

A large, bold, red letter 'A' logo. The letter is stylized with a thick stroke and a slight curve at the top. It is positioned centrally above the word 'AREVA'.

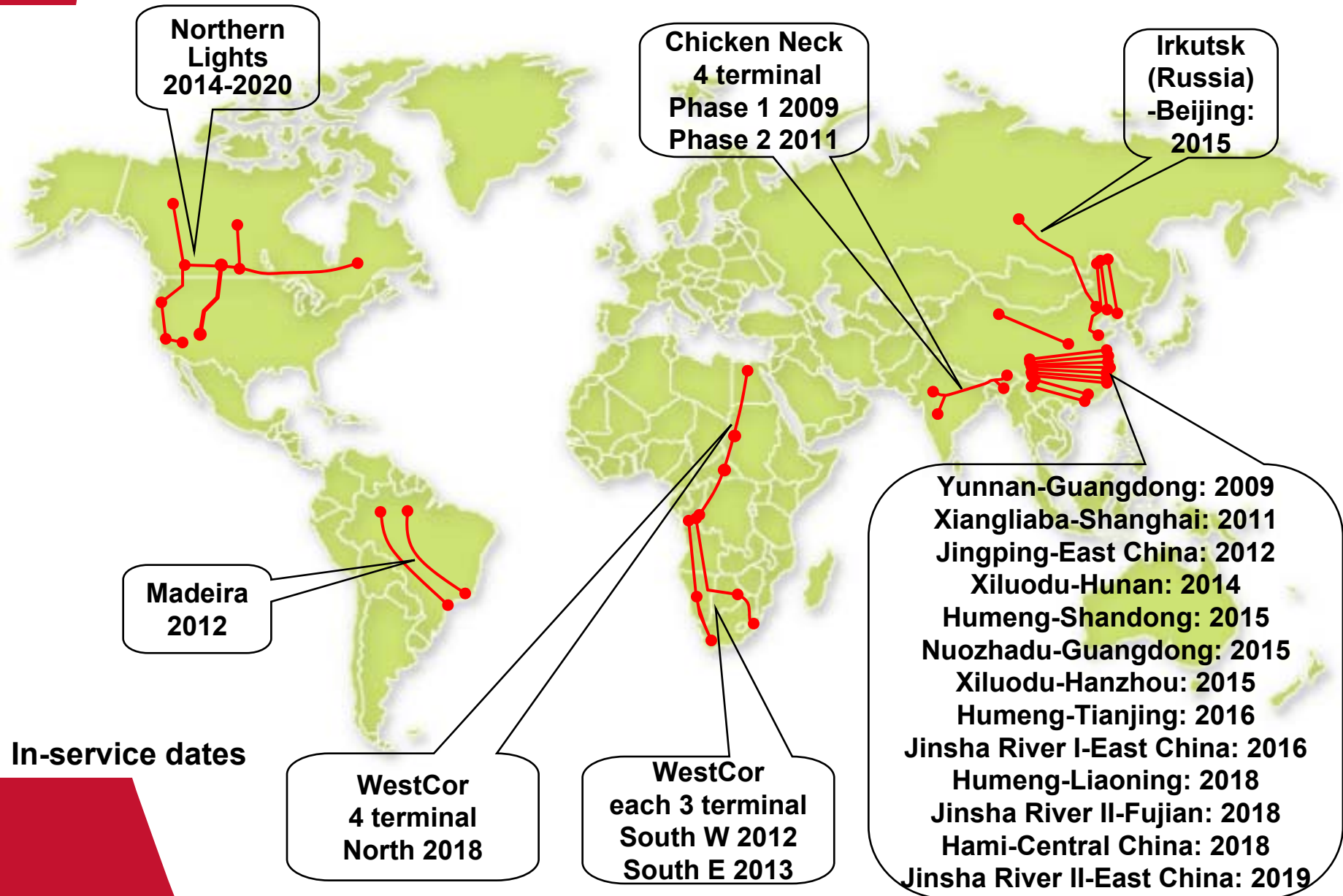
AREVA

800kV DC Transmission

Chris Horwill
Consultant FACTS

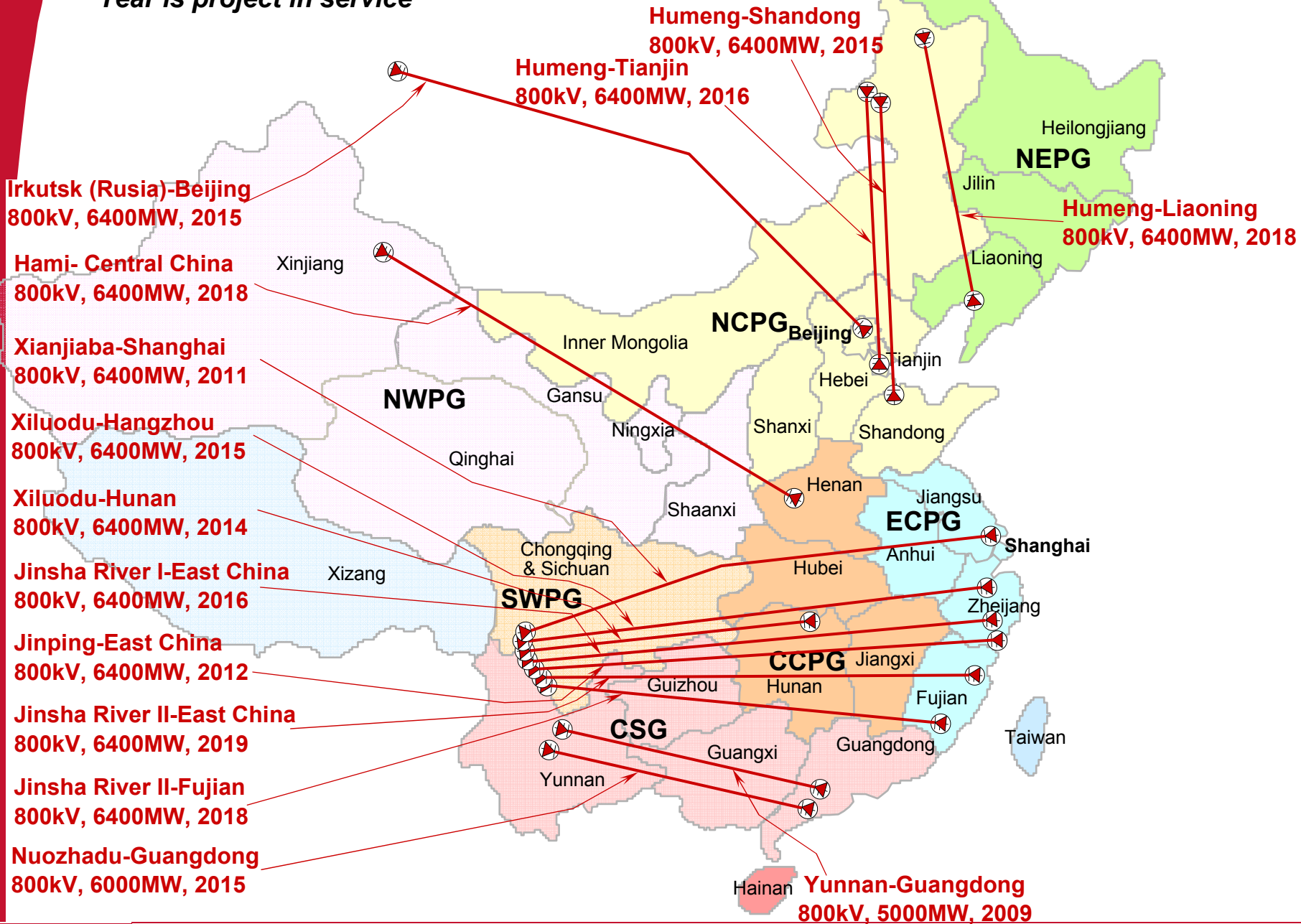
IEEE General Meeting, Tampa FL, June 2007

Potential market for 800kV DC projects



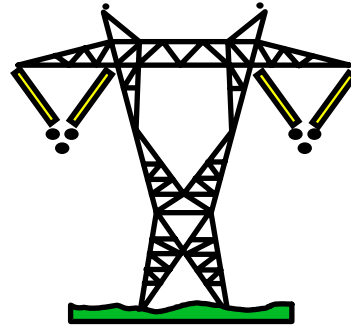
800kV HVDC projects planned in China 2009-2019

