UHVDC Equipment

Urban Astrom

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What has been done by ABB?

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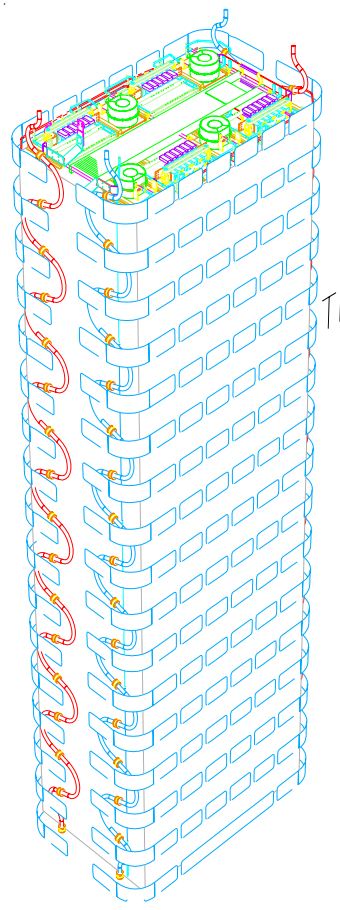
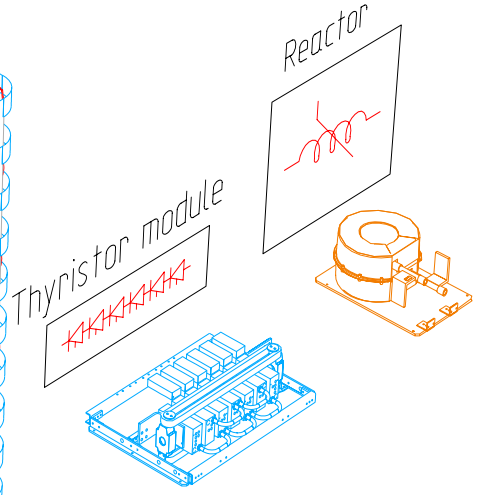
- Itaipu ±600 kV HVDC transmission system in operation since 1985, forced energy unavailability 0.05% year 2000, both bipoles
- Cooperation with NIIPT on UHVDC since 1988
- STRI test laboratory established in 1991 for UHVDC research
- 800 kV HVDC project started in cooperation with Eletrobras/CEPEL/Furnas 1993 (system studies, design and tests of equipment)
- New tools for calculation of stresses in oil/paper insulation systems developed, based on ion conduction model
- 800 kV HVDC equipment successfully tested 1994
  - Wall bushing (oil porcelain)
  - Support and string insulators

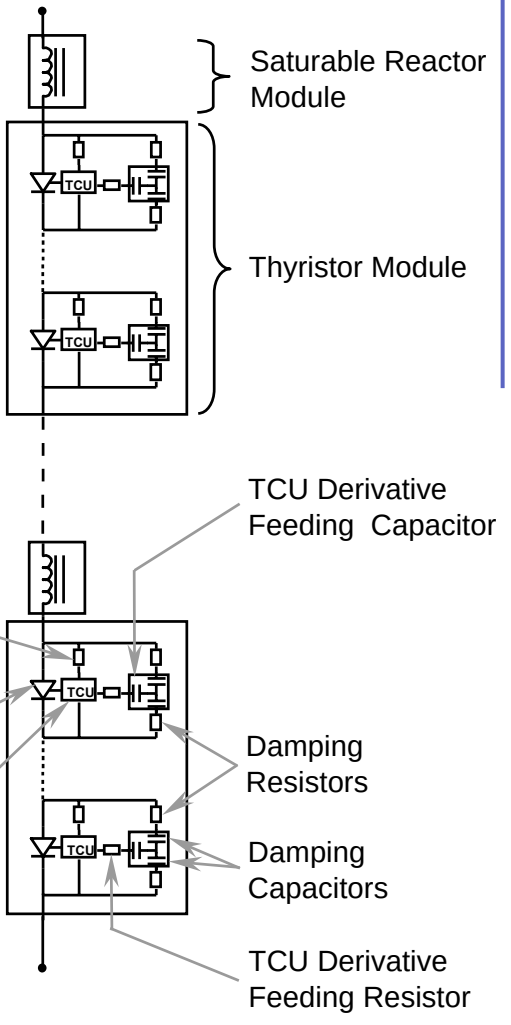
Resistive voltage distribution

- When applicable, DC equipment is built up by modules with resistive voltage distribution between the modules, controlled by actual resistors
- With a proper voltage grading, each module will experience the same stress at 800 as at 500 kV pole voltage
- This is valid for:
  - Thyristor valves
  - Pole arresters
  - Voltage dividers
  - DC PLC capacitors
  - DC harmonic capacitors
- For outdoor equipment there must be a proper coordination between internal and external voltage distribution (PLC-capacitors, DC voltage divider)

Thyristor Valve Layout







Thyristors

- The valve voltage is not decisive for the thyristor. Will be handled by sufficient number of thyristor positions in series. Due to the well defined voltage grading each individual thyristor position have the same electrical stress in an 800 kV valve as in a 500 kV valve!
- The critical parameter for the thyristors is the short circuit current. This is given by the ratio between rated DC current and transformer reactance, i.e. at 800 kV DC and 3125 A (5000 MW bipole power) the stresses on the thyristors will be the same as for the Sylmar Replacement project

