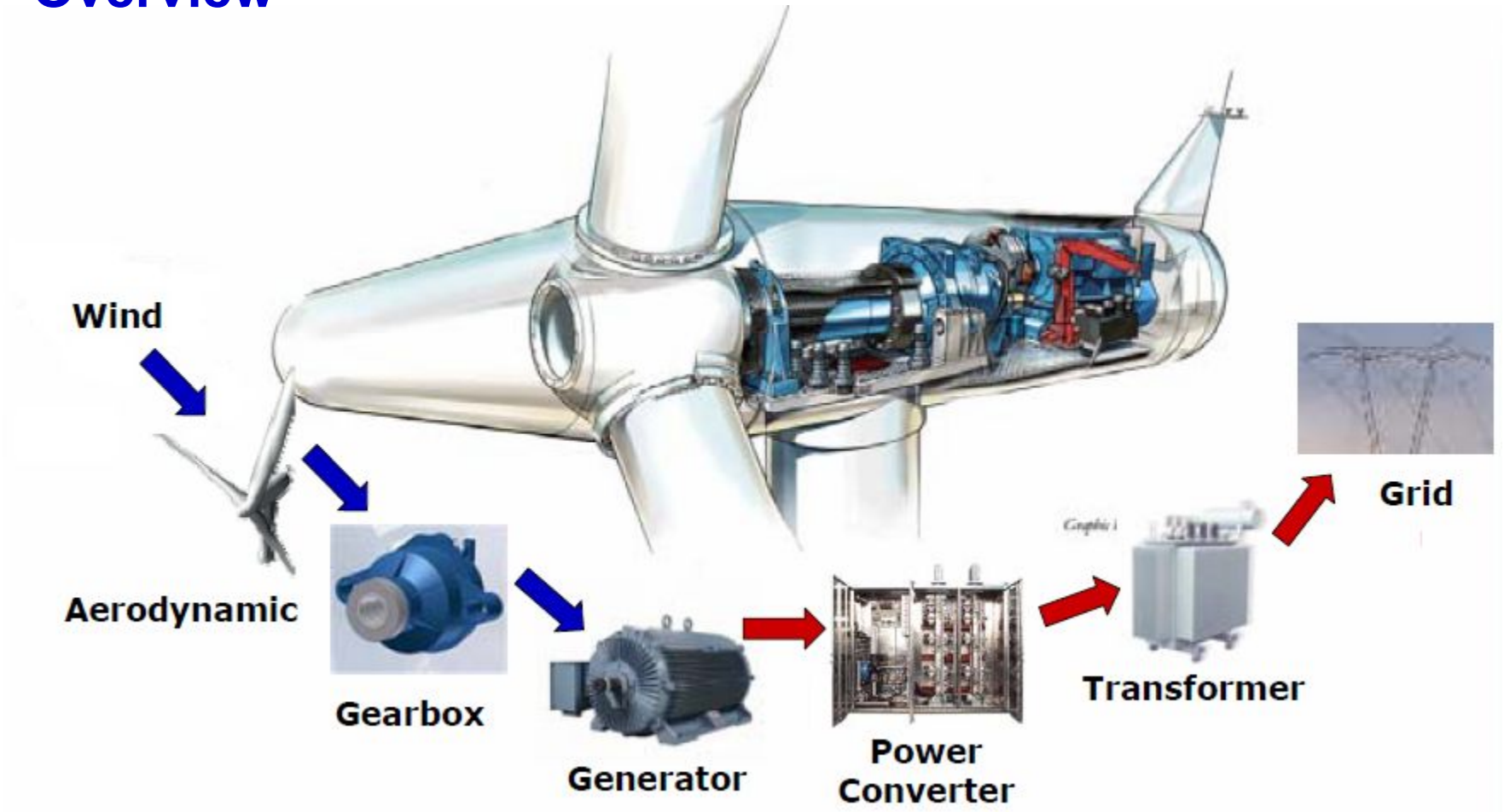



Length: 1,150 km
Pipe Size: 24” and 30”
Capacity: 225,000 bpd
Pump stations: 10

Source: Kinder Morgan Canada Inc.