Year is project in service

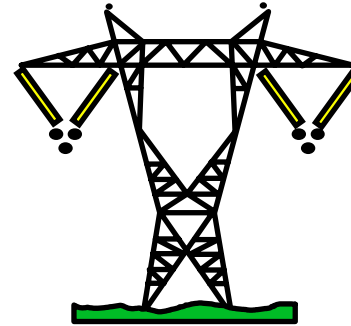
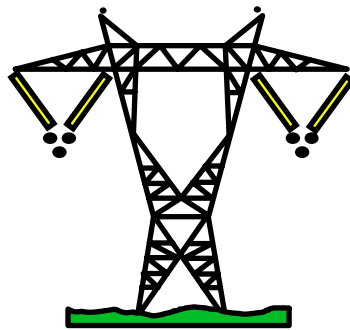


- ▶ **Large HVDC schemes, 5000MW – 6400MW are used to access hydro power resources, hence renewable energy with no CO₂ emissions**
- ▶ **HVDC is more economic than AC for schemes with transmission distances longer than 700km**
- ▶ **800kV DC reduces the overall transmission losses**
- ▶ **Right of way is smaller than 2 off 500kV HVDC or 5 off 500kV AC alternatives**

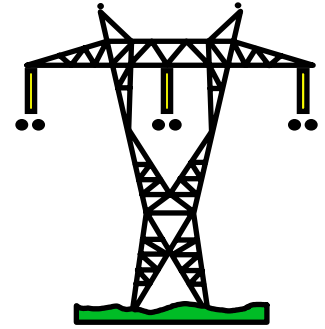
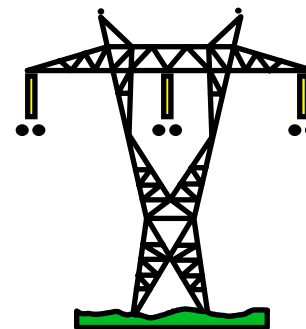
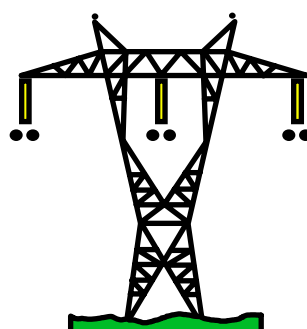
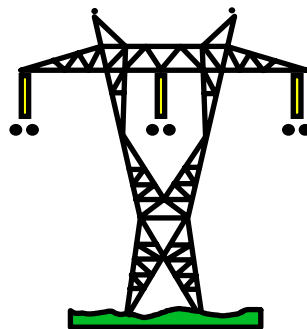
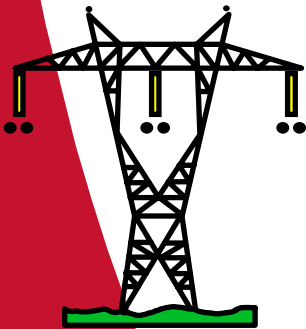
Transmission options for up to 6400MW



