
AREVA

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800kV DC Transmission

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Consultant FACTS

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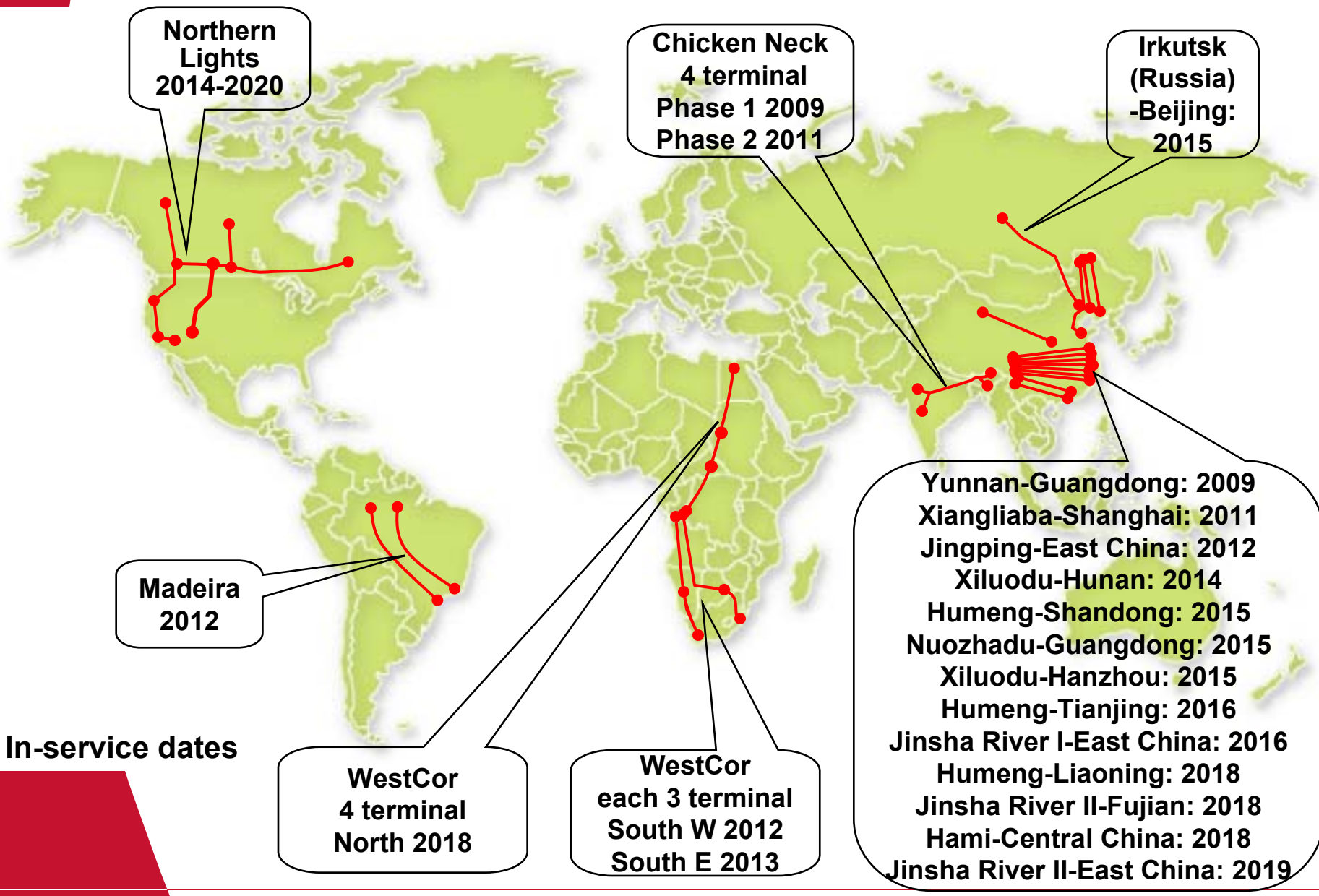
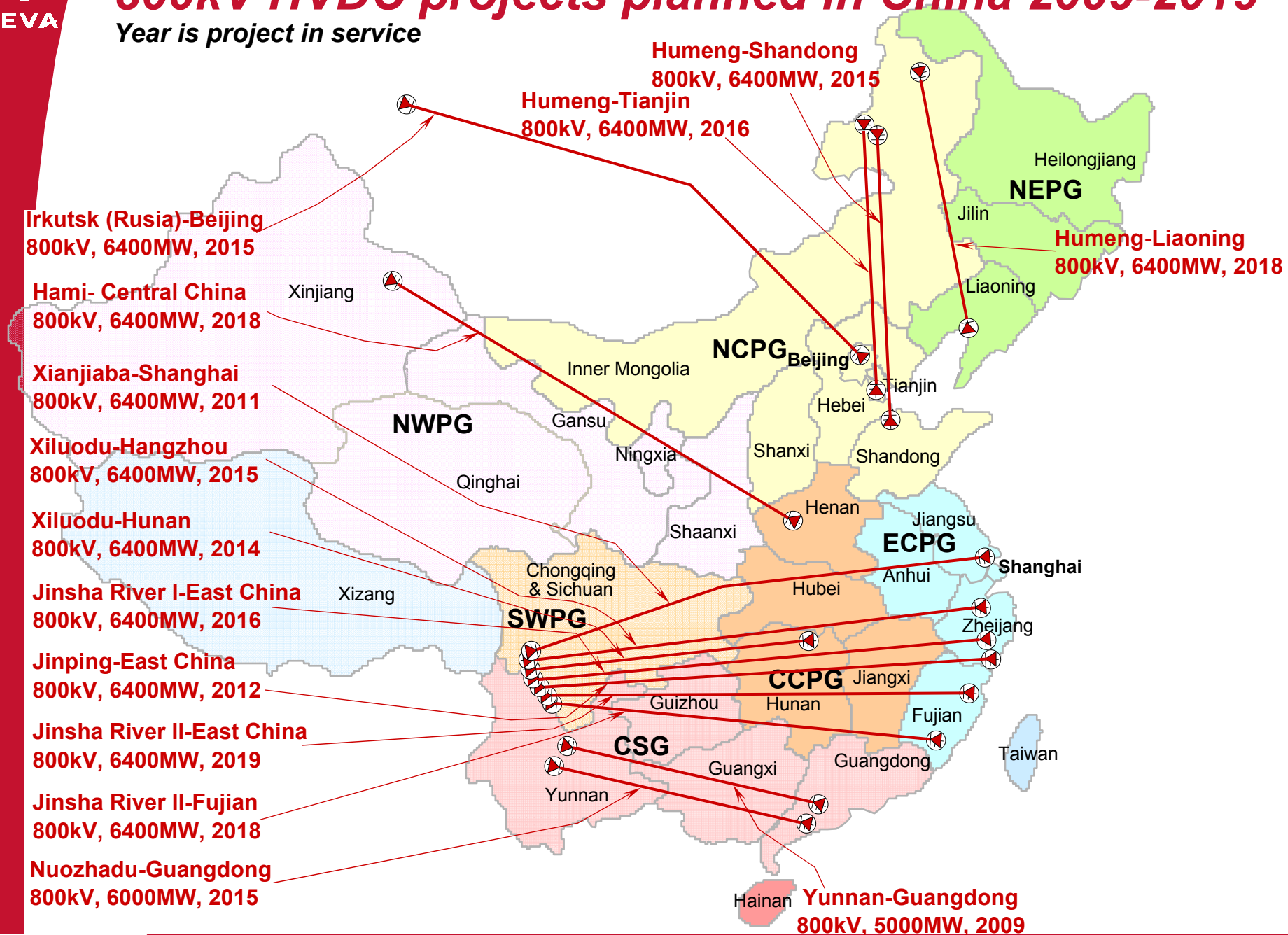
Potential market for 800kV DC projects

UHVDC Prospects 600kV-800kV



800kV HVDC projects planned in China 2009-2019

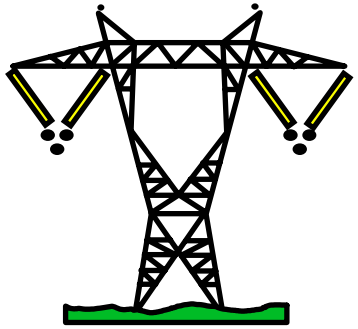
Year is project in service



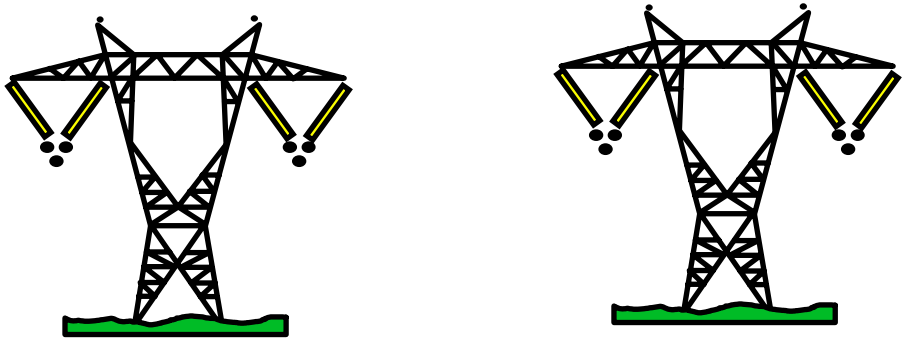
Benefits of HVDC at 800kV

- Large HVDC schemes, 5000MW – 6400MW are used to access hydro power resources, hence renewable energy with no CO_2 emissions
- HVDC is more economic than AC for schemes with transmission distances longer than 700km
- 800kV DC reduces the overall transmission losses
- Right of way is smaller than 2 off 500kV HVDC or 5 off 500kV AC alternatives