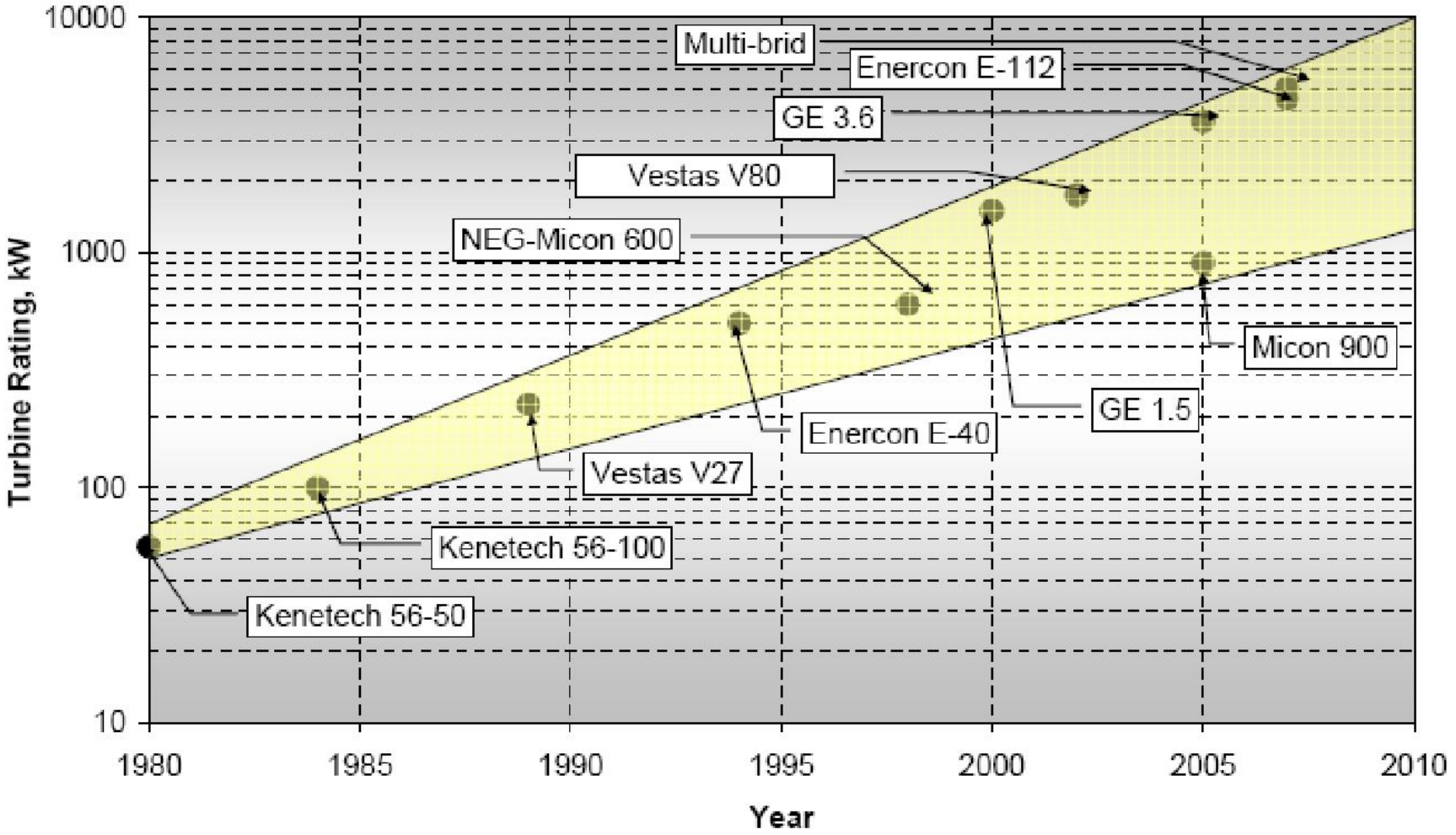
# Applications In Wind Energy Systems

- Overview



# Applications In Wind Energy Systems

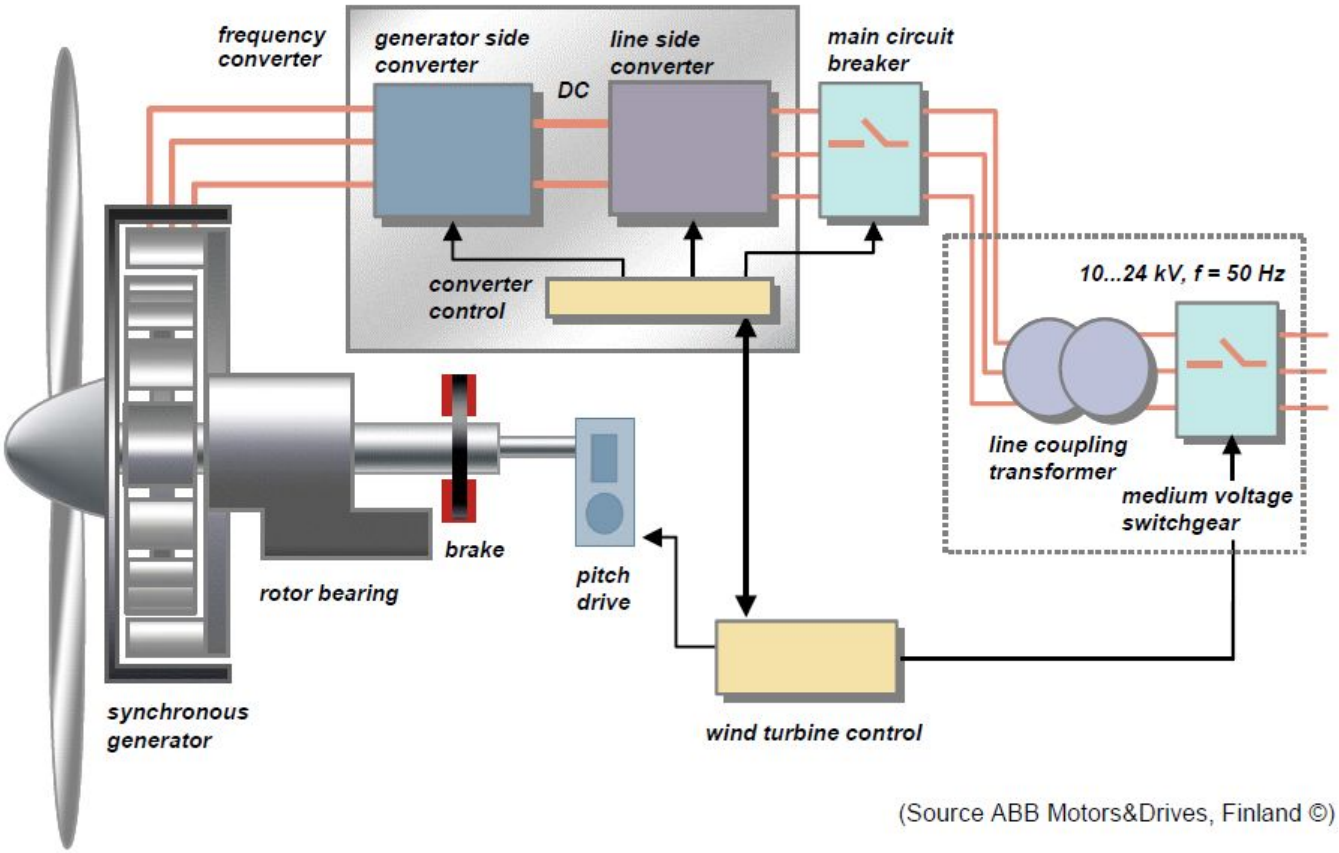
- **Wind Generator Power Rating**




Source: National Renewable Energy Laboratory