1 off $\pm 800\text{kV}$ tower



2 off $\pm 500\text{kV}$ towers

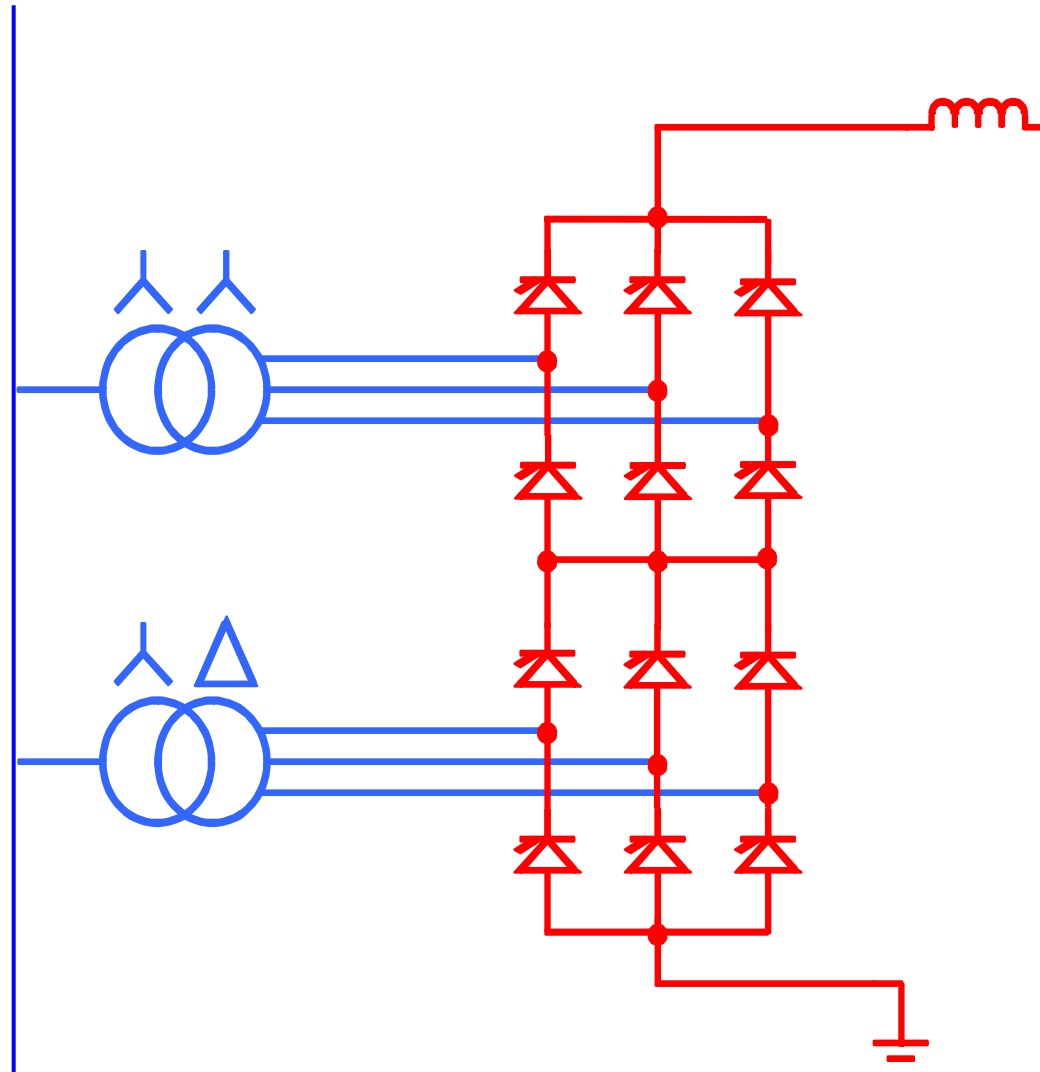


5 off 500kV AC towers

Scheme Configuration

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

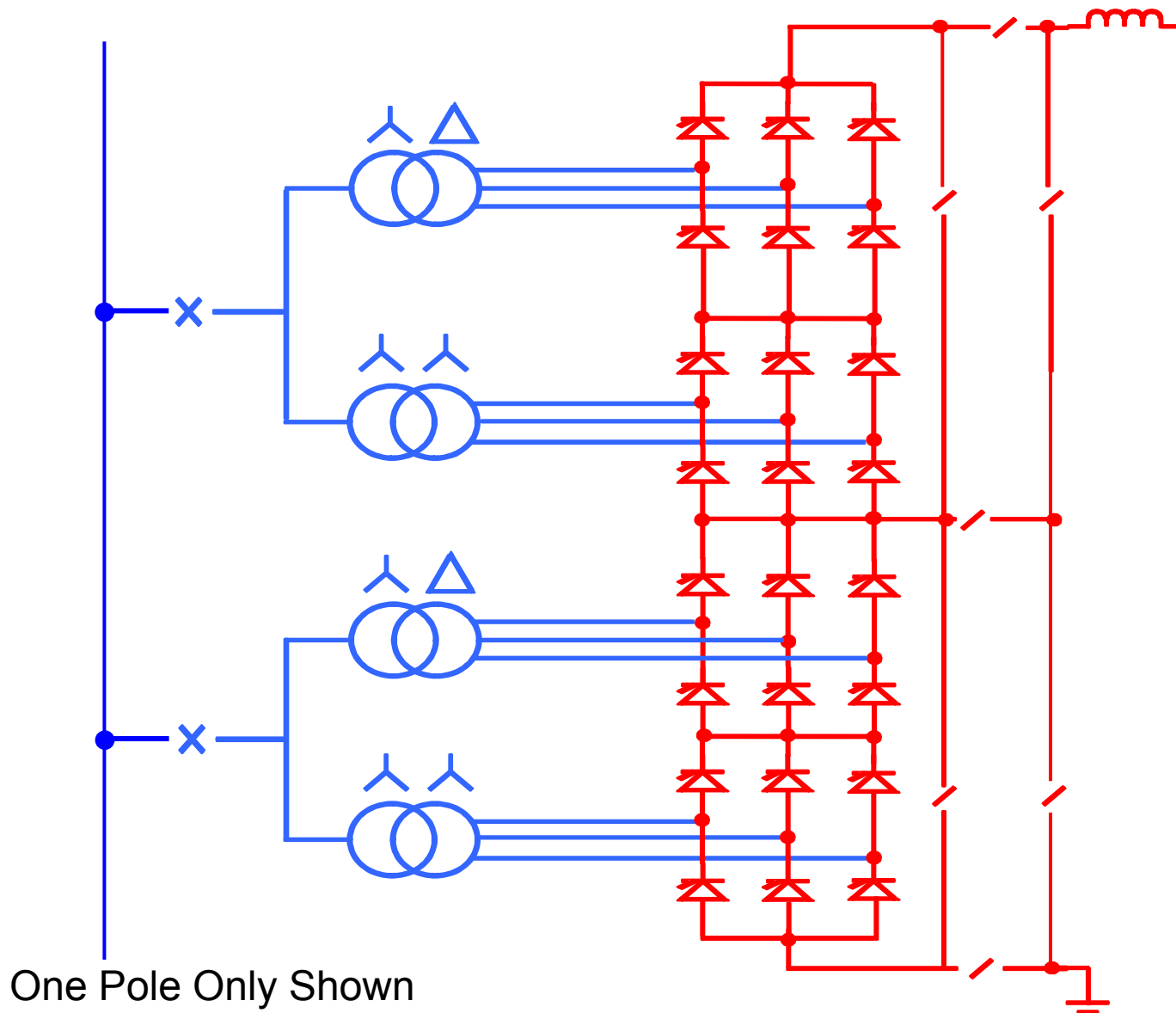
1 x 12 Pulse Converter Per Pole



One Pole Only Shown

- ▶ **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



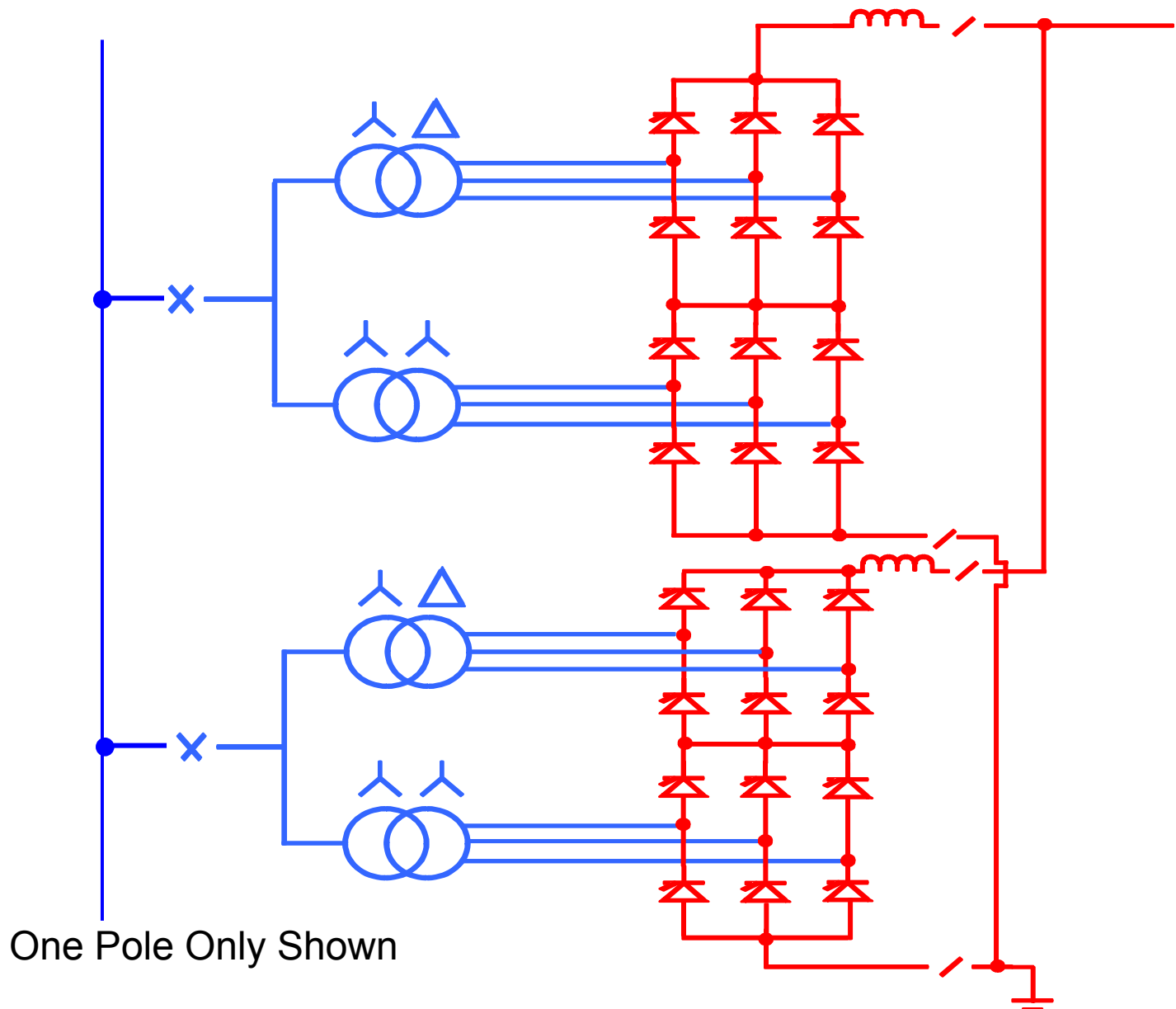
One Pole Only Shown

- ▶ **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