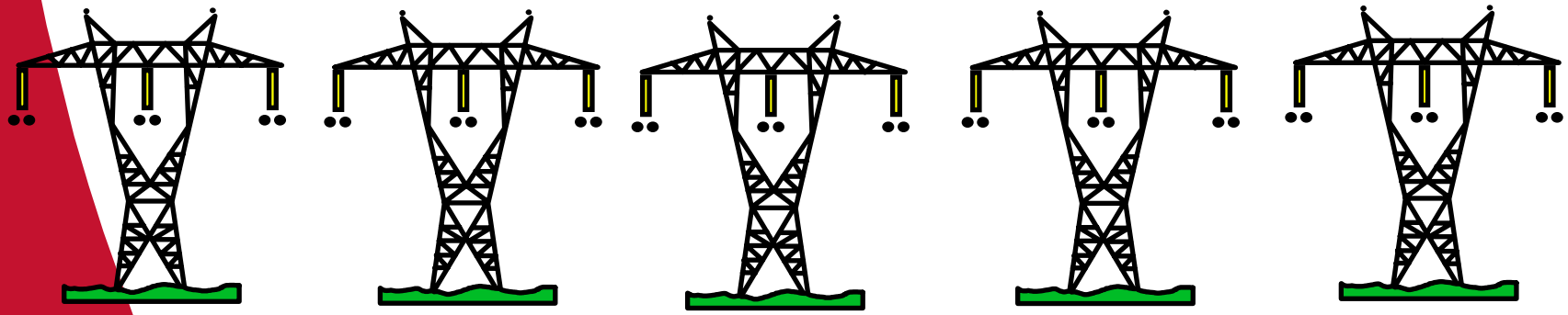
Transmission options for up to 6400MW



1 off ±800kV tower



2 off ±500kV towers



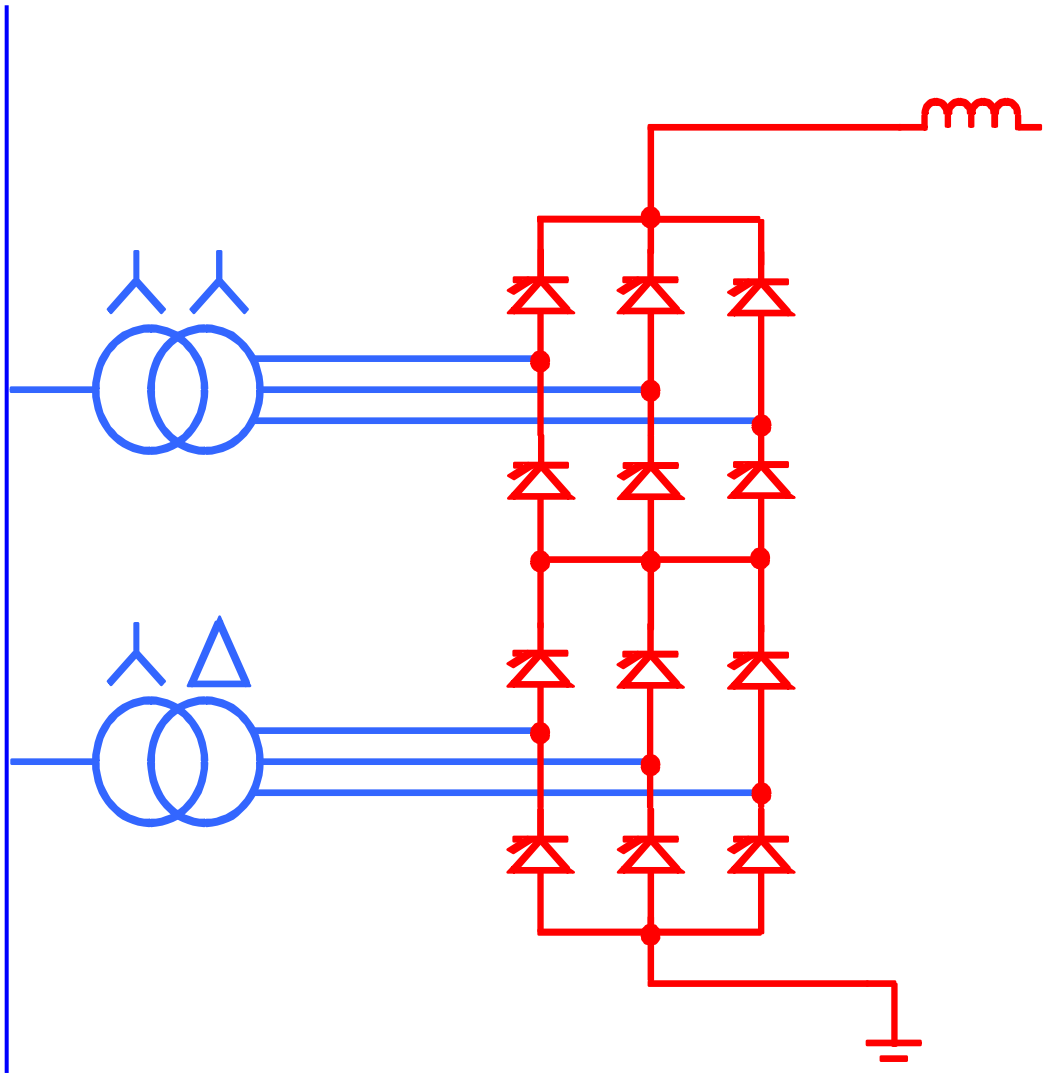
5 off 500kV AC towers

Scheme Configuration

Assumed Scheme Rating

- 6400MW
- +/-800kV, 4000A Bipole
- Single pole rating 3200MW
- Single phase 2 winding converter transformers