# Applications In Wind Energy Systems

- **Permanent Magnet SG**

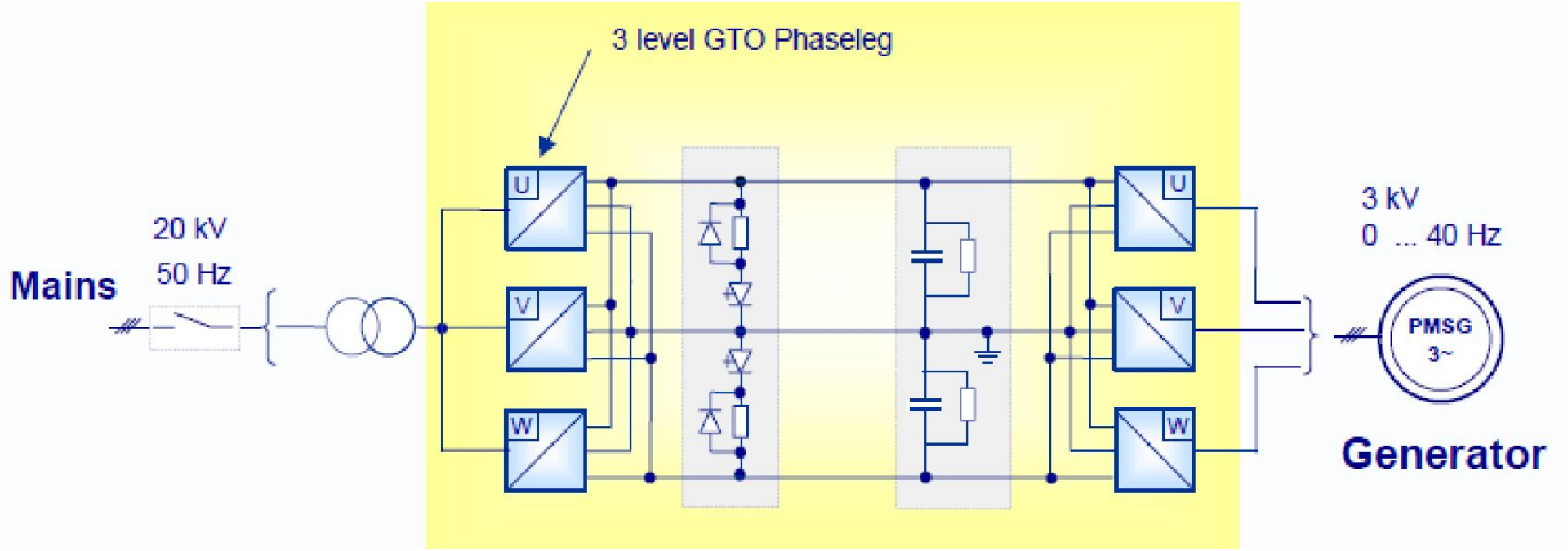



(Source ABB Motors&Drives, Finland ©)

✔ Direct driven, no gear box
✔ Completely decoupled from grid

# Applications In Wind Energy Systems

- **Examples - Multibrid M5000 (5MW PMSG)**