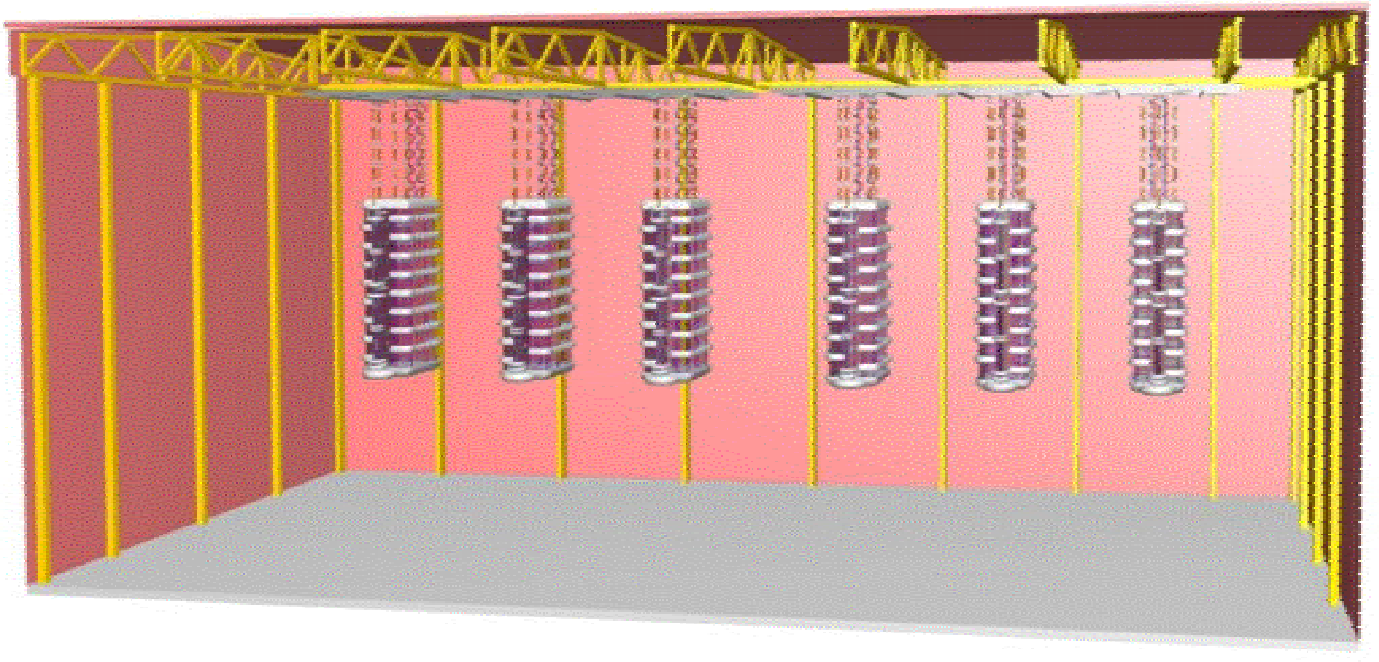
Experience of 14000 5” thyristors

Project	Power Transmitted, MW	Number of thyristors	Commis-sioned year	Nominal Current, A	Overload Current, A
Garabi 1 Brazil	1100	1728	2000	4020	-
Garabi 2 Brazil	1100	1728	2002	4020	-
Three Gorges-Changzhou, China	3000	4176	2003	3000	3555 @20°C
Rapid City USA	2x100	336	2003	3920	-
Three Gorges-Guandong, China	3000	4176	2004	3000	3555 @20°C
Sylmar Replacement Pproject USA	3100	2016	2004	3100	3650 @20°C