1 x 12 Pulse Converter Per Pole



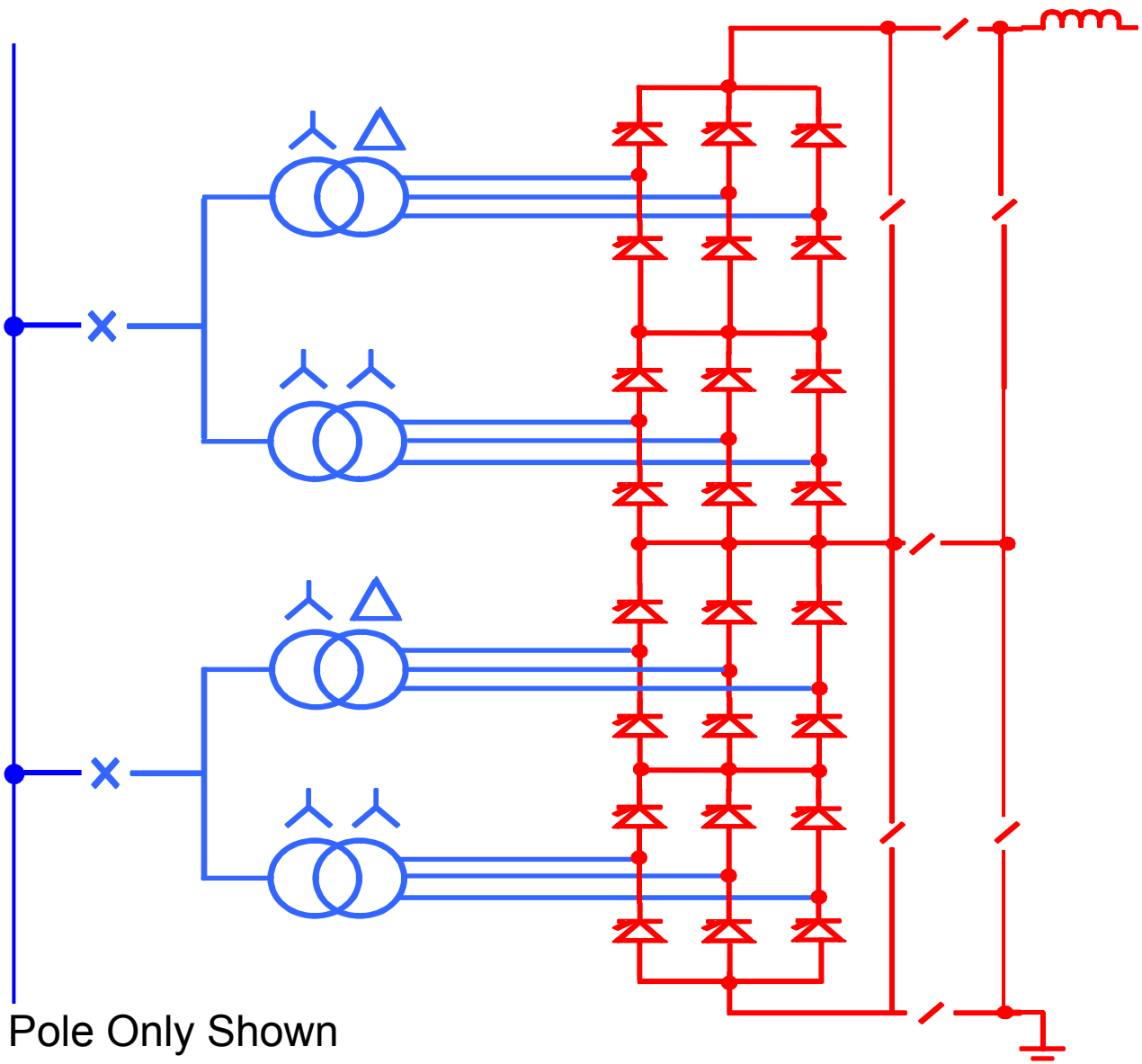
One Pole Only Shown

1 x 12 Pulse Converter Per Pole

- Transformer fundamental frequency rating approximately 620MVA
  - Unlikely this can be transported to generation end
- Converter trip removes up to 3200MW
  - This may be difficult for the grid to manage
  - May not be acceptable for availability reasons
- Valve would need to be designed for much higher capacitive inrush currents at commutation
- No bypass switches

- AREVA T&D has chosen to concentrate on multiple converter options
  - 2 x 12 pulse series connected converters per pole

2 x 12 Pulse Series Connected Converters



One Pole Only Shown

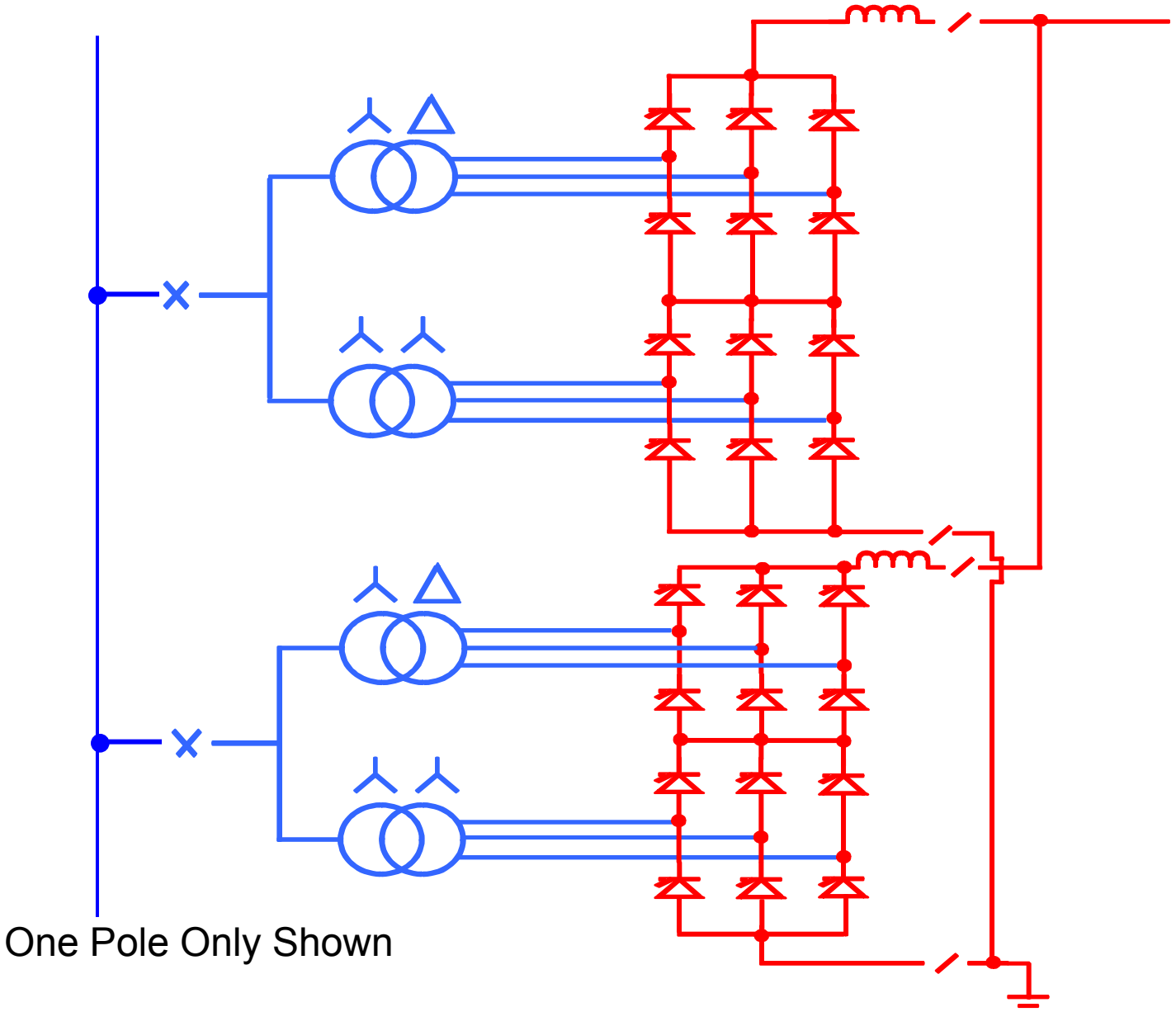
Series bridges 400kV + 400kV

- Equal sizes of switched blocks
- Would allow common transformer design
  - Would this be economic?
  - Would this be useful to operator?
  - Could have different valve winding bushings
- Valve design would be common and the voltage within present experience
- Maximum bypass switch voltage 400kV
- Maximum switched block 1600MW
- Staged build step is 400kV

2 x 12 Pulse Series Connected Converters

- Series connected converters have already been used for 600kVdc
- Transformer fundamental frequency rating approximately 320MVA
  - Should be possible to transport to generation end
- Converter trip removes up to 1600MW
  - This should be acceptable
- DC component or single pole line fault removes 3200MW
  - This would be extremely infrequent
- Assuming equal bridge sizes:
  - Valve voltage less than present maximum rating
    - 6 pulse bridge = 200kV
    - Today 6 pulse bridge = 250kV
  - Need bypass switches of 400kV

2 x 12 Pulse Parallel Connected Converters



One Pole Only Shown

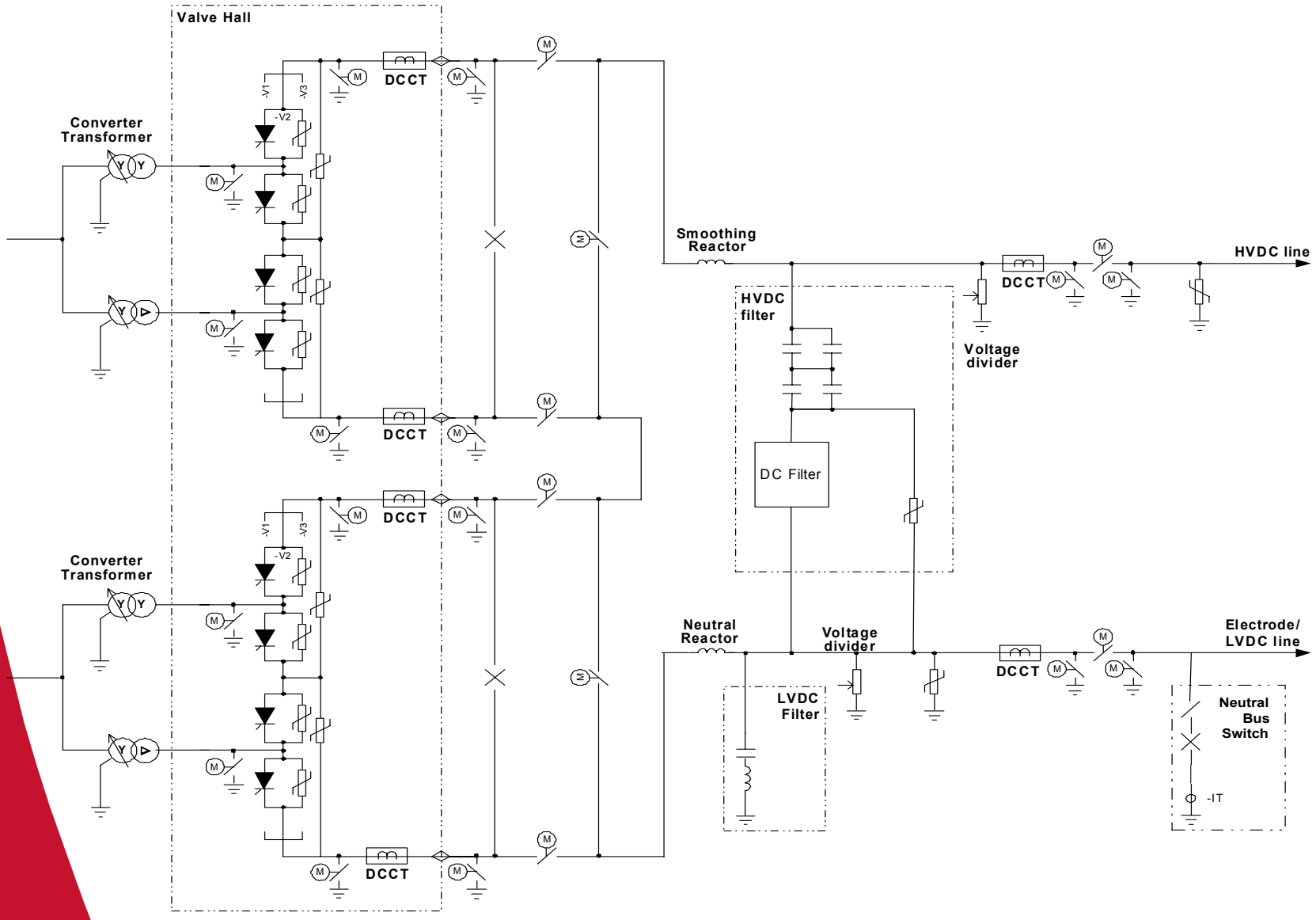
2 x 12 Pulse Parallel Connected Converters