Source: Alstom

**Converter: ALSPA VDM7000**

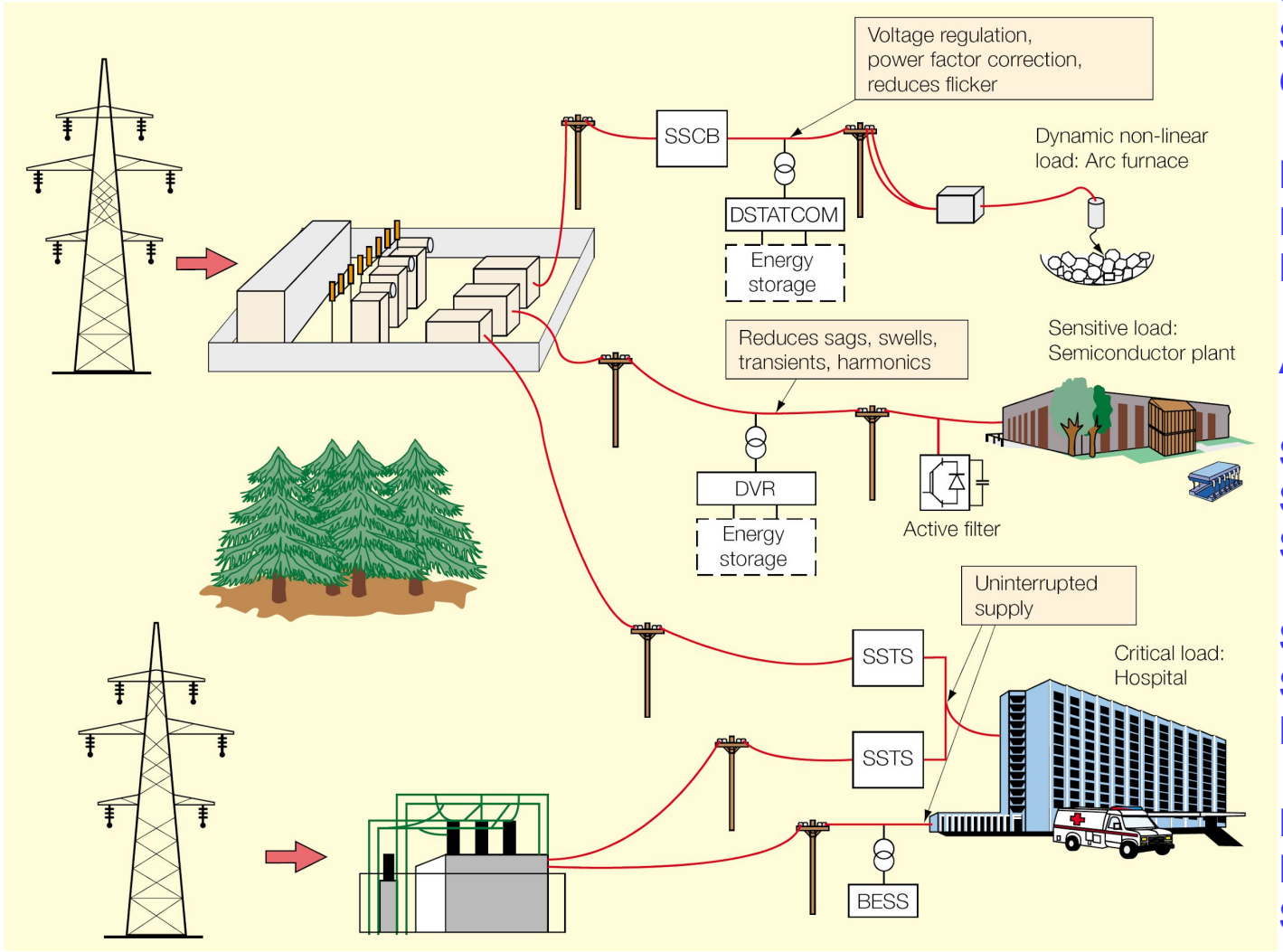
# Applications In Power/Utility Industry

- **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**

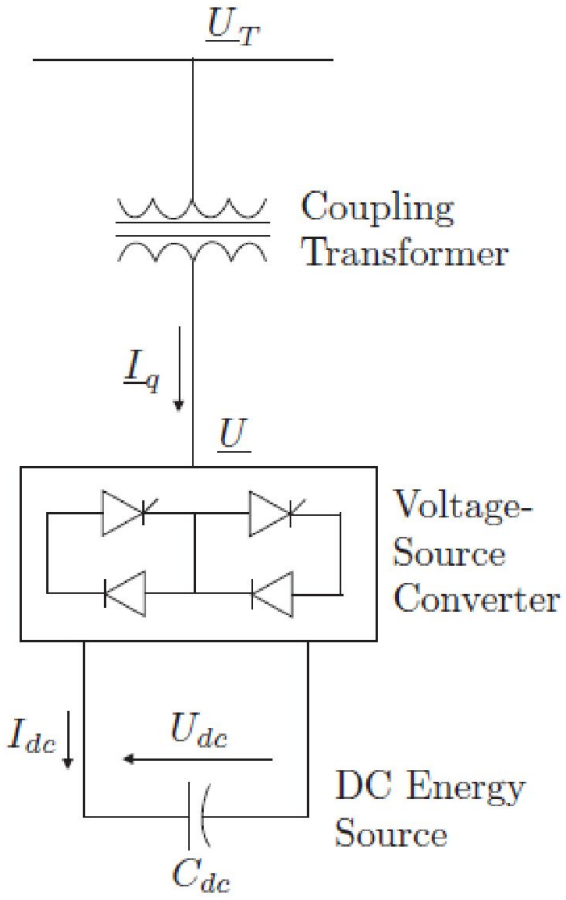
**SSTS:**
**Solid-State Transfer Switch**