No thyristor failure during commercial operation reported

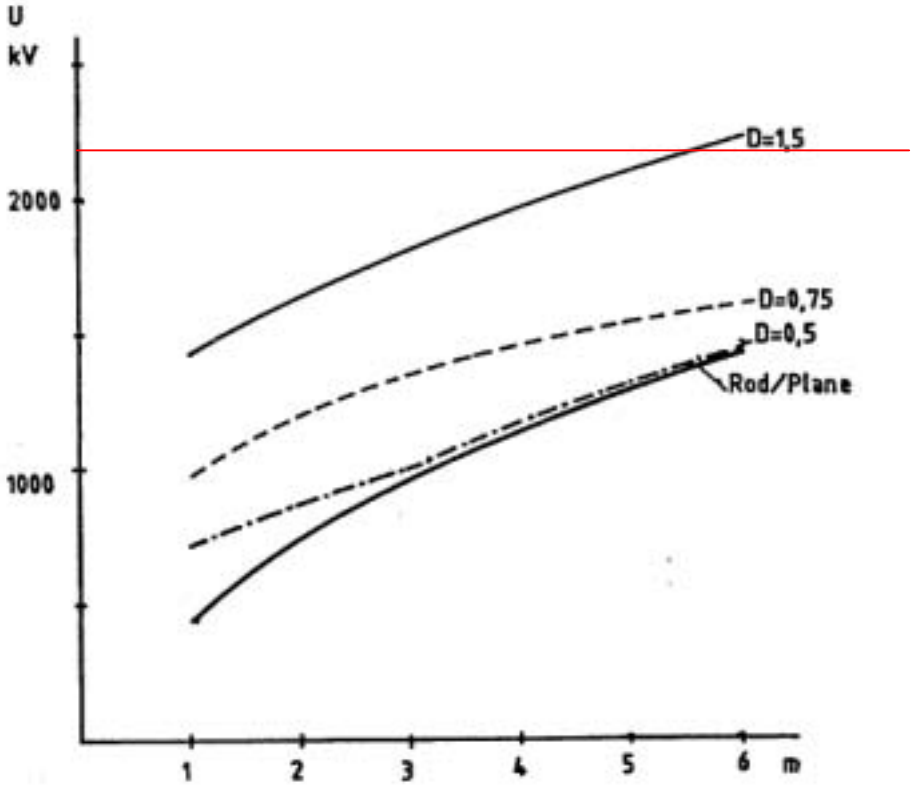
800 kV valve hall

Air clearance in the valve hall will be influenced. This can be calculated using 3-D field calculation programs. The clearances will be verified at the type test of the valve.



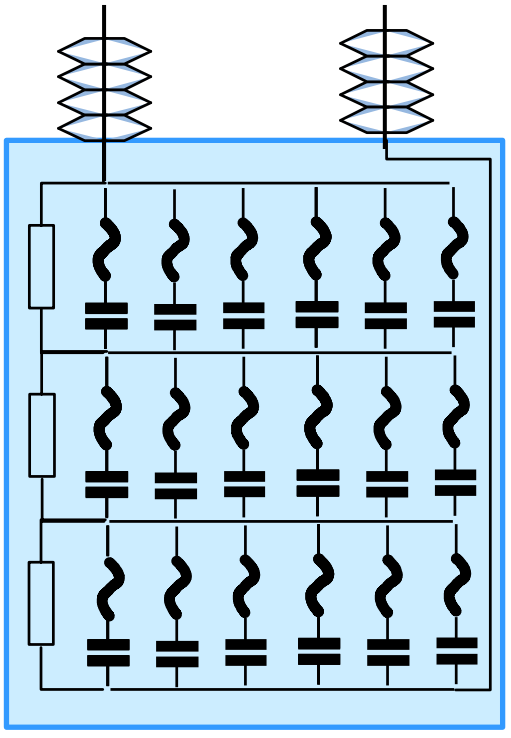
800 kV 3000 A 1500 m altitude

Valve hall clearance



U_{50} for Positive switching impulse for different electrode geometry

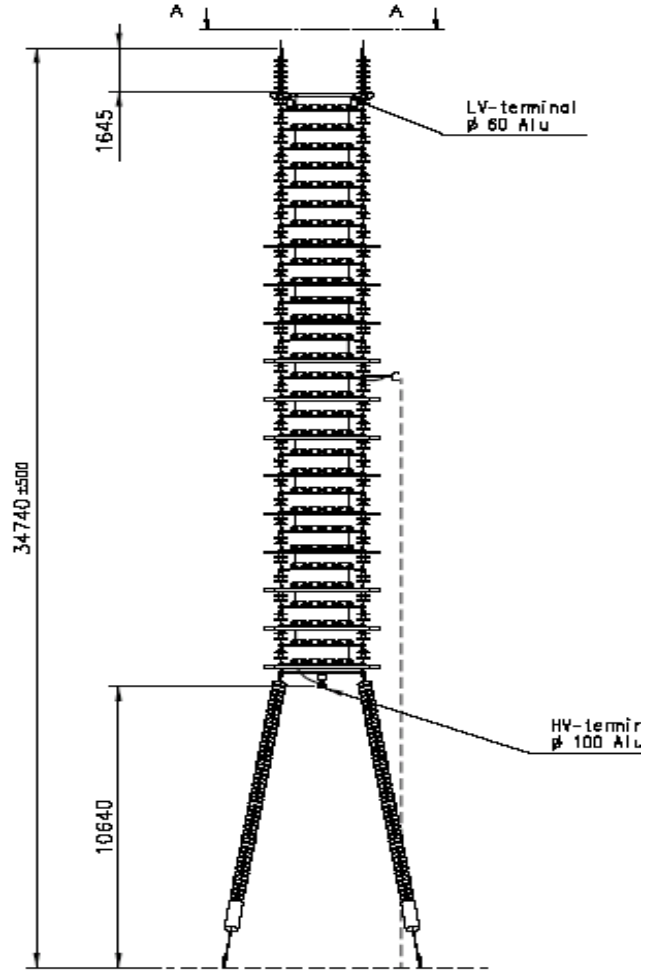
Resistive voltage distribution: DC filter capacitors



The stresses across the groups of parallel connected elements are controlled by the voltage distribution across the grading resistors.