- Parallel connected converters have been used on multi-terminal schemes:
  - SACOI (Italy – Corsica – Sardinia)
  - New England (Canada – USA)
- Each converter needs to be 800kV as one block
- Transformer fundamental frequency rating approximately 320MVA
  - Should be possible to transport to generation end
- Converter trip removes up to 1600MW
  - 800kVdc circuit breakers would be required to trip single converter
- Valve would need to be designed for much higher capacitive inrush currents at commutation
- Do not need bypass switches

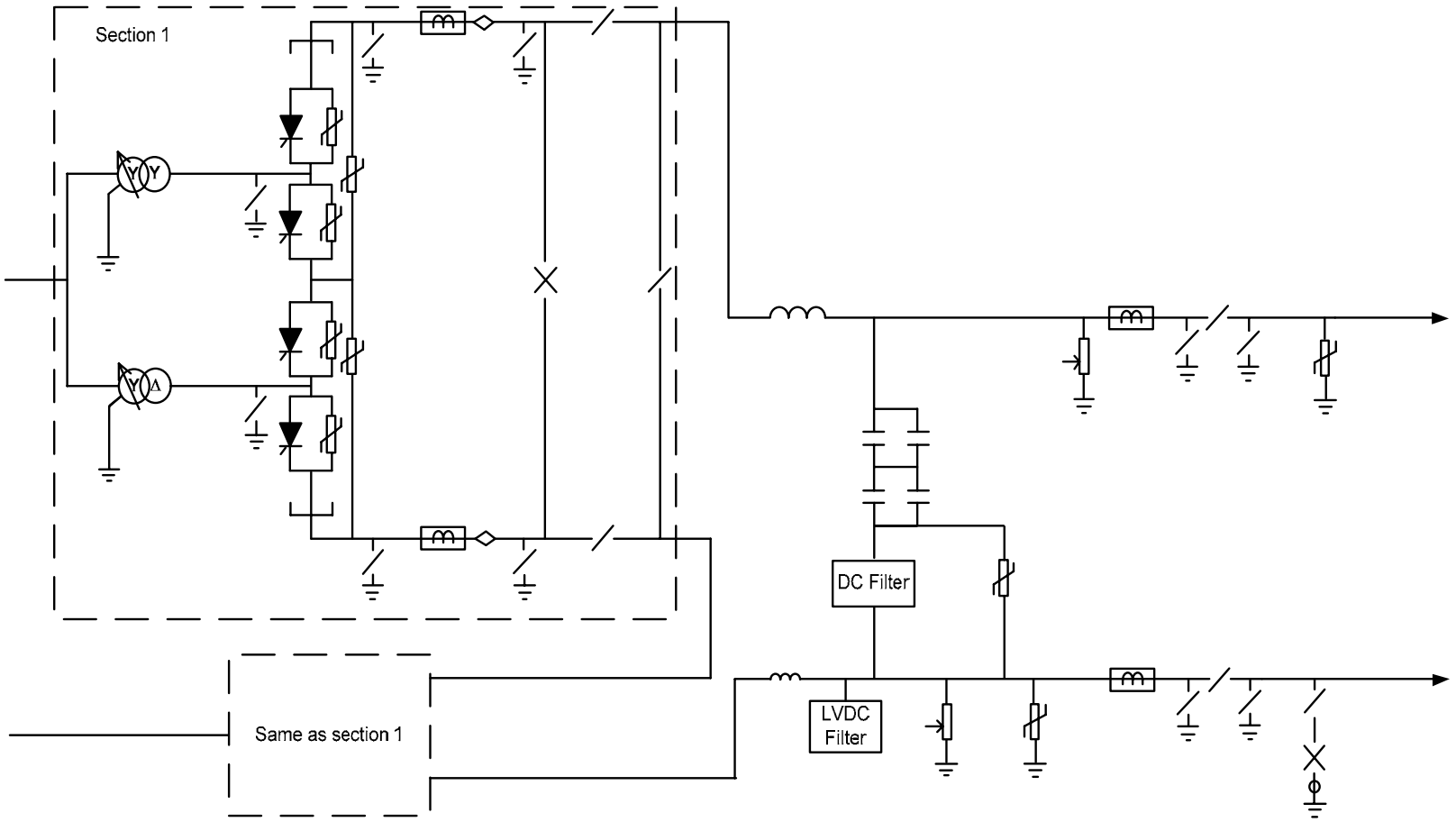
800kV Pole
Basic Assumptions

- 2 off Series connected, 12 pulse bridges per pole
- 1 phase, 2 winding converter transformers
- 1 valve hall per 12 pulse bridge
- 2 hanging bi-valves per phase
- Indoor DC area common to both bridges