**SSCB:**
**Solid-State Circuit Breaker**

**BESS:**
**Battery Energy Storage System**

# Applications In Power/Utility Industry

- **STATCOM**



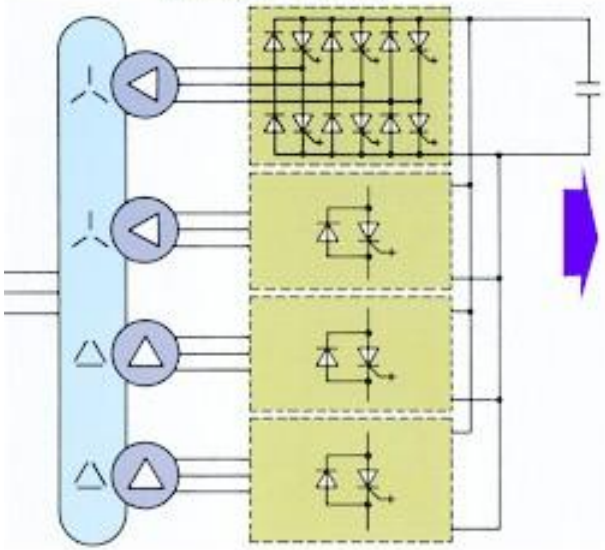

Source: Toshiba Electric

**Purpose: To provide reactive power for voltage regulation**

# Applications In Power/Utility Industry

- 50 MVA STATCOM

Configuration



GTO valves

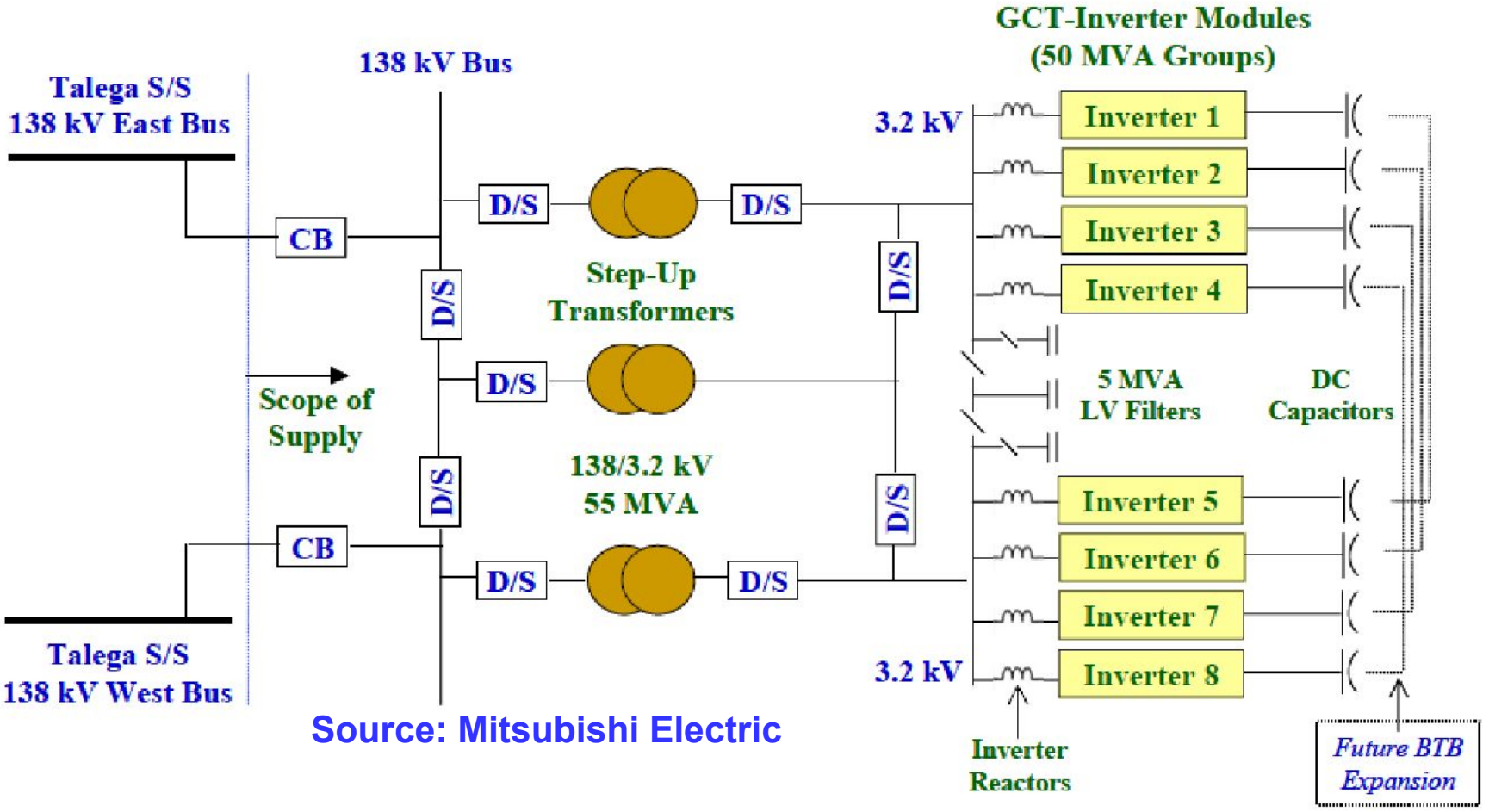
Converter transformer

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**

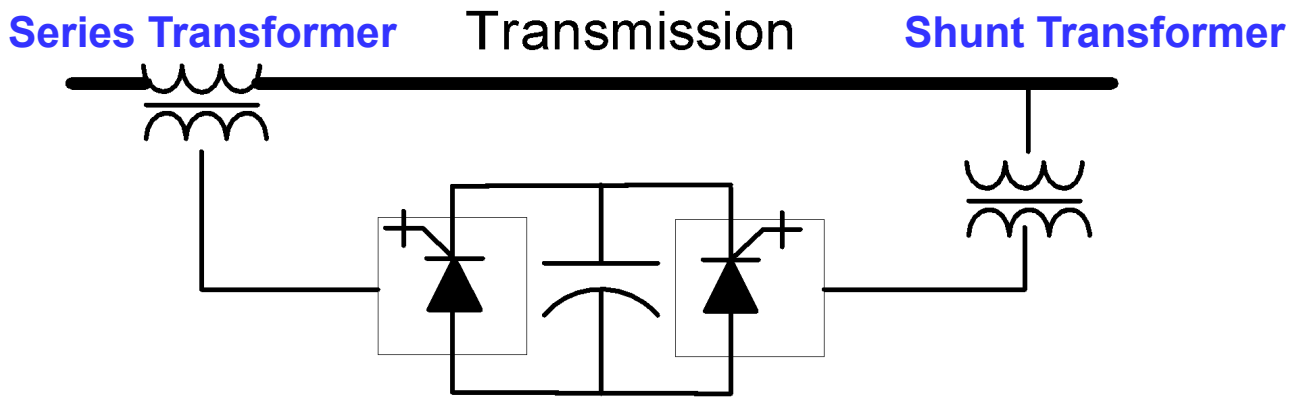



Source: Mitsubishi Electric

**Talega ±100 MVA, 138 kV STATCOM system**

# Applications In Power/Utility Industry

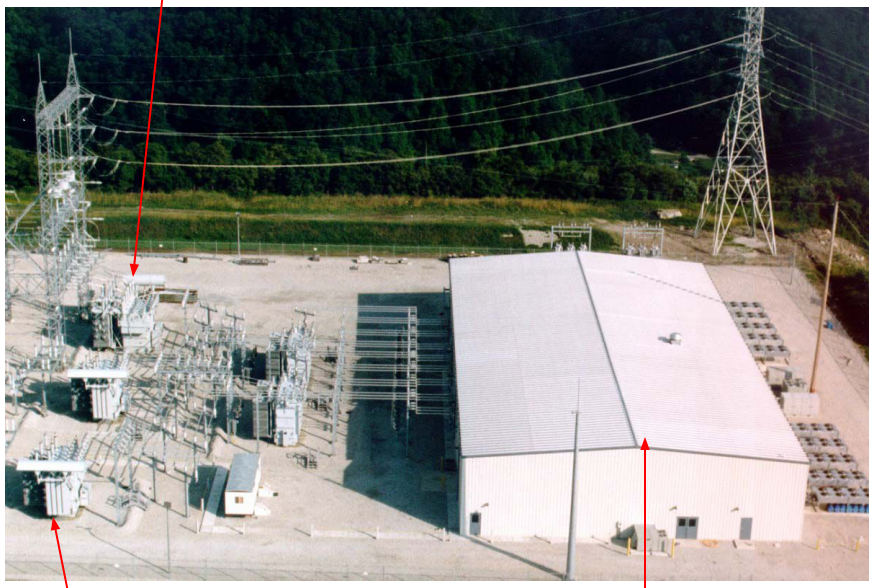
- **UPFC**




- 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)