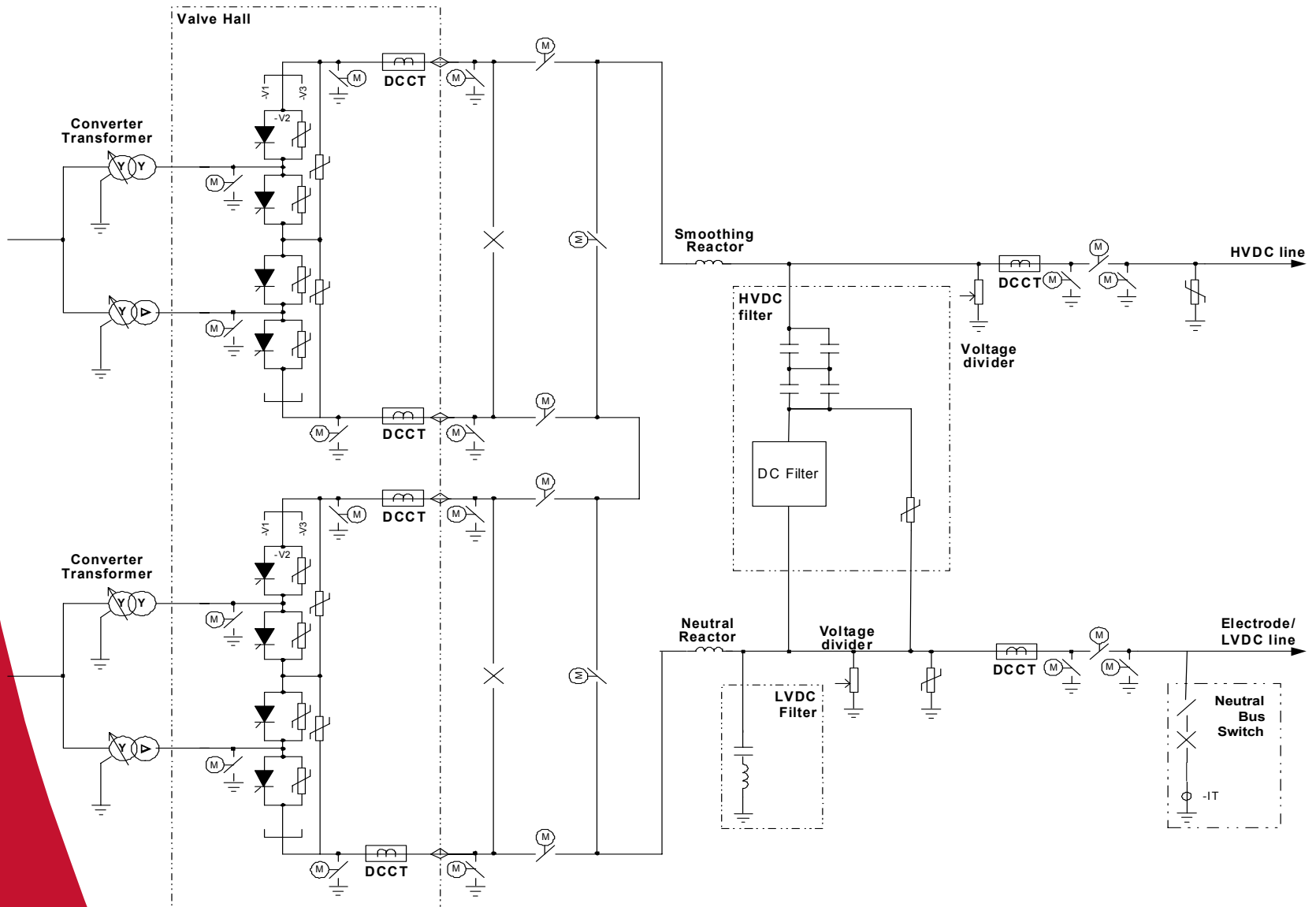
One Pole Only Shown

2 x 12 Pulse Parallel Connected Converters

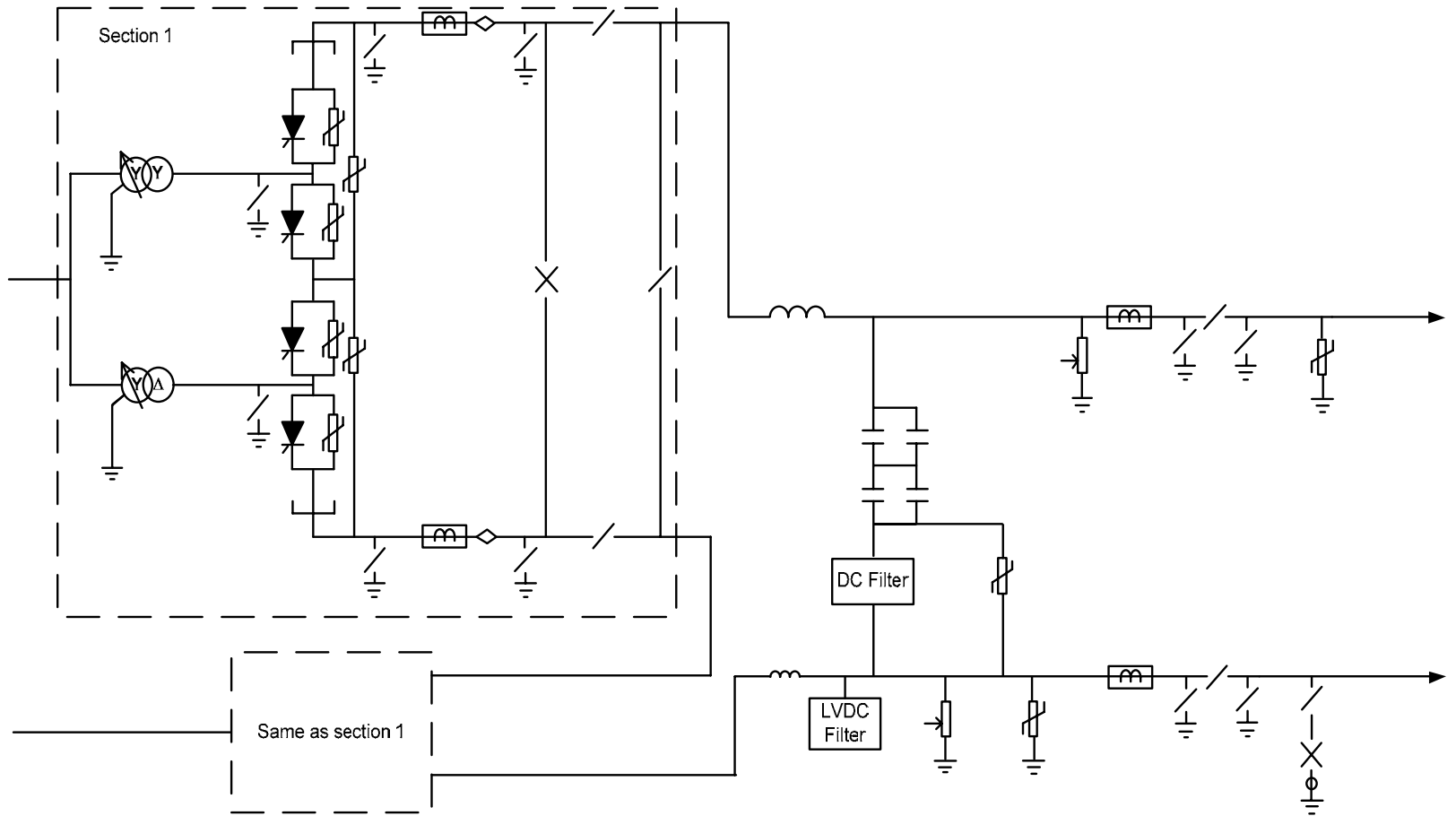
- ▶ **Parallel connected converters have been used on multi-terminal schemes:**
 - ◆ SACOI (Italy – Corsica – Sardinia)
 - ◆ New England (Canada – USA)
- ▶ **Each converter needs to be 800kV as one block**
- ▶ **Transformer fundamental frequency rating approximately 320MVA**
 - ◆ Should be possible to 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**