Single Line Diagram One Pole

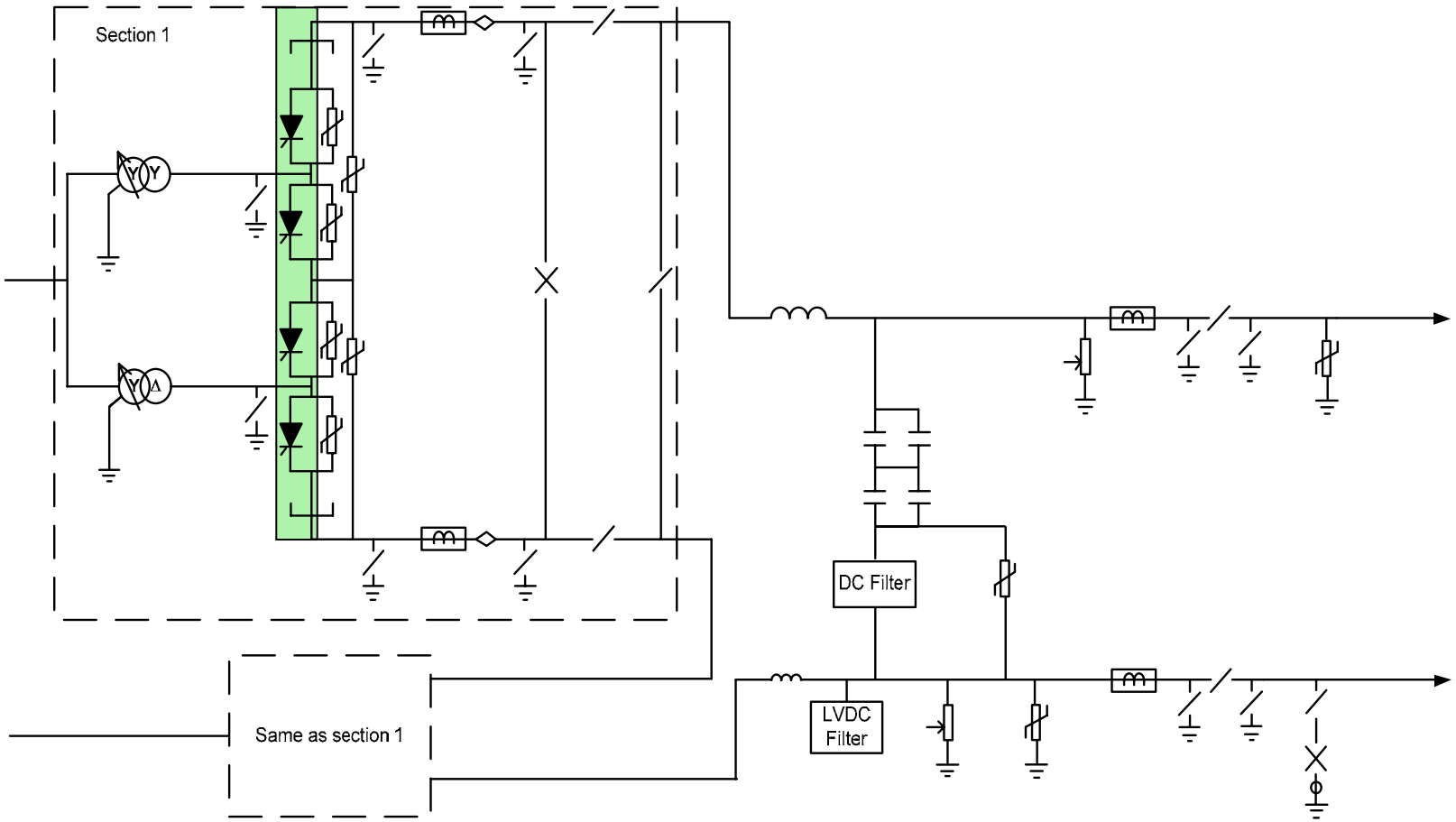


Single line Diagram
One 12 – pulse bridge

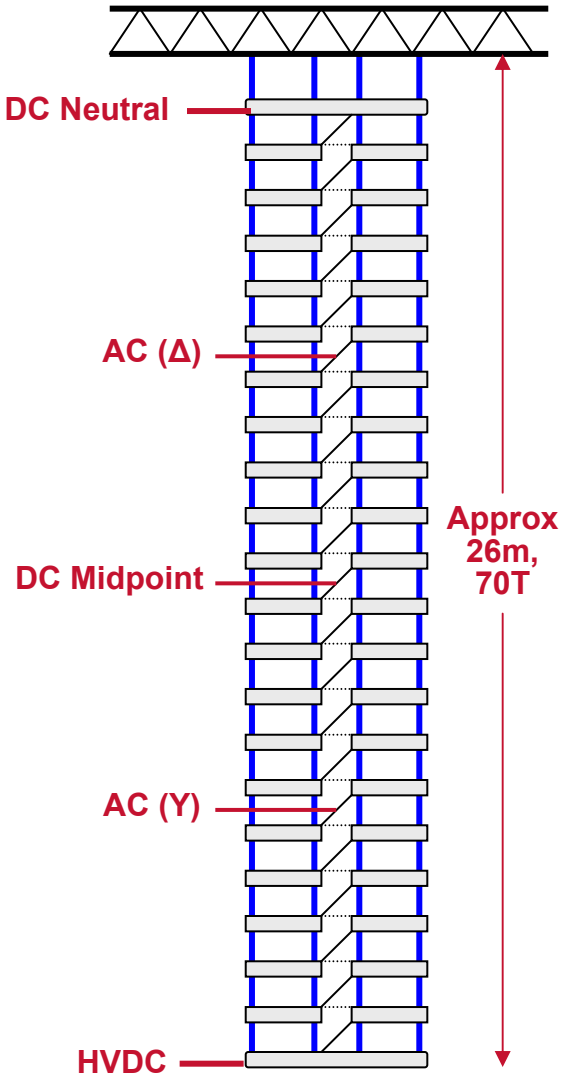


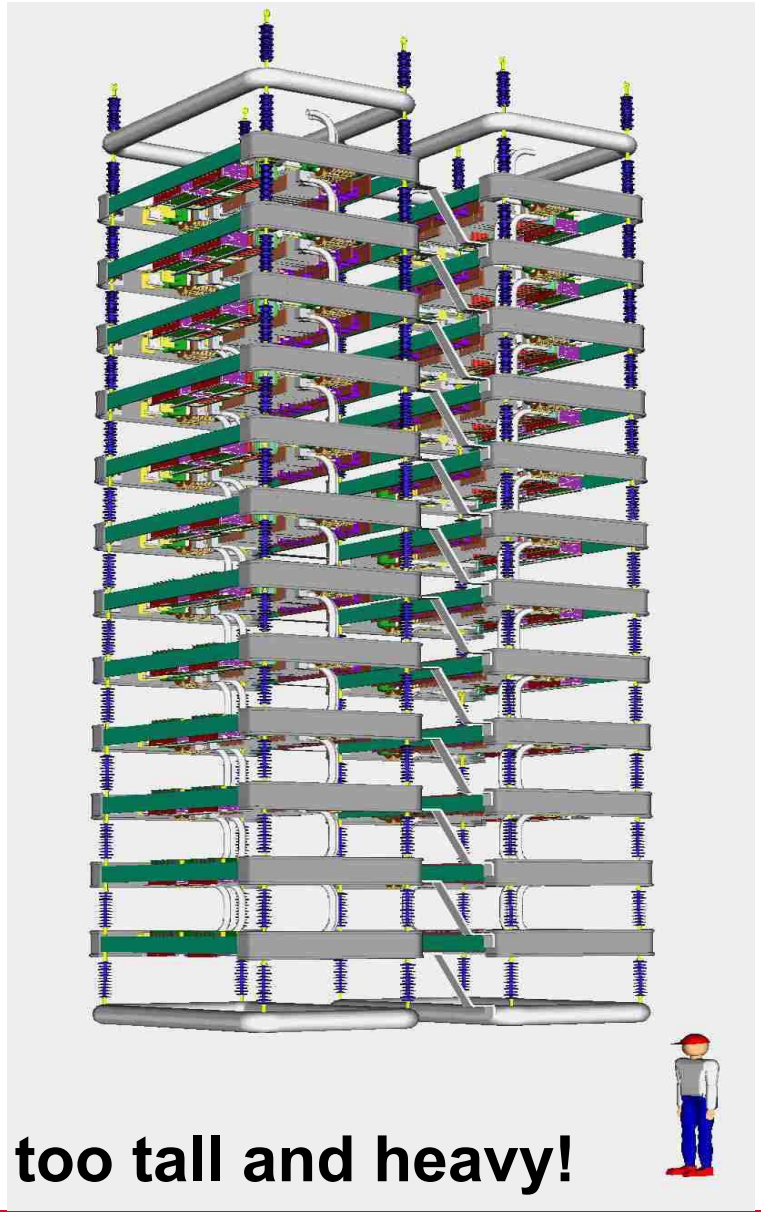
Thyristor Valve

Thyristor Valves



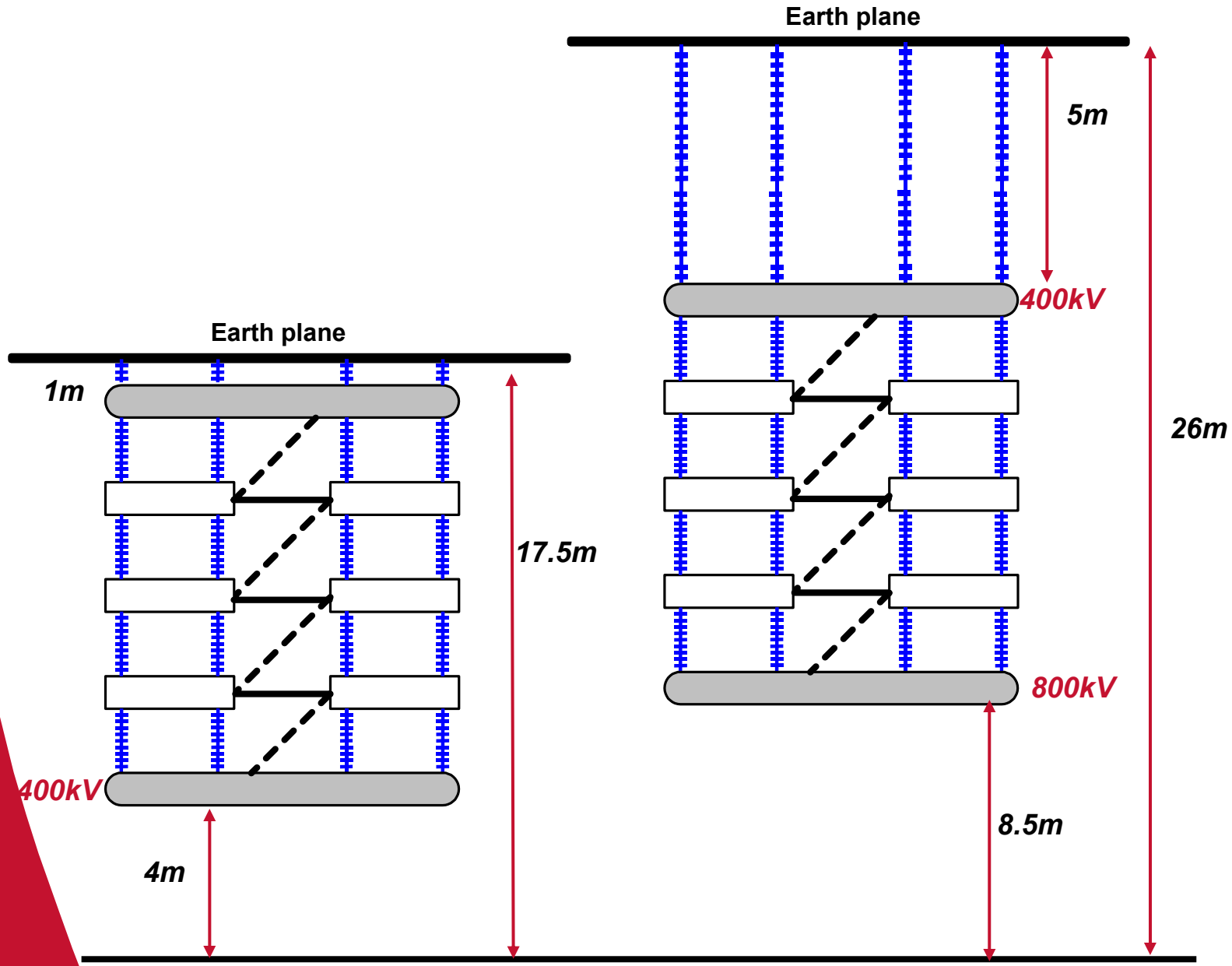
AREVA Suspended Valve





Single suspended valve: too tall and heavy!