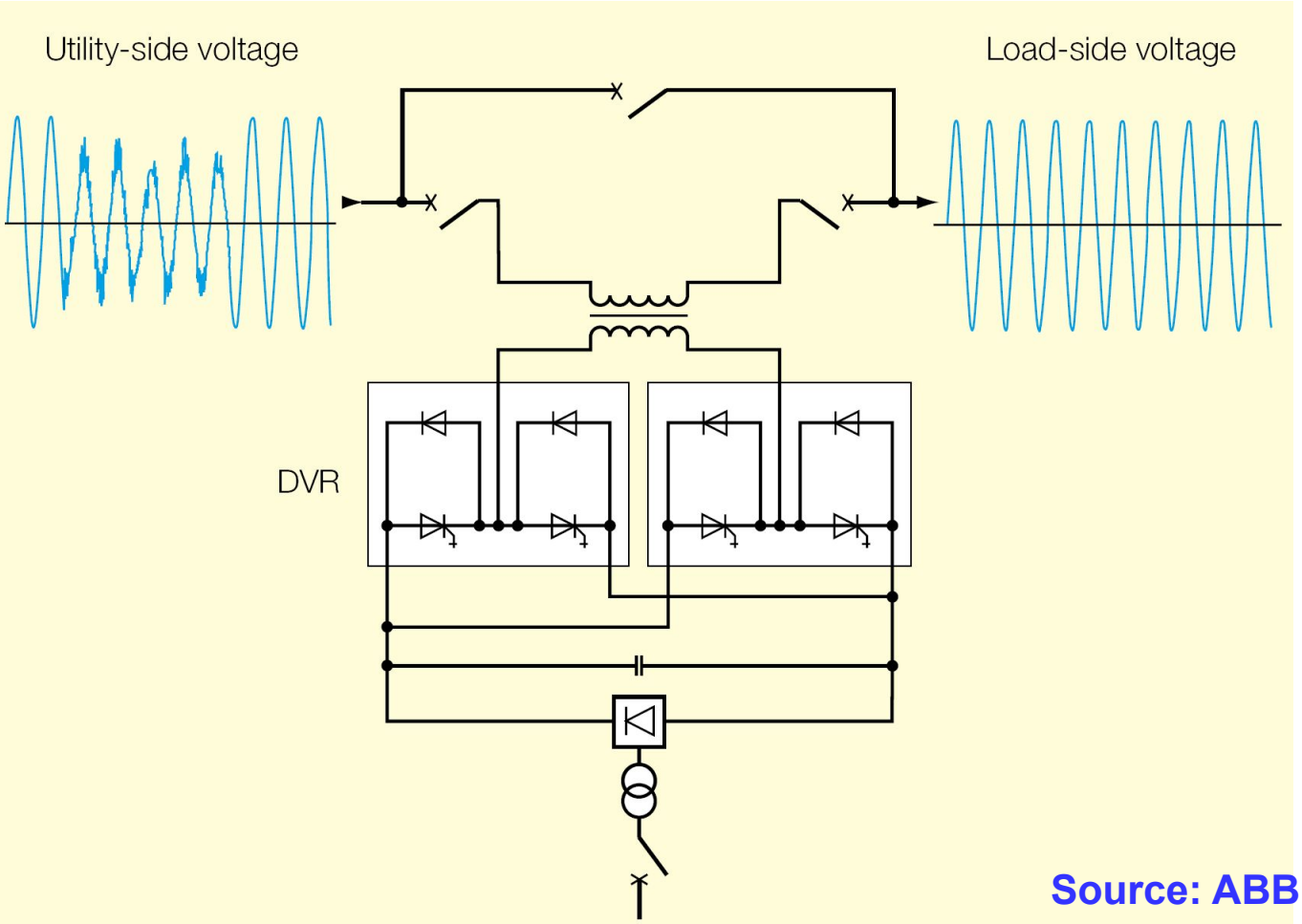

UPFC Equipment

GTO valve hall

Source: AEP Inez UPFC Project

# Applications In Power/Utility Industry

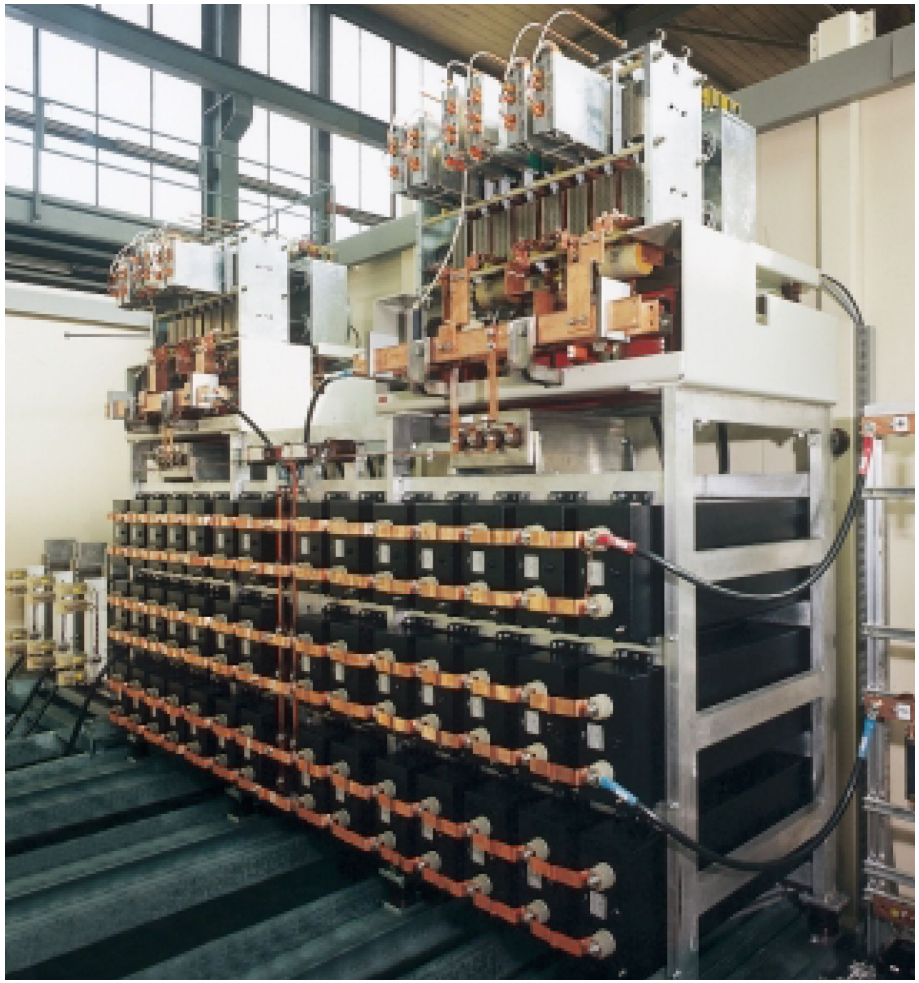
- Dynamic Voltage Restorer (DVR)




Source: ABB

# Applications In Power/Utility Industry

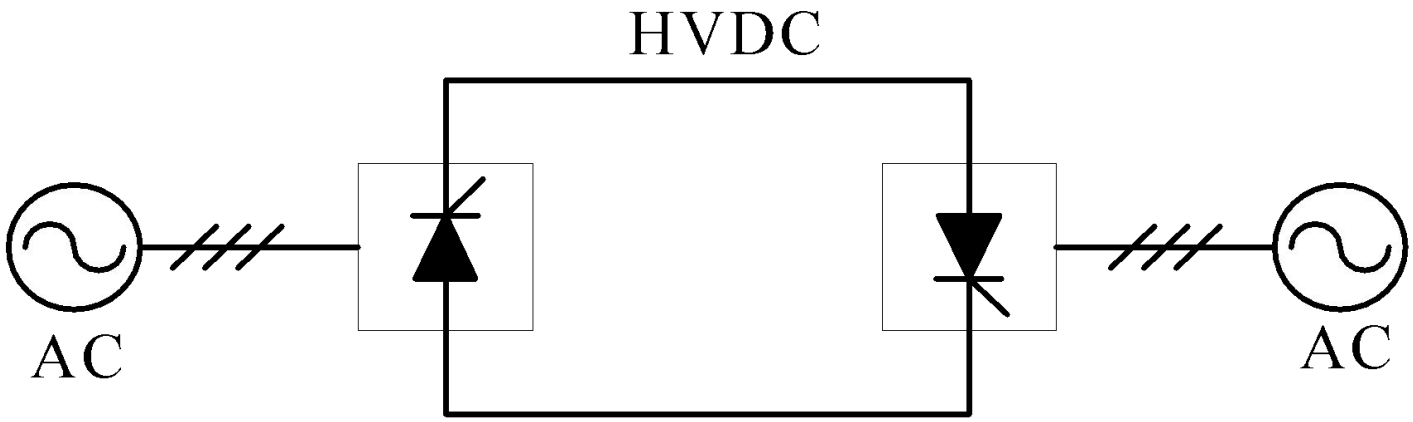
- Dynamic Voltage Restorer (DVR, 4MVA )