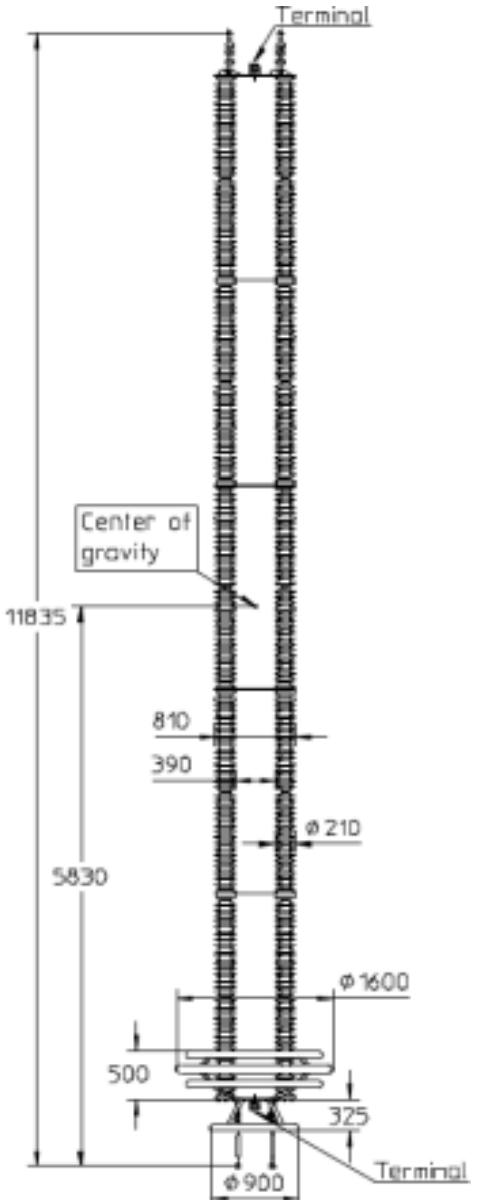
The grading current is of mA order of magnitude.