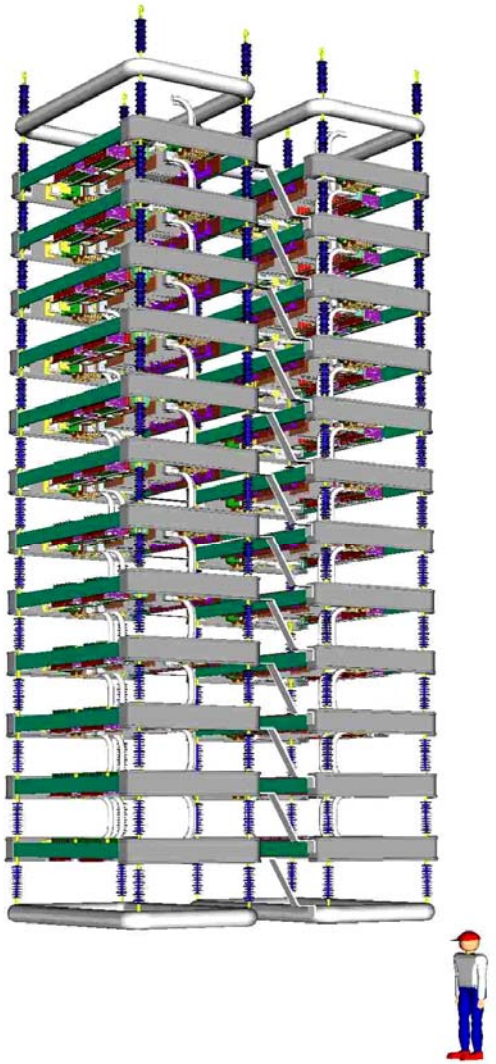
Valve Hall


Earth plane
1m
400kV
4m
17.5m
Earth plane
5m
400kV
800kV
8.5m
26m

State-of-the-art Valve - Introduced 2003

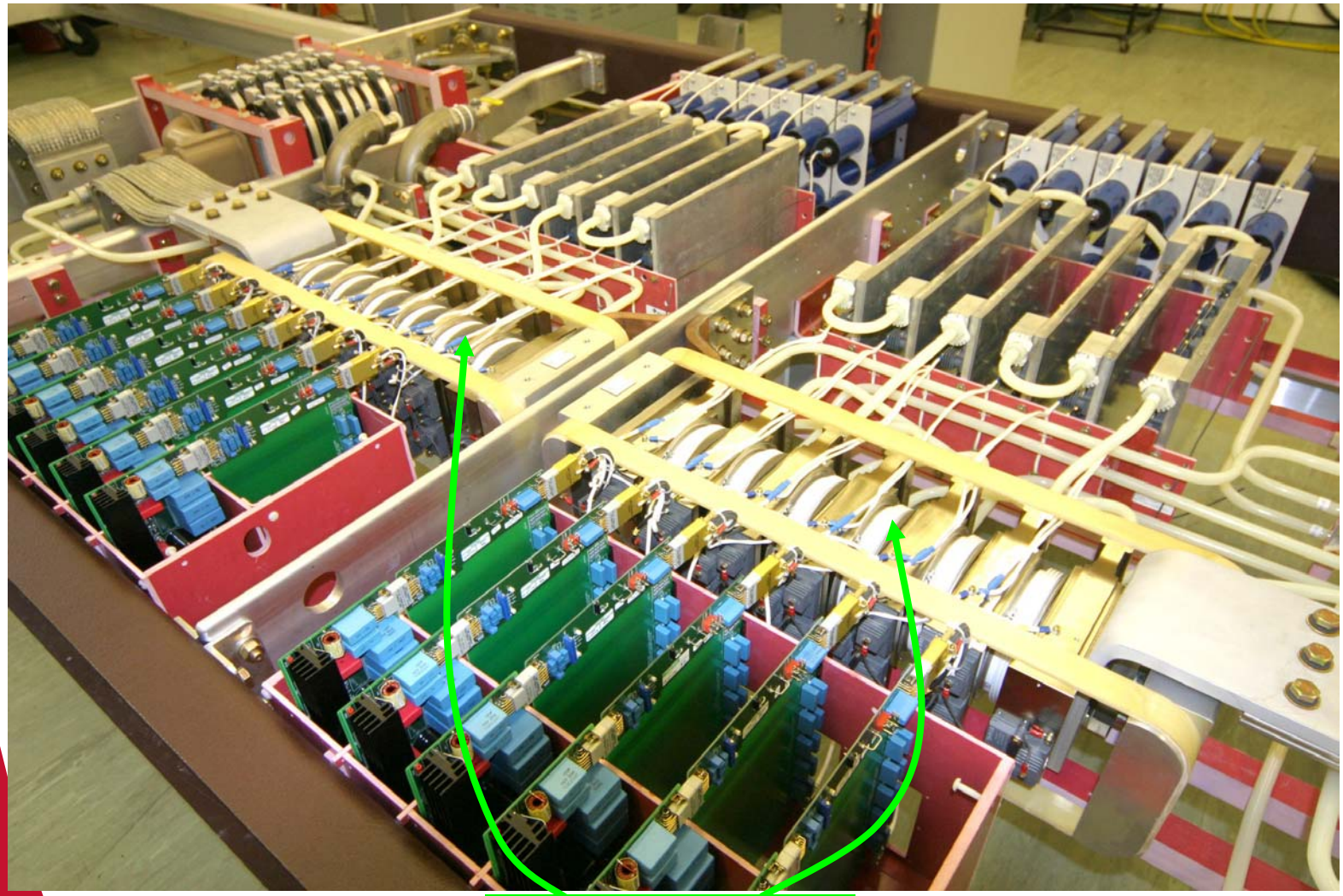
Key attributes:

- **Enhanced capacity**
  - **Up to 500kV, 4000A as single block**
- **Flexible**
  - **Thyristors up to 150mm diameter**
- **Greater power density giving reduced space**
- **Significantly cheaper than previous valves**
- **Rapid thyristor replacement without disturbing power connections or cooling pipe-work**
  - **Due to thyristor clamped assembly system**
- **Direct water/glycol cooled**
- **Suspended structure to ease seismic qualification**