Source: ABB

# Applications In Power/Utility Industry

- HVDC

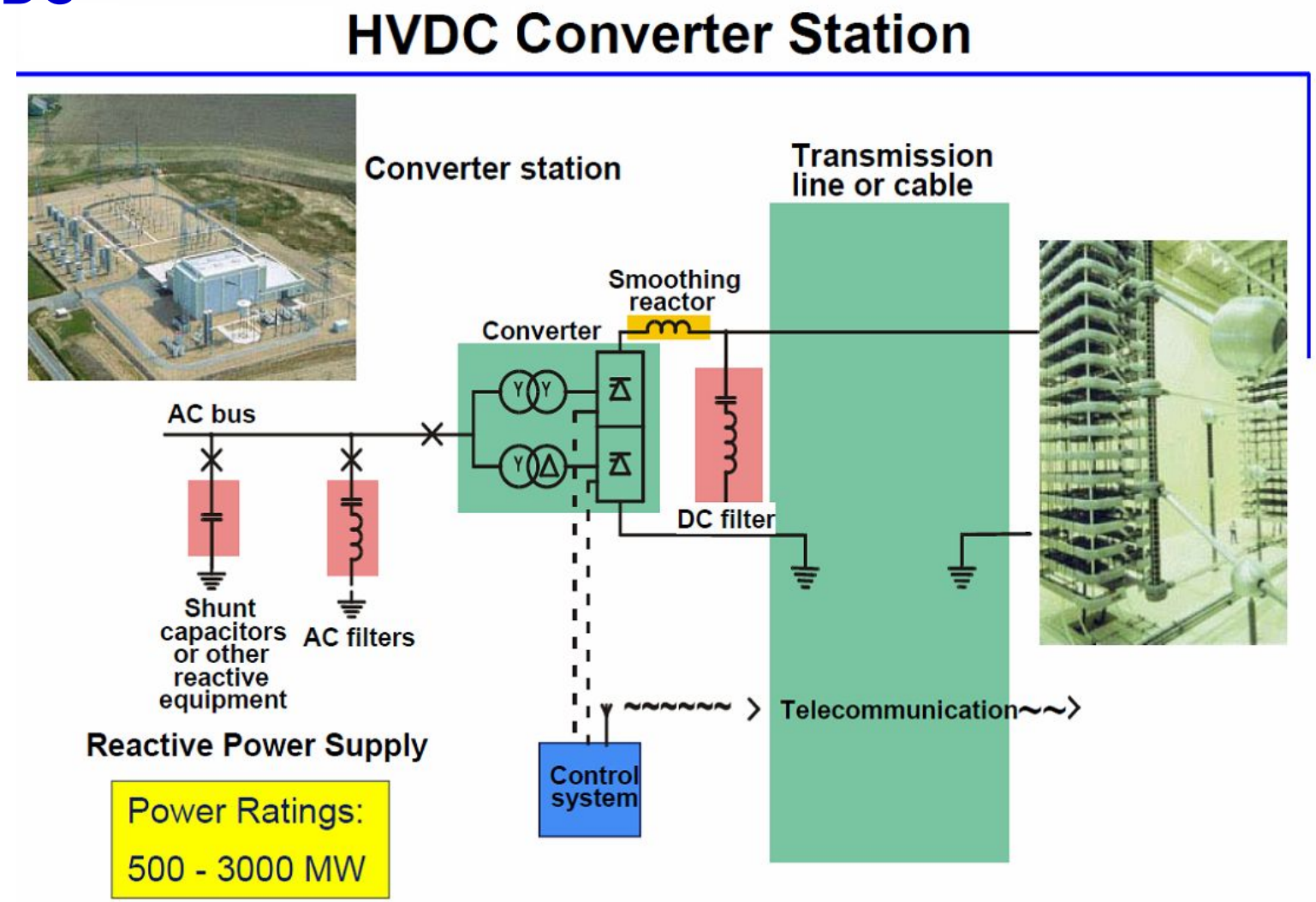



**Main Benefits of HVDC**

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

# Applications In Power/Utility Industry

- HVDC




Source: ABB

# Applications In Power/Utility Industry

- HVDC Transmission Québec - New England

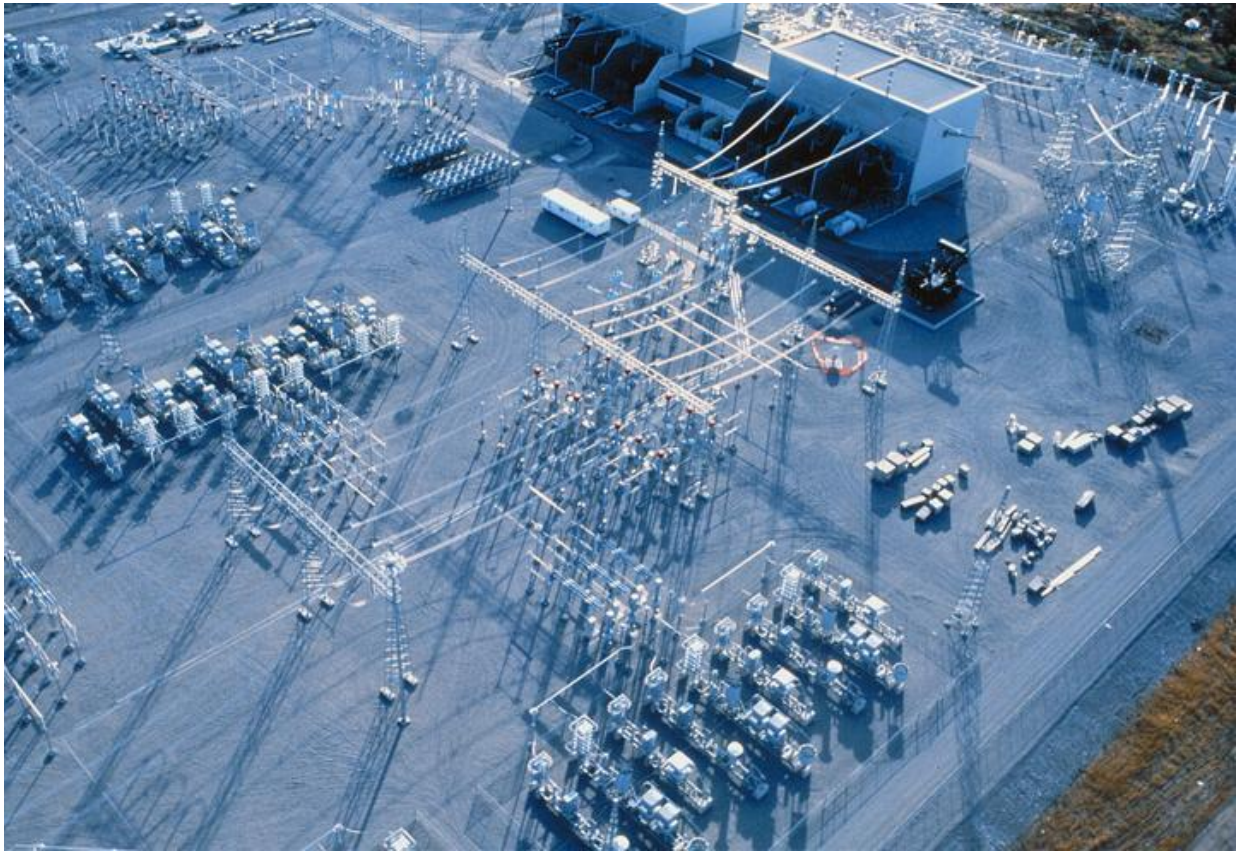

Source: ABB

