

**Gunnar Asplund
ABB Power Systems
HVDC
Ludvika, Sweden**

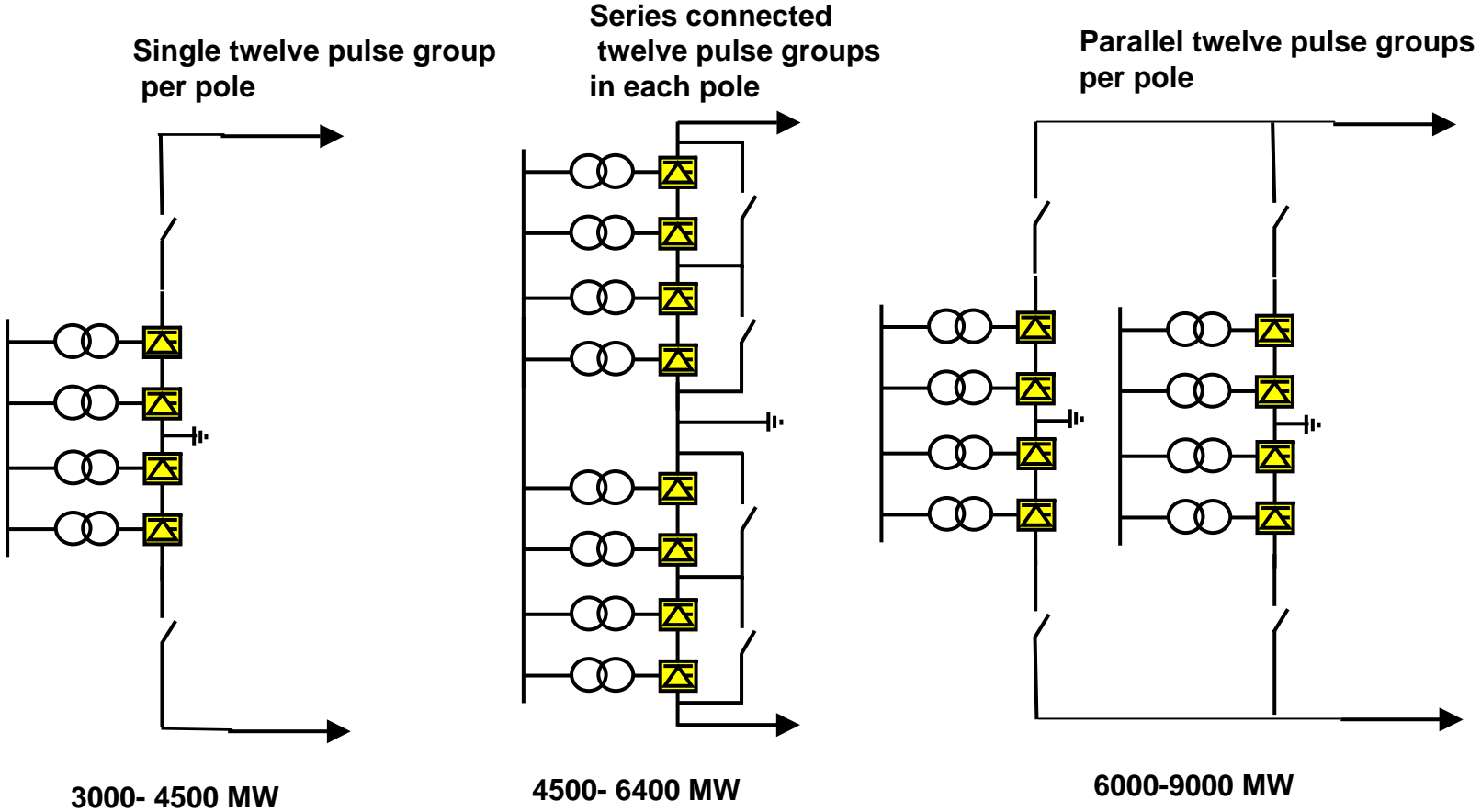
**HVDC Equipment
for
800 kV HVDC**

**Brazil-China-India Summit
Meeting on
HVDC & Hybrid Systems**

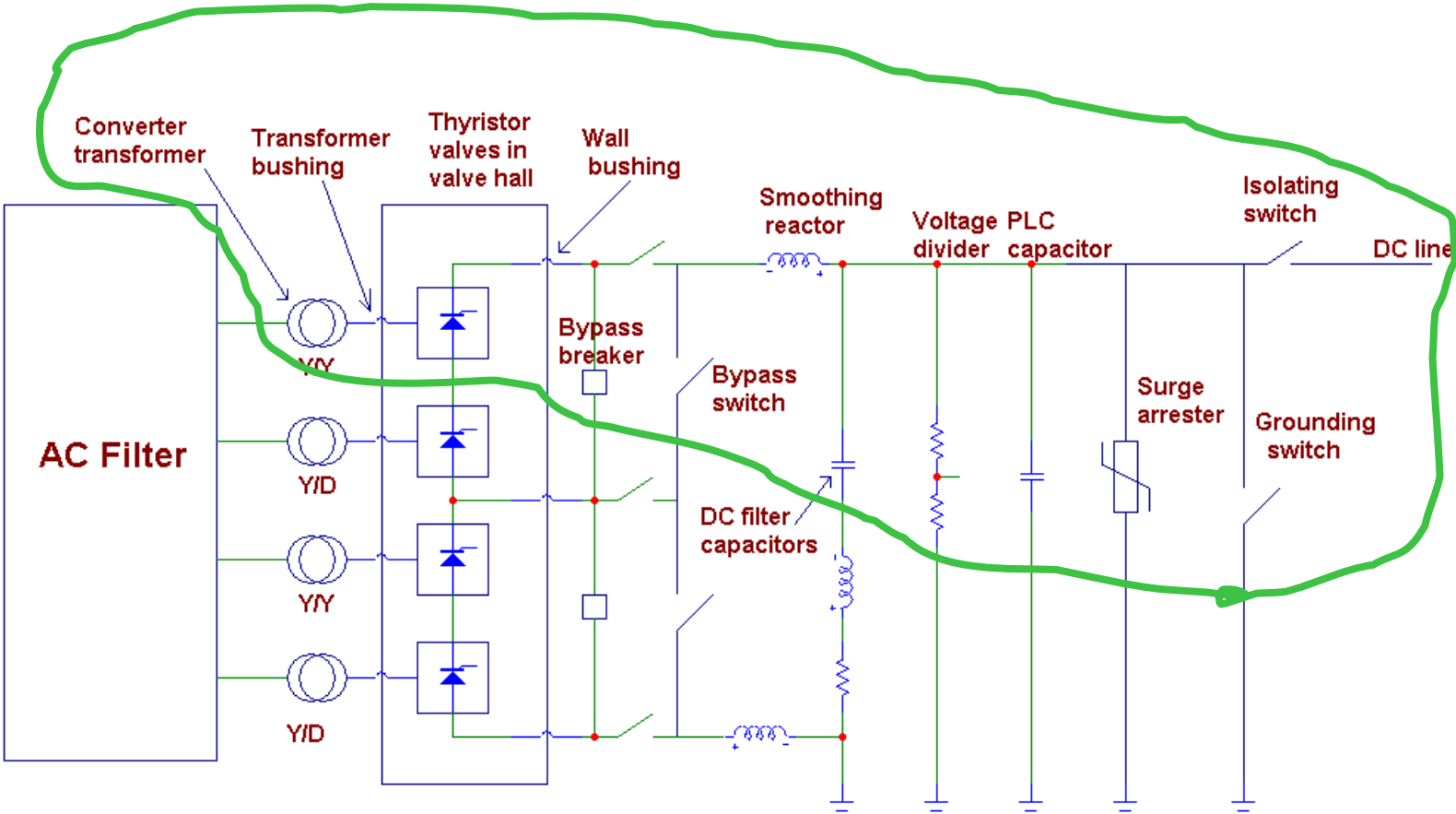
**Rio de Janeiro
July 16-18 2006**



Converter options



UHVDC- one pole



Exposed to 800 kV dc



Development areas

- External insulation:
 - Transmission lines
 - (Converter stations)
- Converter transformers, barrier system, cleats and leads
- Wall bushing, mechanical
- Transformer bushings, thermal, electrical
- Seismic/mechanical questions (very high structures in the DC-yard)
- Reliability

Insulation coordination

Transformer references

Project	Nominal dc level	LIWL	SIWL	DC 2h	Polarity reversal
Itaipu	600	1800	1500	965	690
HQ/NEH	500	1425	1300	762	486
Rihand-Delhi	500	1550	1290	800	568
3GC	500	1675	1425	810	597

Transformer - 800 kV

Design base	Nominal dc level	LIWL	SIWL	DC 2h	Polarity reversal
Itaipu	800	2400	2000	1287	920
HQ/NEH	800	2280	2080	1219	778
Rihand-Delhi	800	2480	2064	1280	909
3GC	800	2680	2280	1296	955