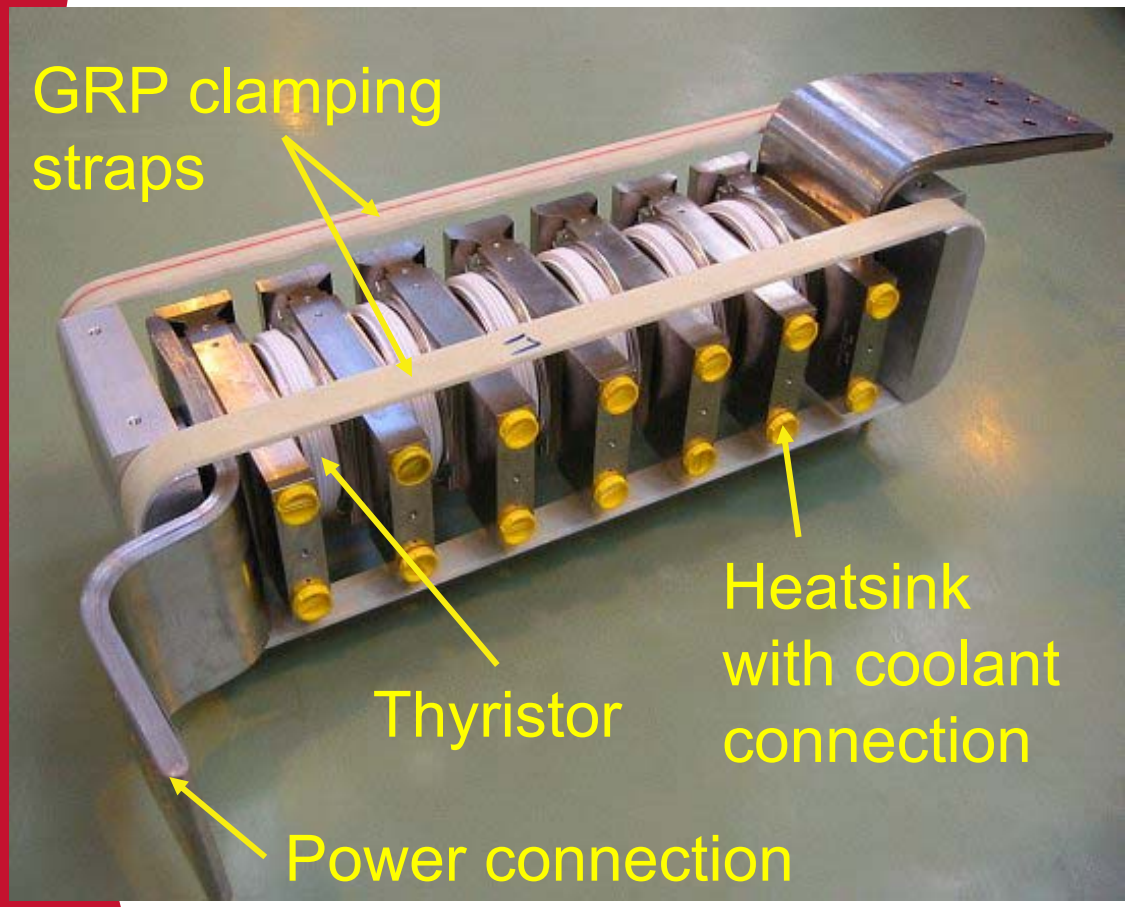


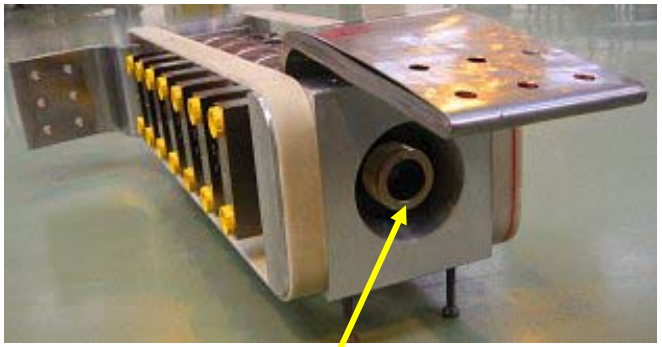
Standardized and modularized for flexibility