| 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

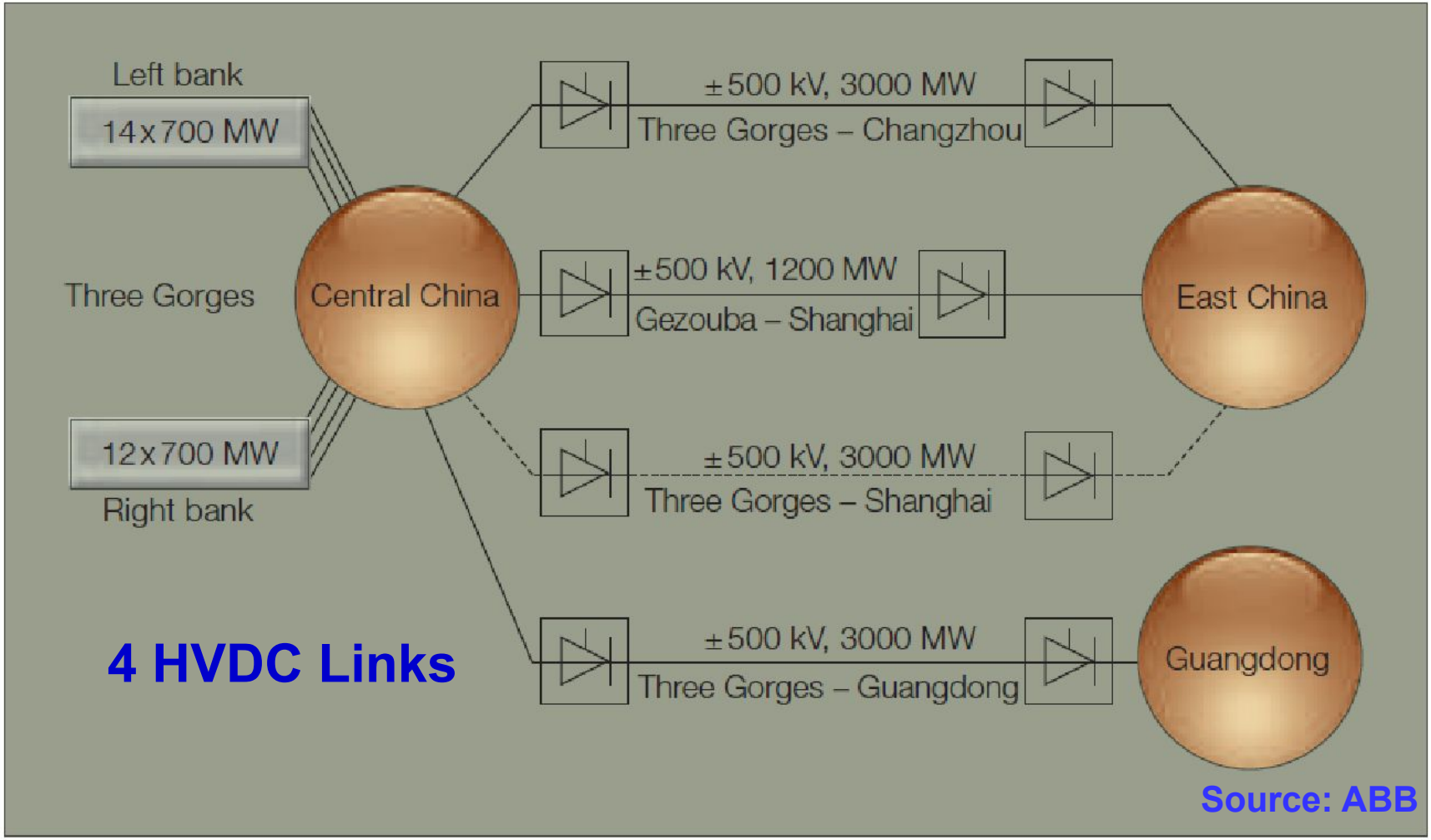


Source: ABB

Radisson Converter Station

# Applications In Power/Utility Industry

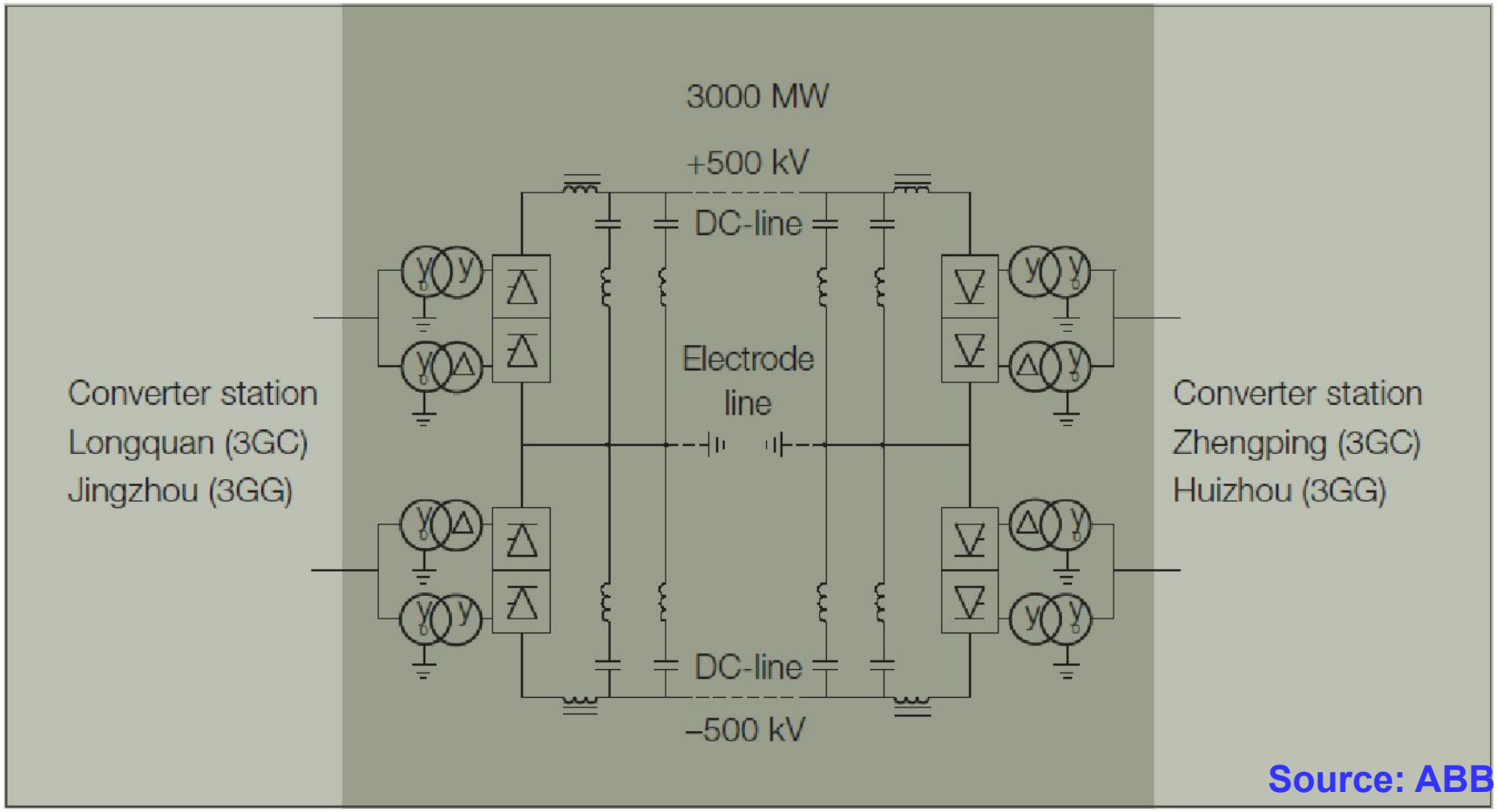
- HVDC Project in China



# 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


Thyristor valve hall

Length of overhead DC line: 940 km

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# Thanks