- ▶ **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**

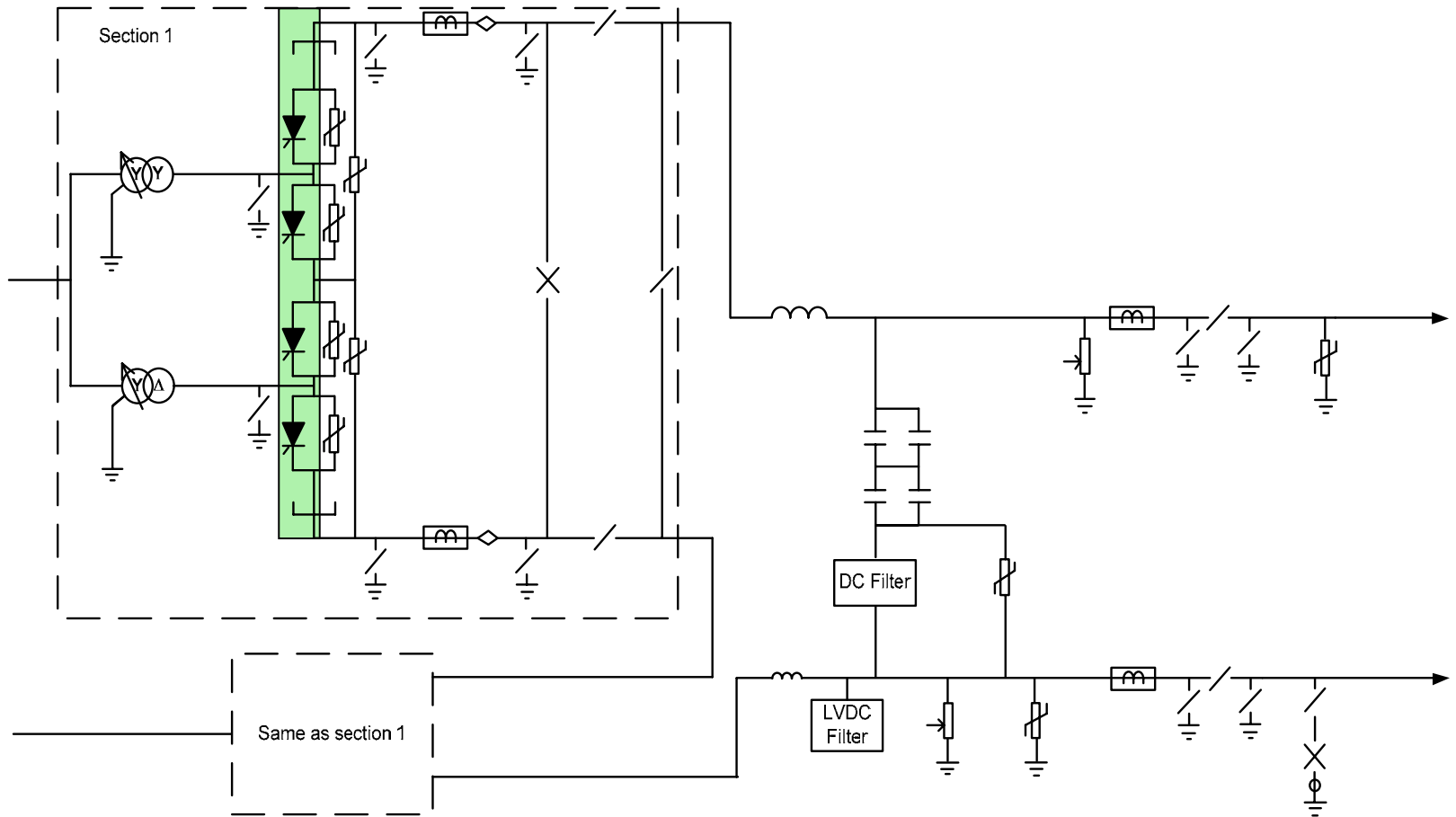
Single Line Diagram One Pole

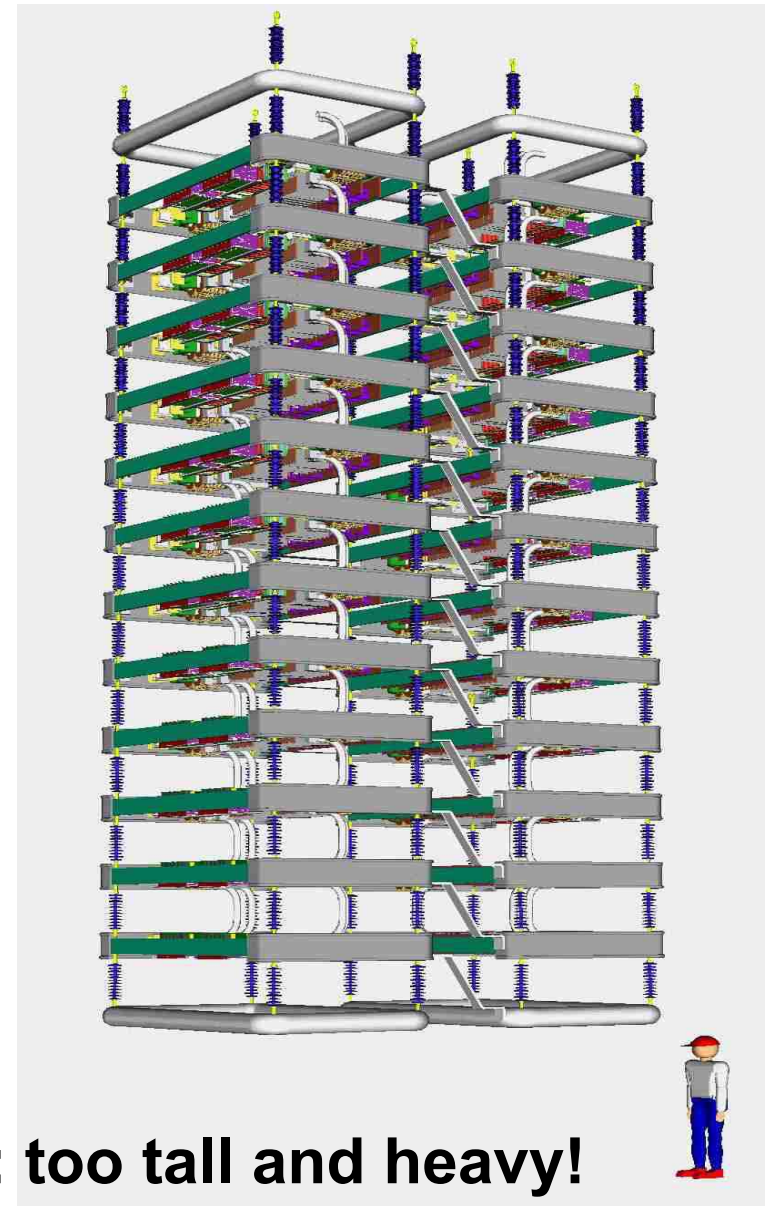
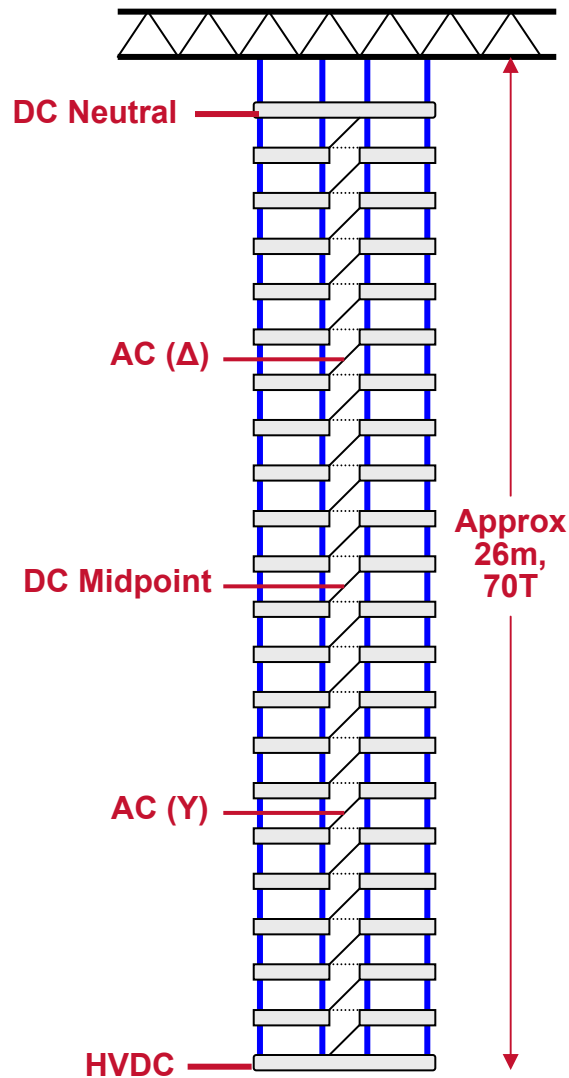