H400 Valve Module comprising 2 valve sections Building Block



Thyristor Clamped Assembly



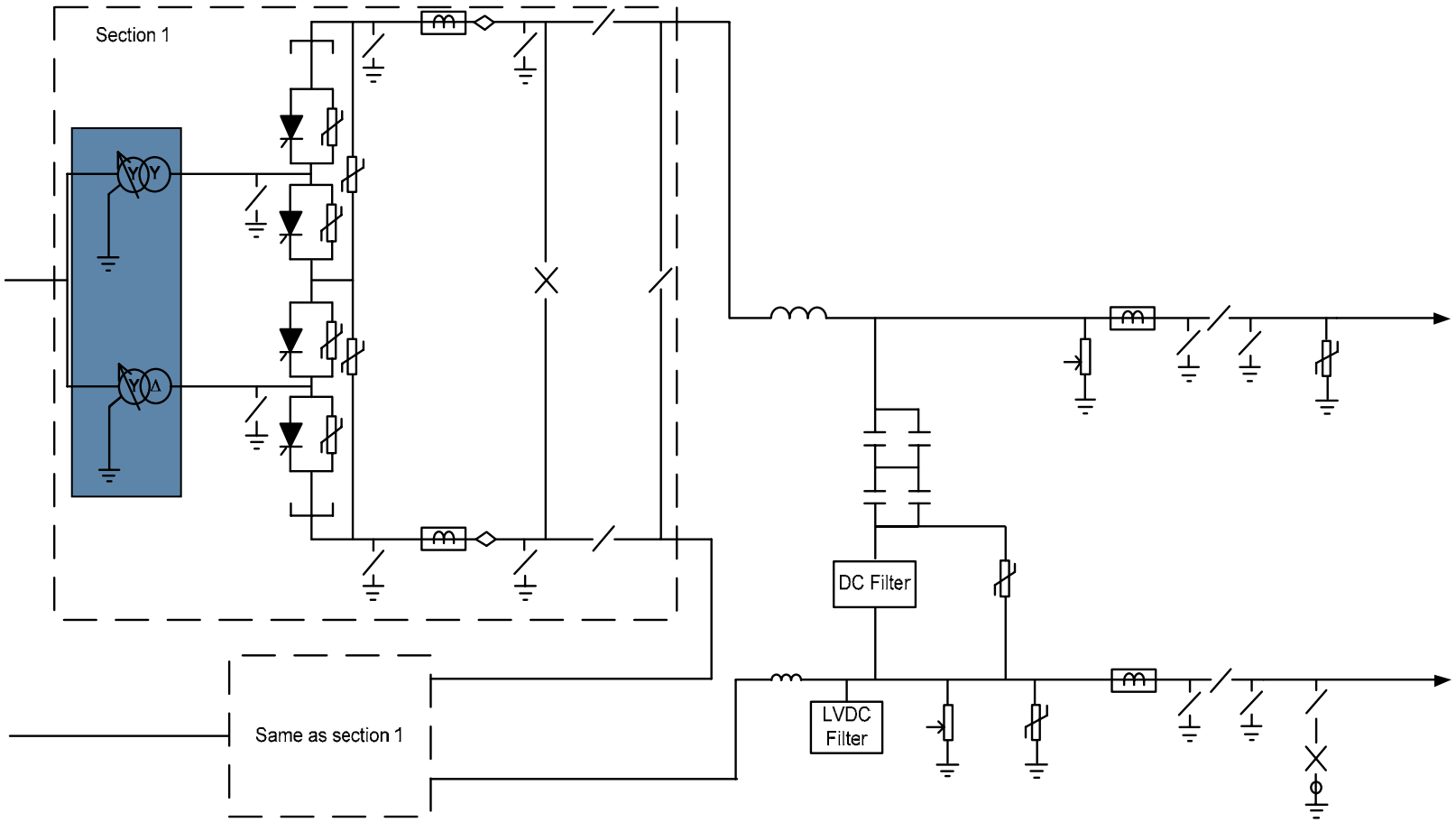


Loading adaptor for thyristor changing tool

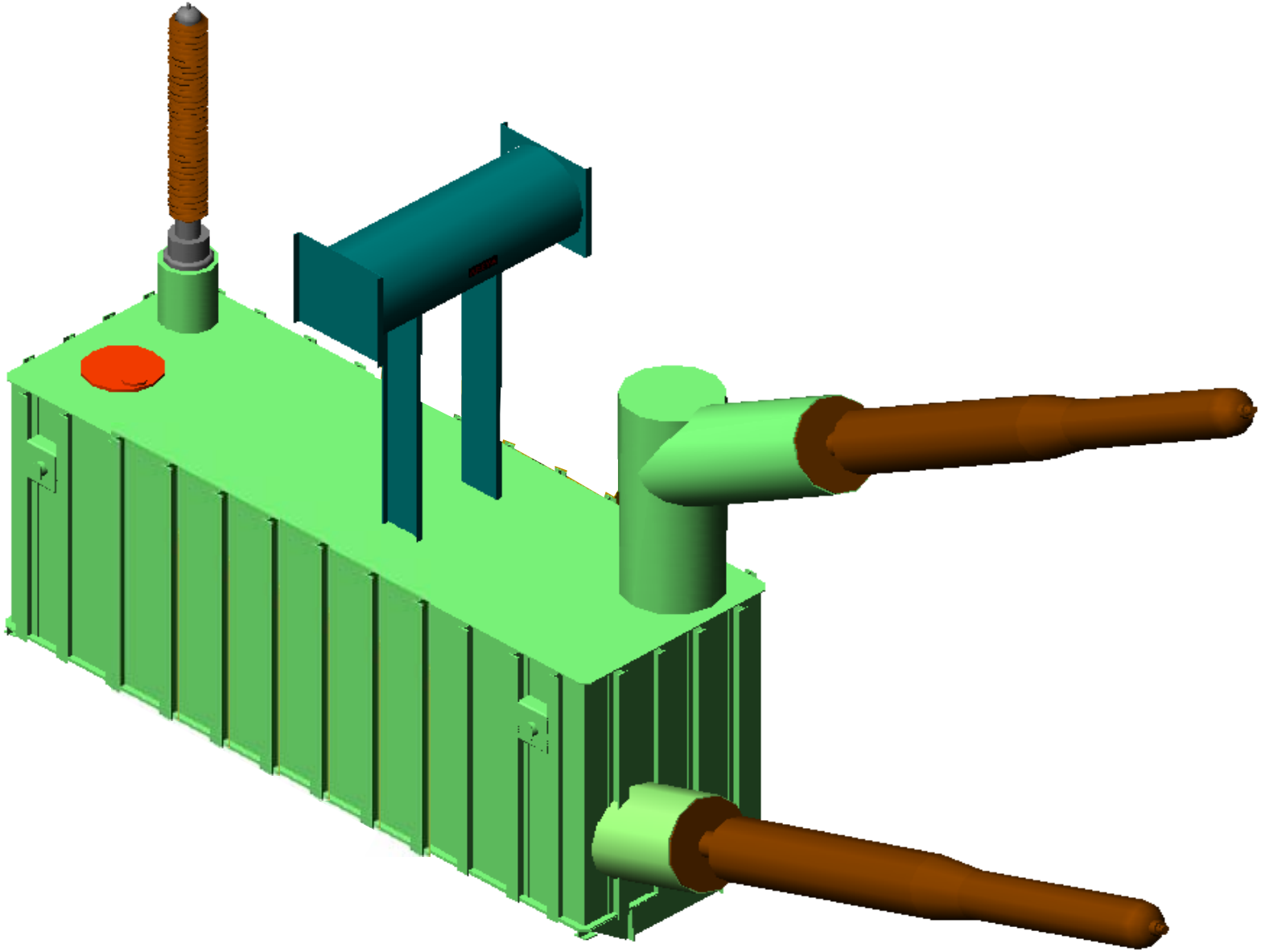
Example of 12 pulse Thyristor Valve

Converter Transformer

Converter Transformers



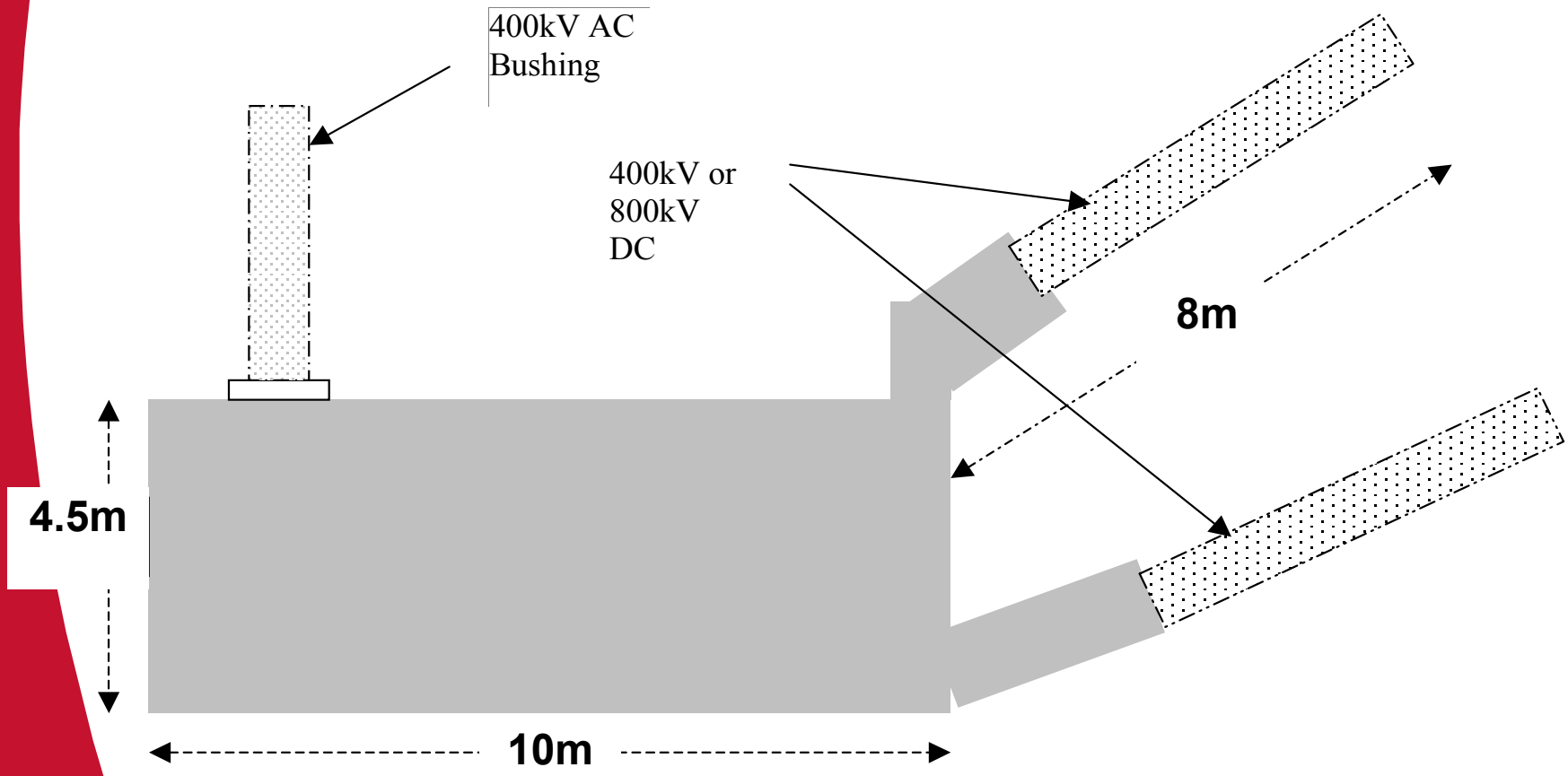
Converter Transformer for 800kV Arrangement



Converter Transformer for 800kV Technical Challenges

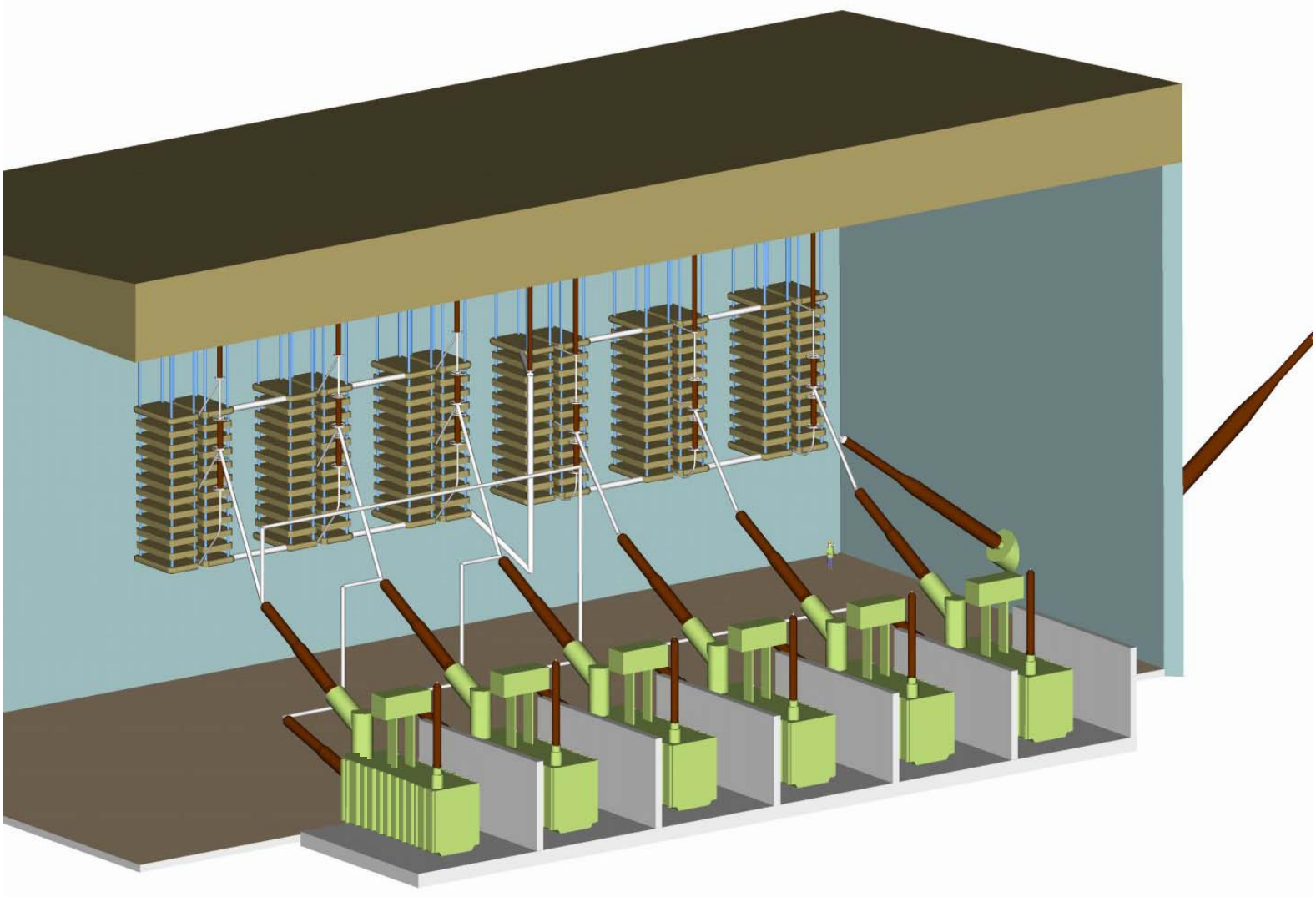
- DC side bushings
- Oil free designs required
- Composite insulation rather than porcelain
- Solid insulation/Gas insulation?
- Mechanical strength due to extreme length.

Converter Transformer for 800kV Schematic diagram



Valve Hall Layout

Upper Voltage Block Valve Hall



400kV to 800kV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