DC harmonic filter capacitor 800 kV



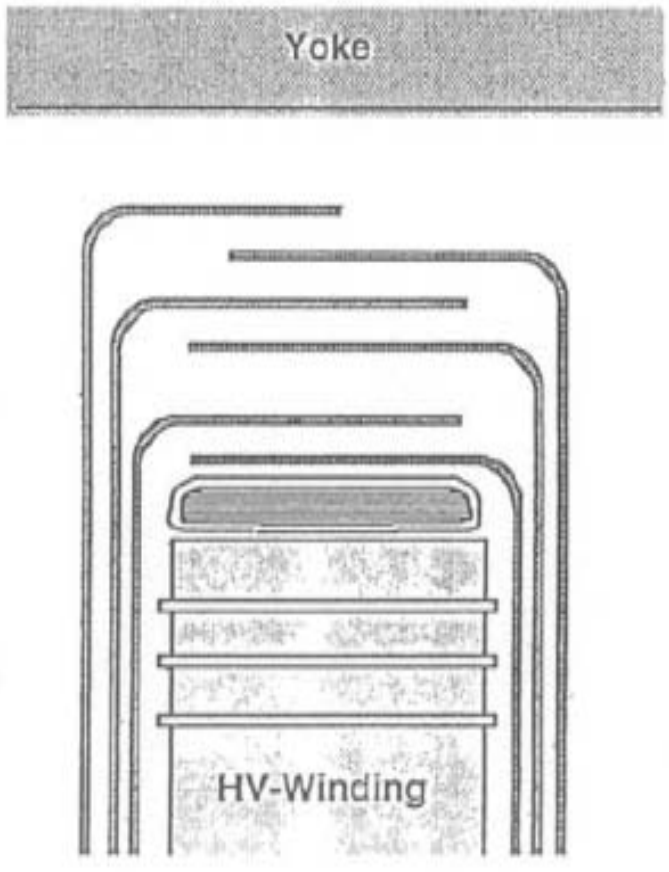
3GC 500 kVDC capacitor

DC pole arrester for 800 kV



Transformer main insulation

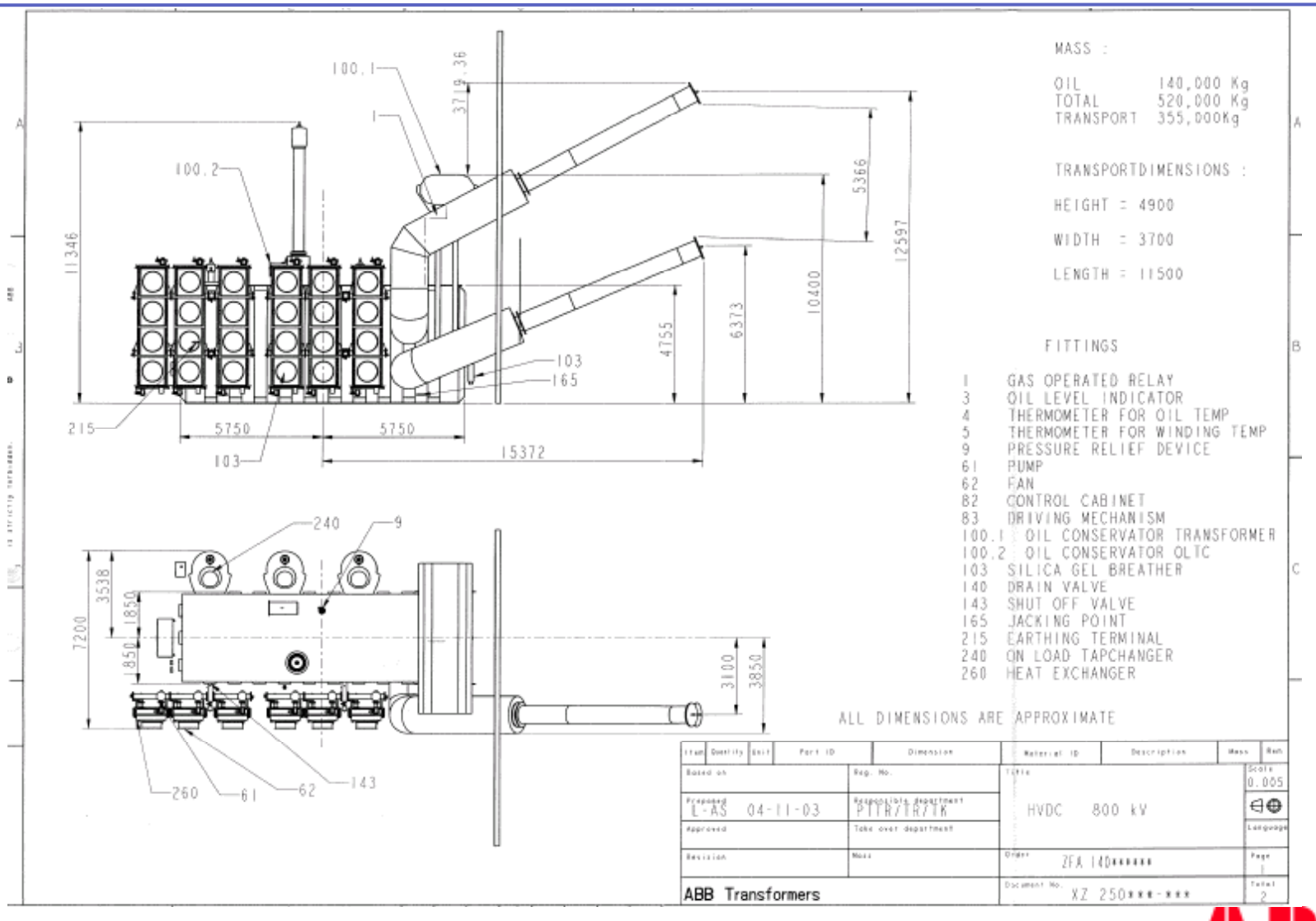
The main insulation for the transformer is split up in parts, in analogy with for example the thyristor valves:



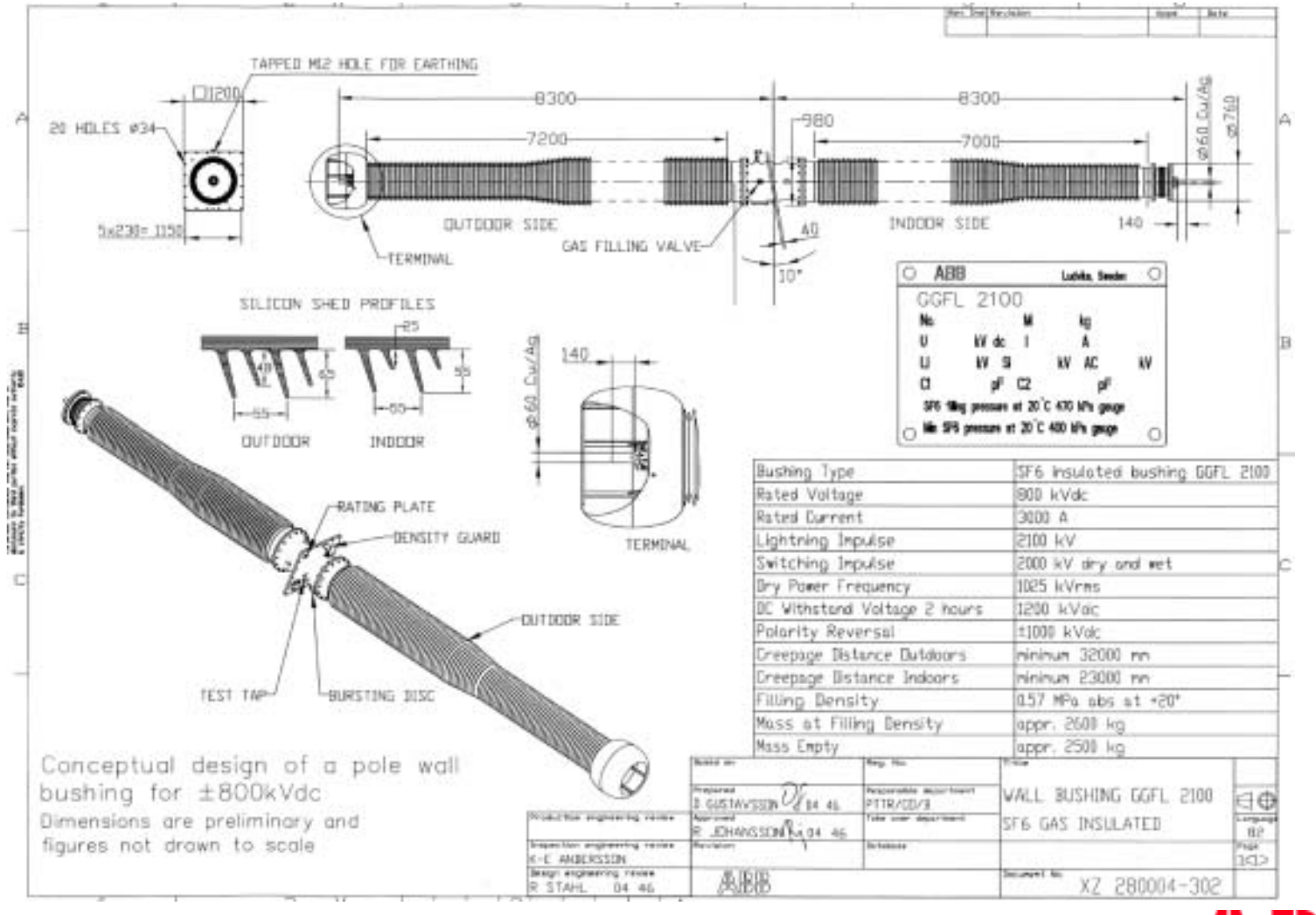
- The volume is divided into sub volumes by insulation barriers to eliminate the effect of large volumes
- The local electric stress in each region will be kept at a safe level
- Since the resistivity of oil and paper depend on temperature and time, the worst possible combinations of parameters will be considered
- Both transient, AC and steady state conditions will be considered
- Both electron conduction and ion conduction must be considered