Single line Diagram One 12 – pulse bridge

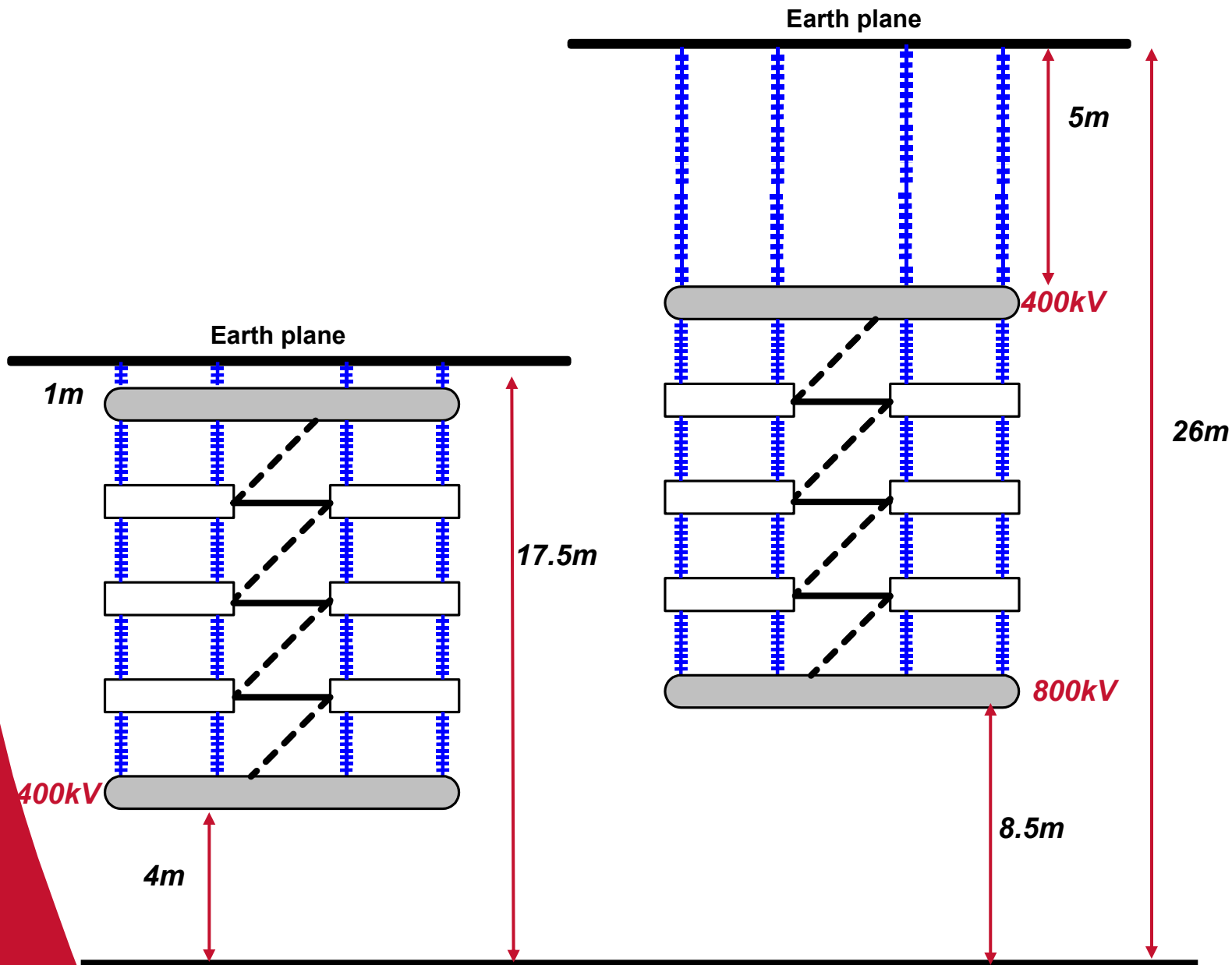


Thyristor Valve



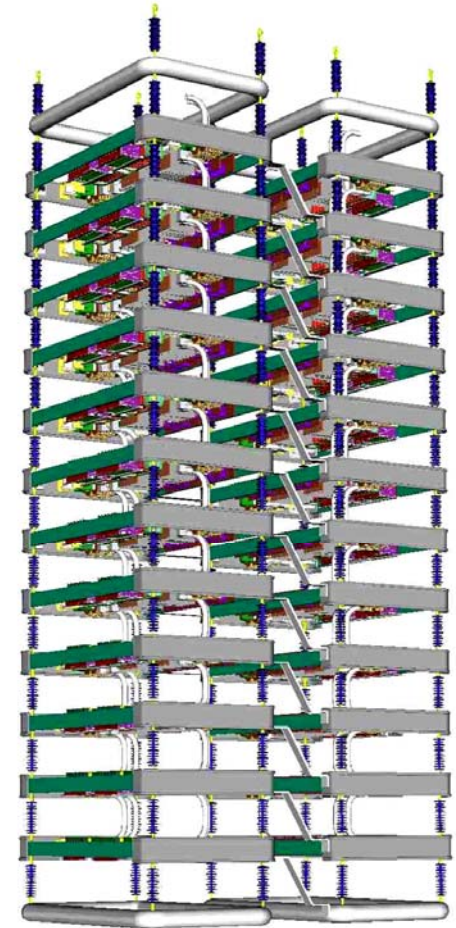


Single suspended valve: too tall and heavy!



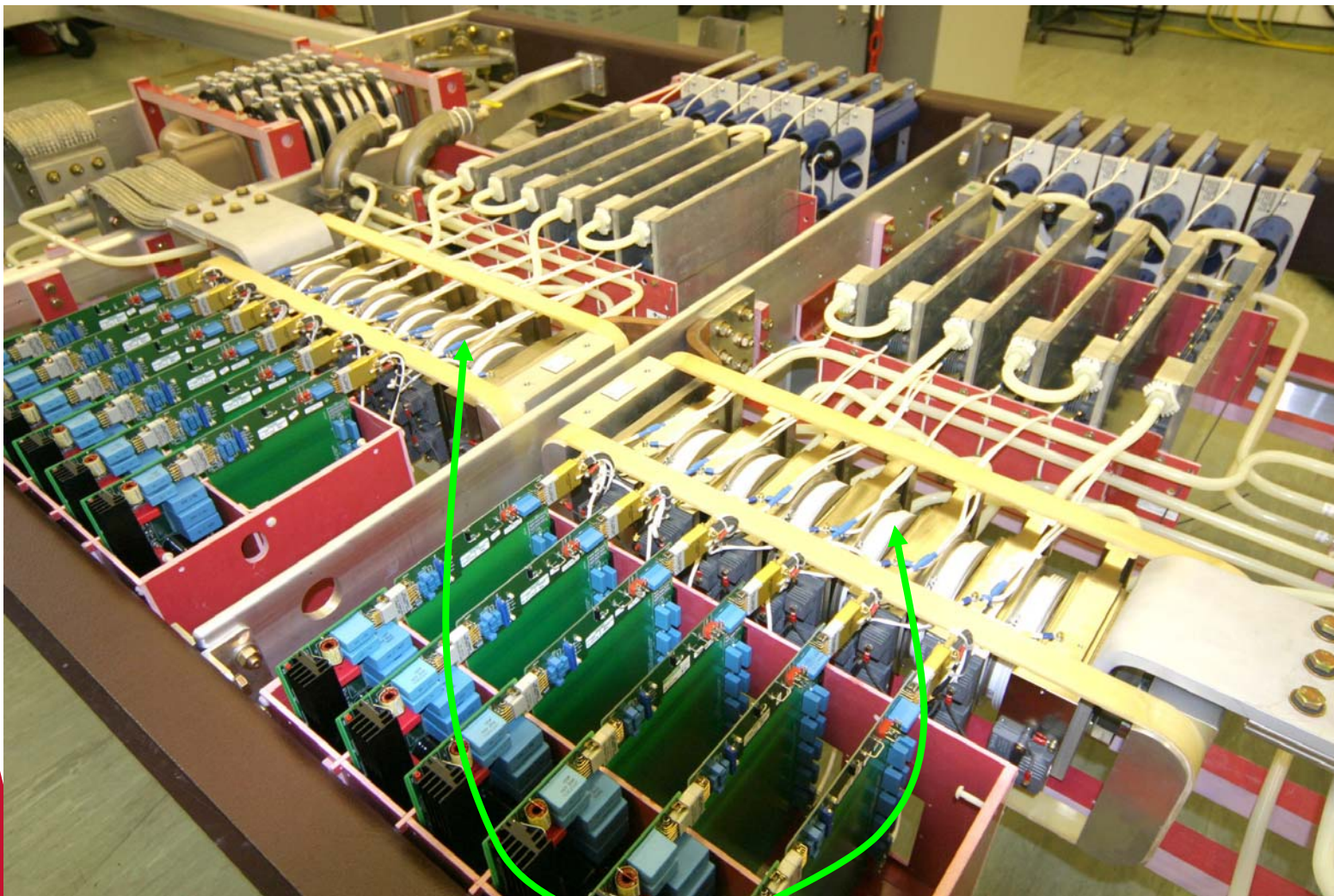
Key attributes:

- ▶ **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**

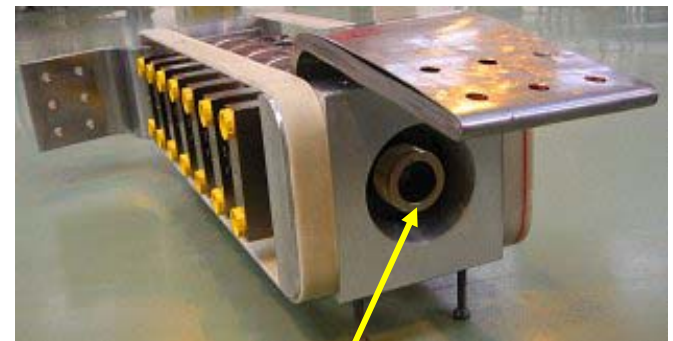
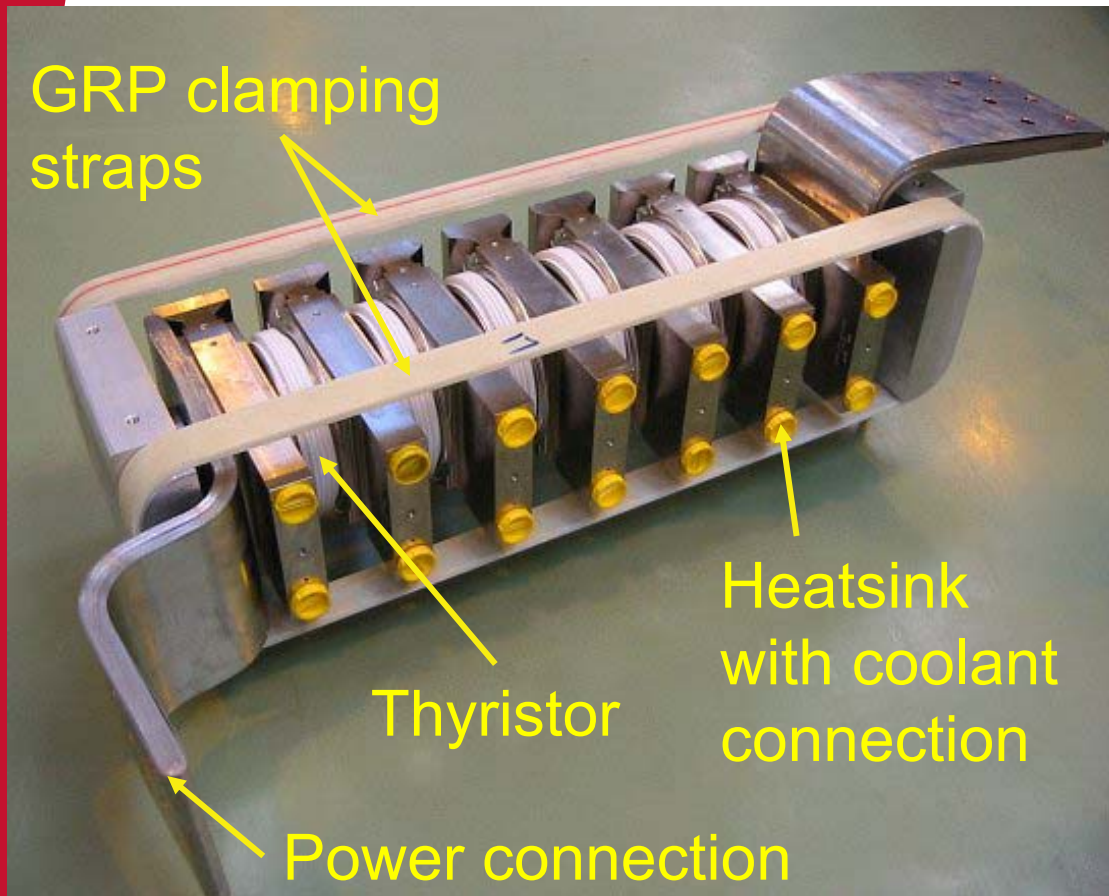


Standardized and modularized for flexibility

H400 Valve Module comprising 2 valve sections Building Block



Thyristor Clamped
Assemblies

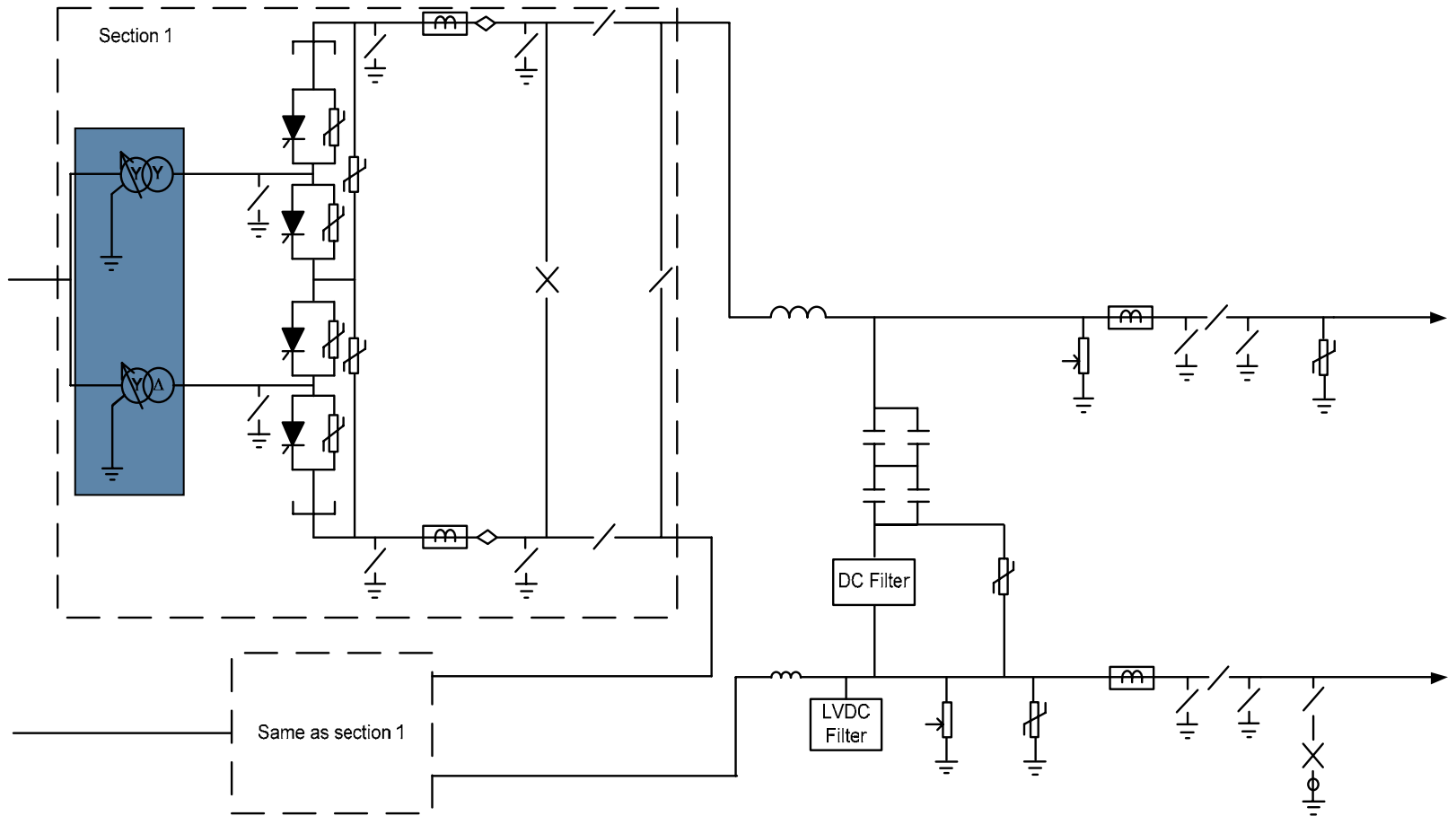


Loading adaptor for thyristor changing tool

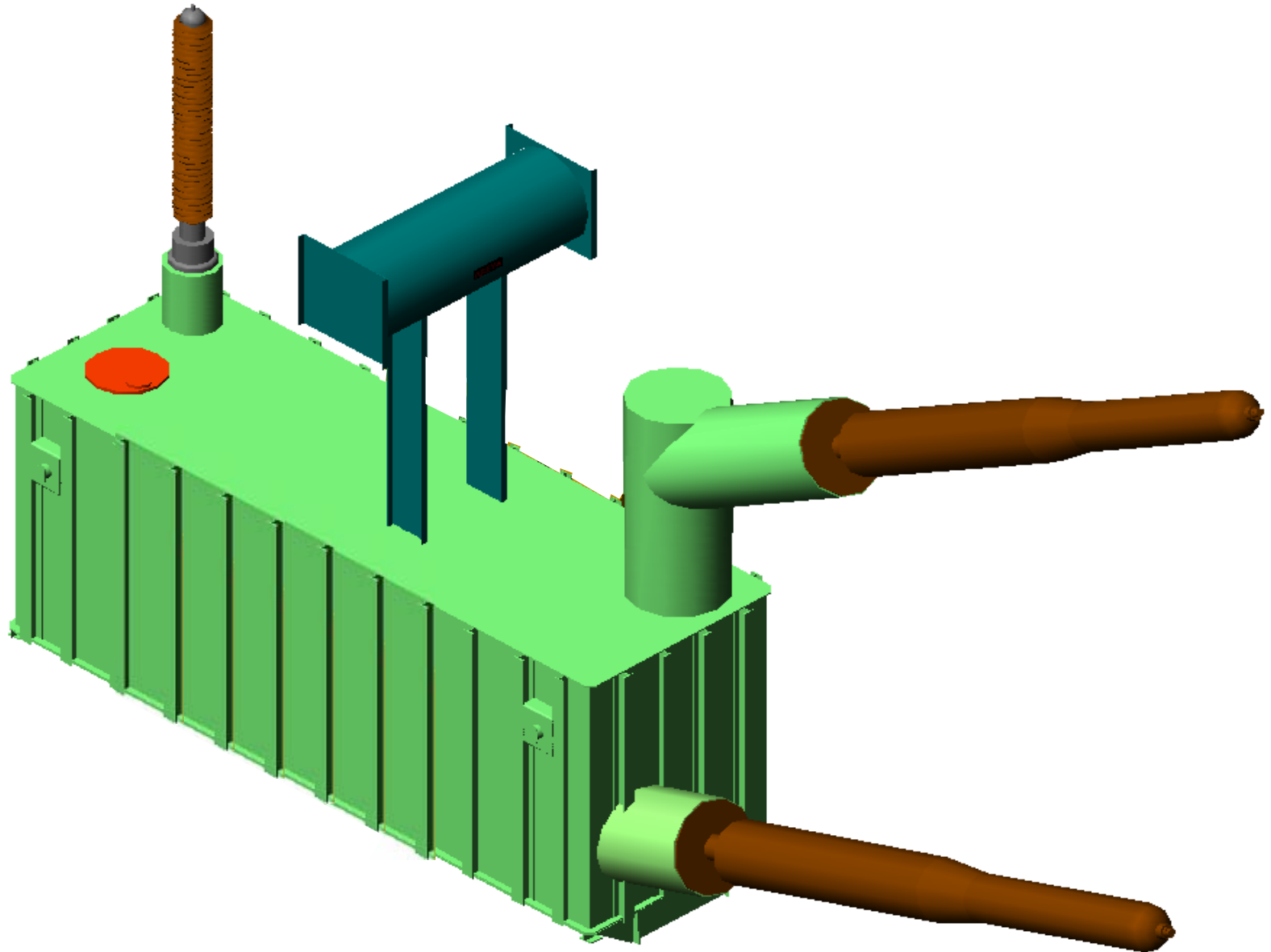
Example of 12 pulse Thyristor Valve



Converter Transformer



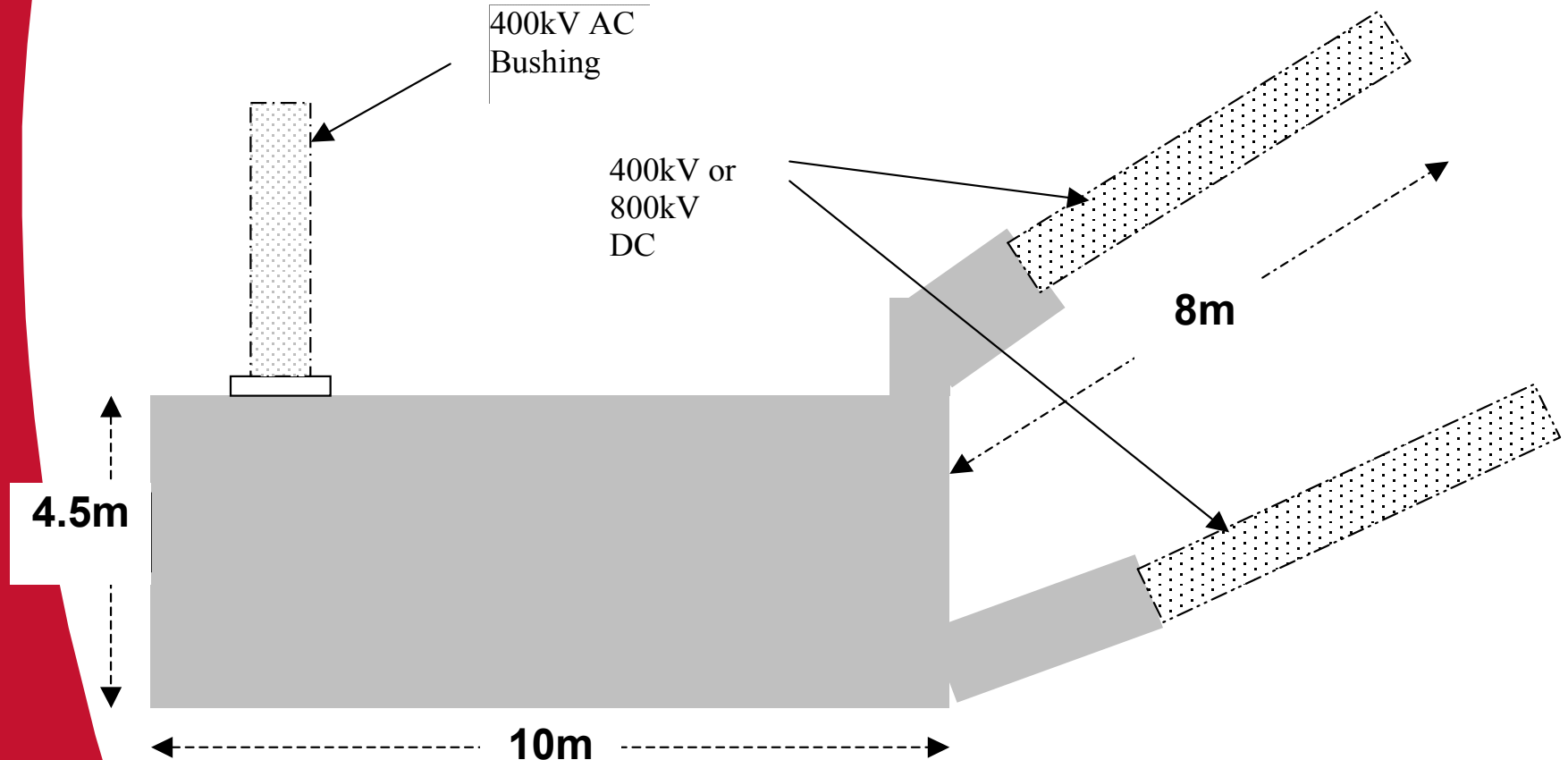
Converter Transformer for 800kV Arrangement