The separate sub volumes do not know whether they are inside a 800 kV converter transformer or in a 500 kV transformer!

800 kV HVDC converter transformer and transformer bushings

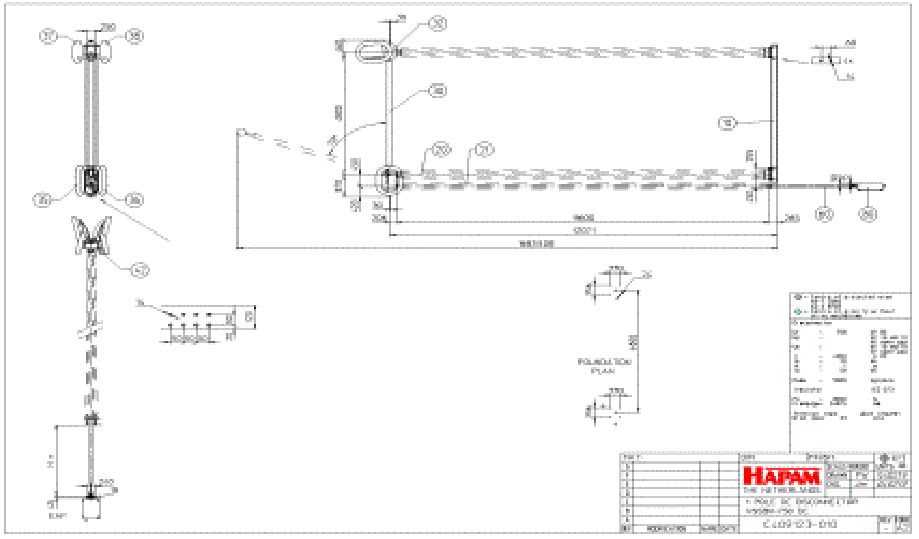


800 kV dry type composite wall bushing

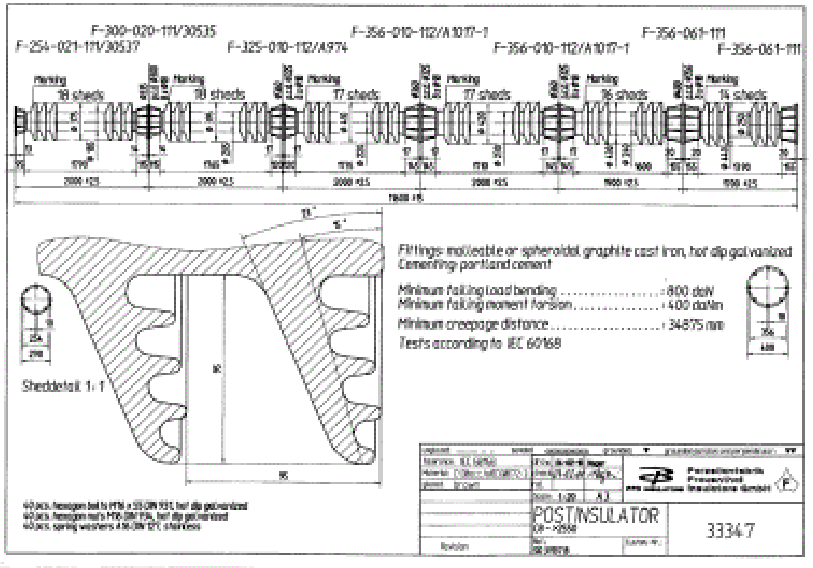


Bushing Type	SF6 insulated bushing GGFL 2100
Rated Voltage	800 kVdc
Rated Current	3000 A
Lightning Impulse	2100 kV
Switching Impulse	2000 kV dry and wet
Dry Power Frequency	1025 kVrms
DC Withstand Voltage 2 hours	1200 kVdc
Polarity Reversal	±1000 kVdc
Creepage Distance Outdoors	minimum 32000 mm
Creepage Distance Indoors	minimum 23000 mm
Filling Density	0.57 MPa abs at +20°
Mass at Filling Density	appr. 2600 kg
Mass Empty	appr. 2500 kg

DC disconnector

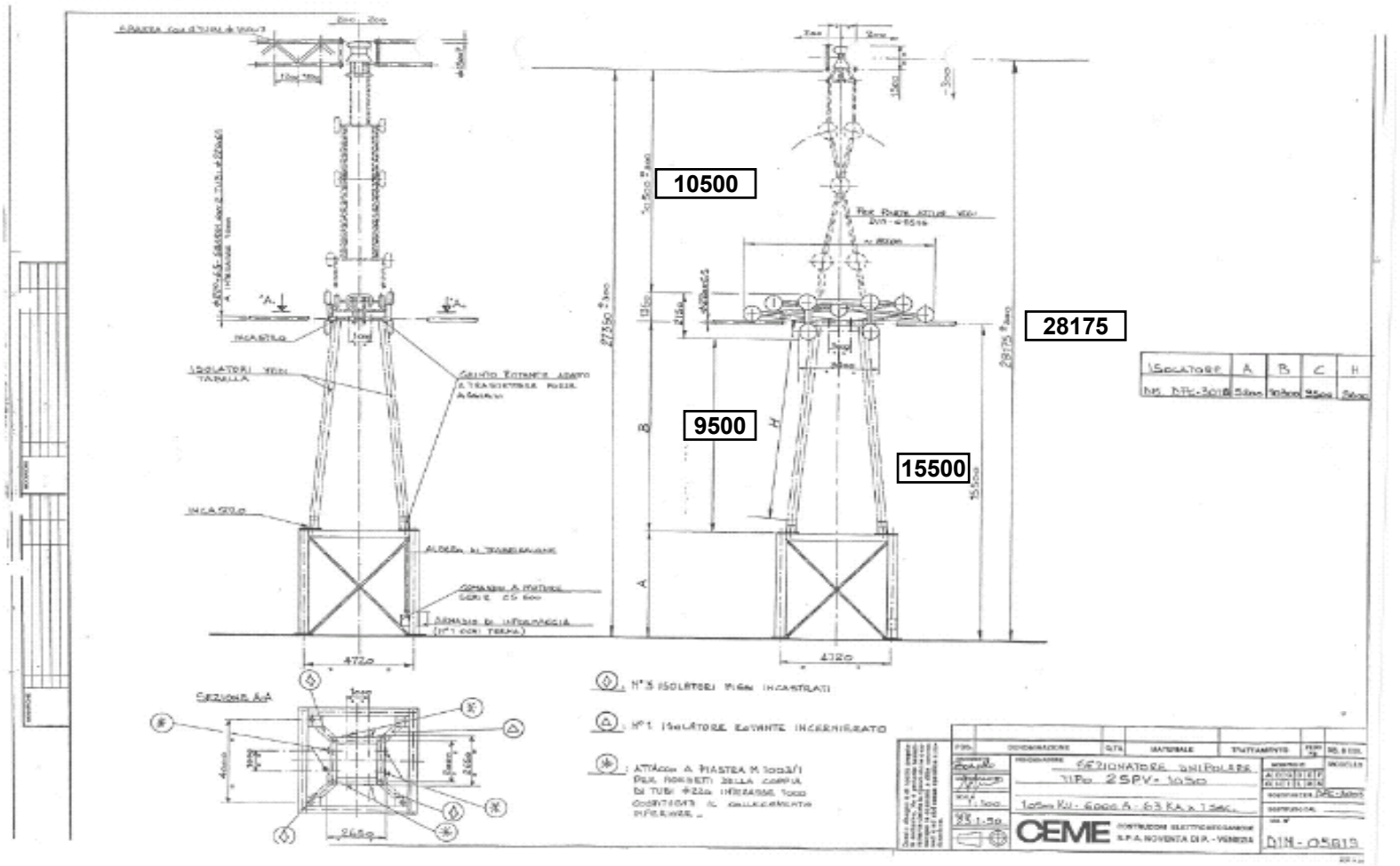


Assembly



Support insulator

Pantograph disconnector



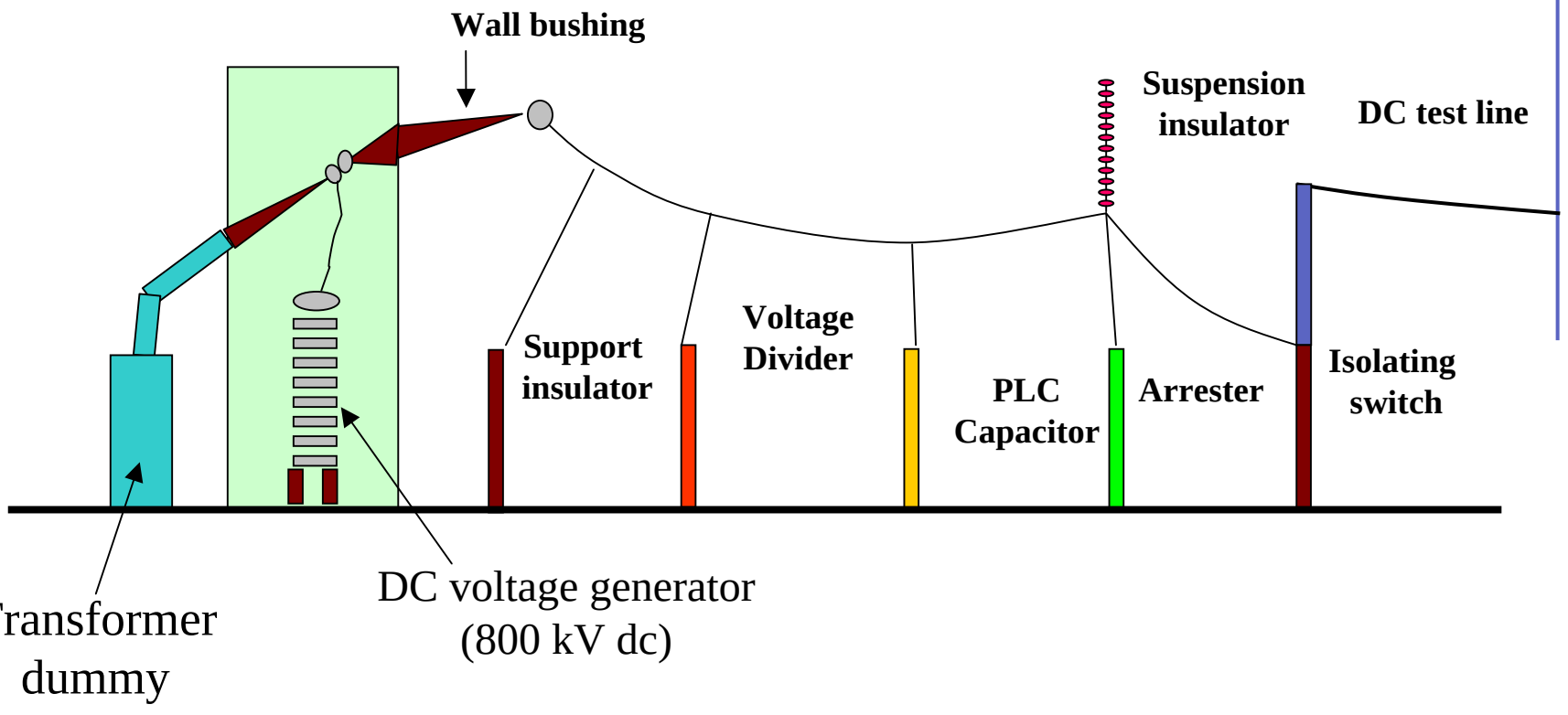
Test voltages for equipment

Equipment	LI	SI	AC_{RMS}	DC	DC Polarity reversal
Converter transformer, Valve side	1744	1518	900	1250	970
Transformer bushing, valve side	1744	1518	900	1250	970
Smoothing reactor, Across	2160/2	N.A.	N.A.	N.A.	N.A.
To ground	1950	1546	N.A.	N.A.	N.A.
Voltage divider	1950	1546	1000 (one minute)	N.A.	N.A.
Disconnecting switch	1950	1546	N.A.	N.A.	N.A.
PLC capacitor	1950	1546	N.A.	N.A.	N.A.
Wall bushing	1800	1518	1000 (one minute)	1235	1030
Thyristor multiple valve	1800	1518	N.A.	1040 (3 hrs)	N.A.

Test facilities in Ludvika

Test	Required kV	Available STRI, kV	Available TRAFO, kV
Lightning impulse	2000	3200	2800
Switching impulse	1550	1750	2000
AC	1000	1050	1000
DC	1250	1200	1075

UHVDC- proposed test circuit




ABB

Experience high current

	U_{dc} kv	I_{dc} A	Trafo	Smoothing Reactor	Wall bushing	DC connector
Itaipu	**±600**	**2610**	**314MVA 1φ/3W**	**Oil filled 278 mH**	**Porcelain**	
IPP	**±500**	**1920**	**305MVA 1φ/3W**	**Oil filled 300 mH**	**Porcelain**	**Southern States 4000A**
HQ/NEH	**±500**	**2260**	**402MVA 1φ/3W**	**Air core 2X150 mH**	**Porcelain (Si greased)**	**Hapam 3600 A**
3GC/3GG	**±500**	**3000**	**300MVA 1φ/2W**	**Oil filled 270 mH**	**Si rubber**	**Cegelec 4000 A**
Sylmar replacement	**±500**	**3100**	**620MVA 1φ/3W**	**Air core 2x50 mH**	**Si rubber**	**Hapam 4000A**
Highgate BtB	**57**	**3600**	**240MVA 3φ/3W**	**Air core 12 mH**	**-**	-
Vindhyachal BtB	**70**	**3600**	**156MVA 3φ/2W**	**Oil filled 40 mH**	**-**	-
Garabi BtB	**70**	**3930**	**192MVA 1φ/3W**	**Air core 2x50 mH**	**-**	-