Converter Transformer for 800kV Technical Challenges

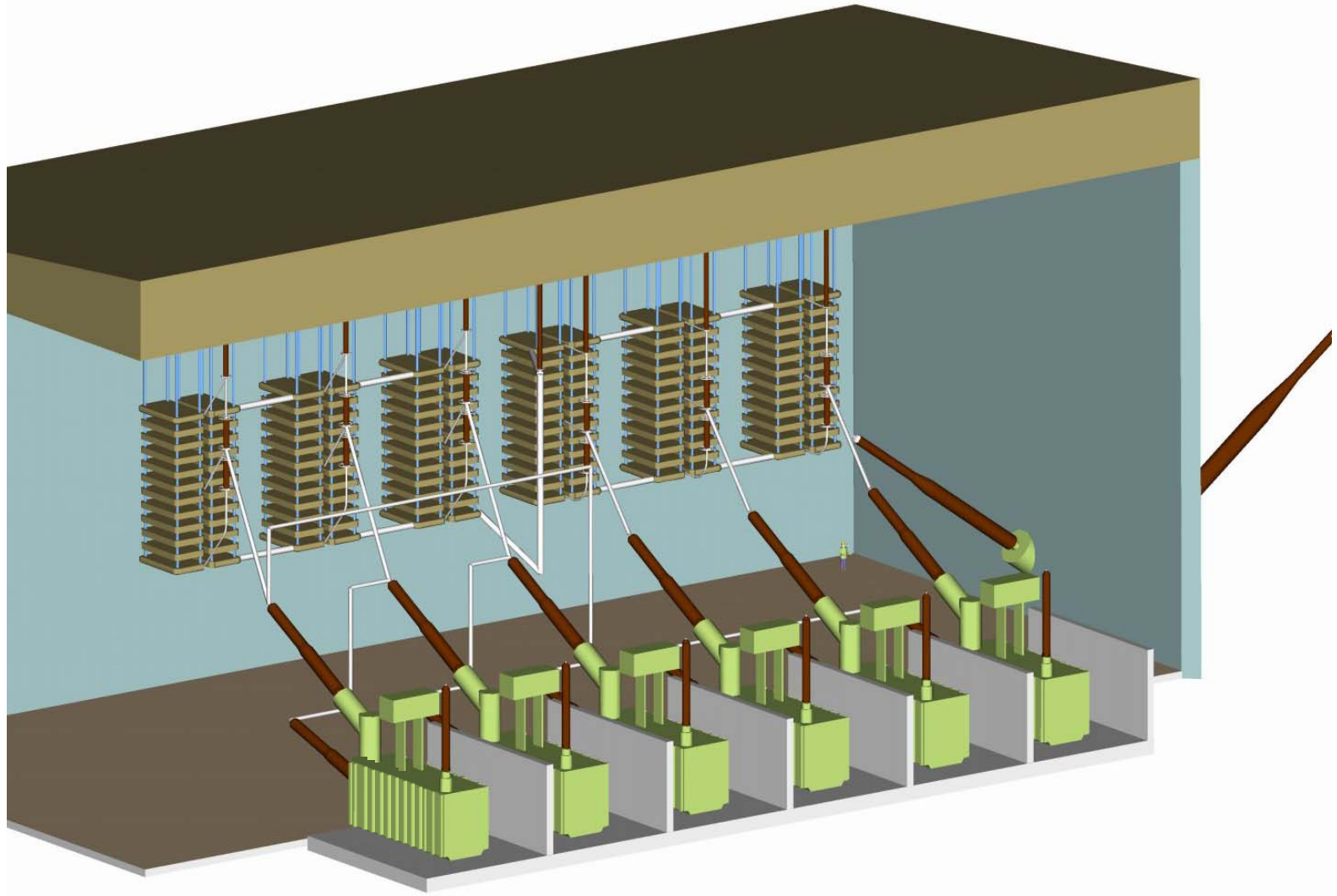
- ▶ **DC side bushings**
- ▶ **Oil free designs required**
- ▶ **Composite insulation rather than porcelain**
- ▶ **Solid insulation/Gas insulation?**
- ▶ **Mechanical strength due to extreme length.**

Converter Transformer for 800kV Schematic diagram



Valve Hall Layout

Upper Voltage Block Valve Hall



400kV to 800kV



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