800 kV transformer

Transformer data upper group

Transformer type: Two-winding converter transformer

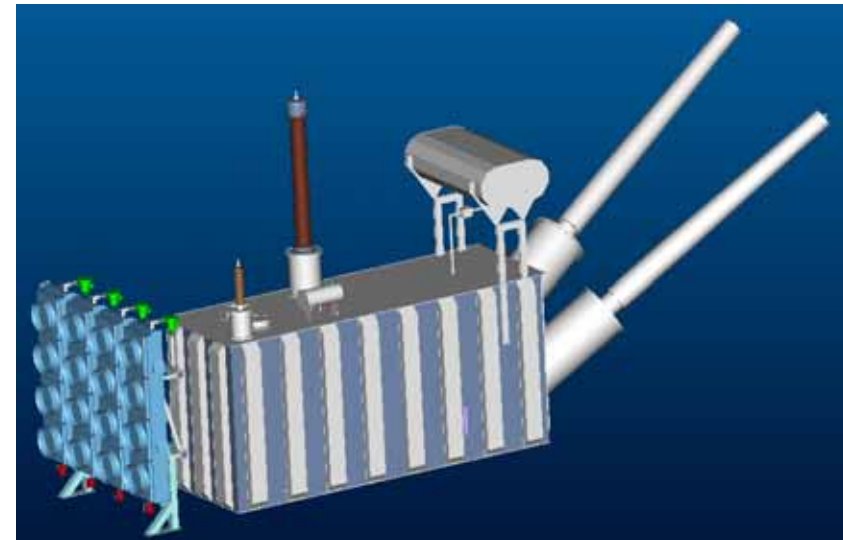
Rated power: 248 MVA

Rated voltages: 525/168,4 kV

No-load loss: 170 kW

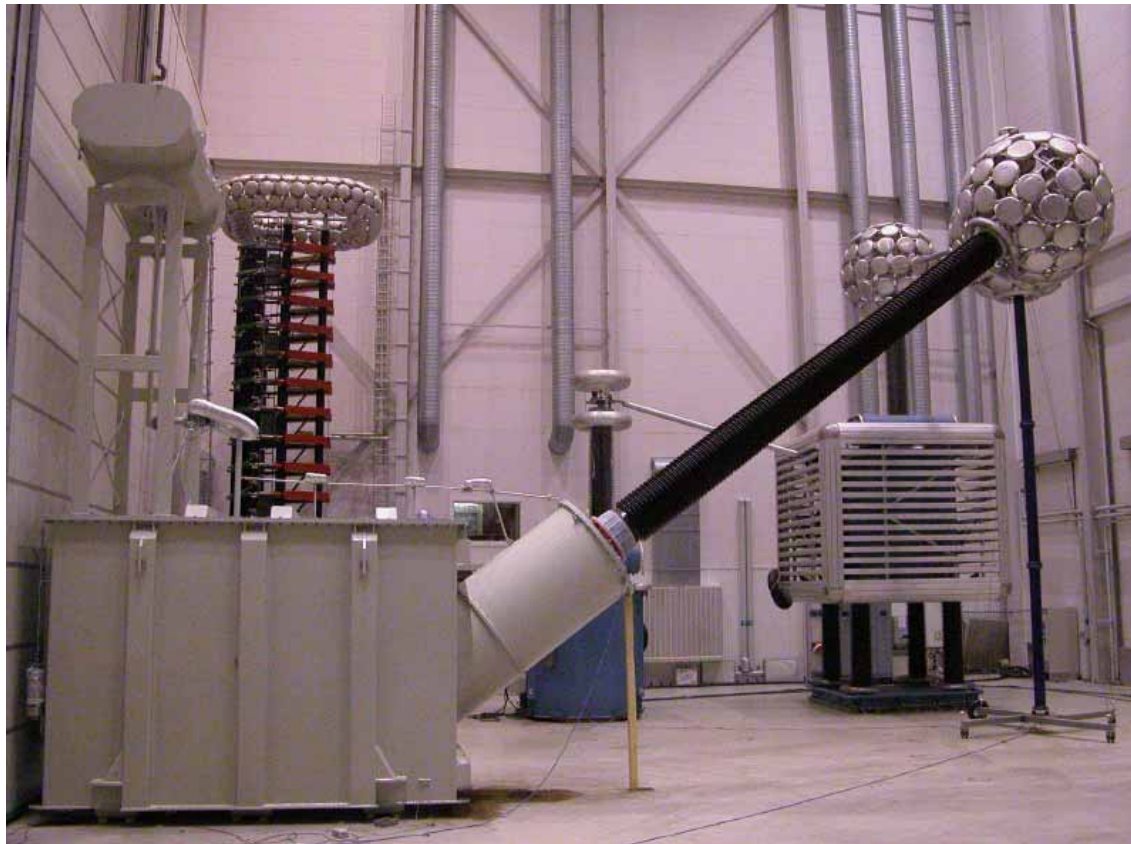
Load loss (50 Hz): 600 kW

Height	4850 mm
Width	3500 mm
Length	10850 mm
Weight	260 tons

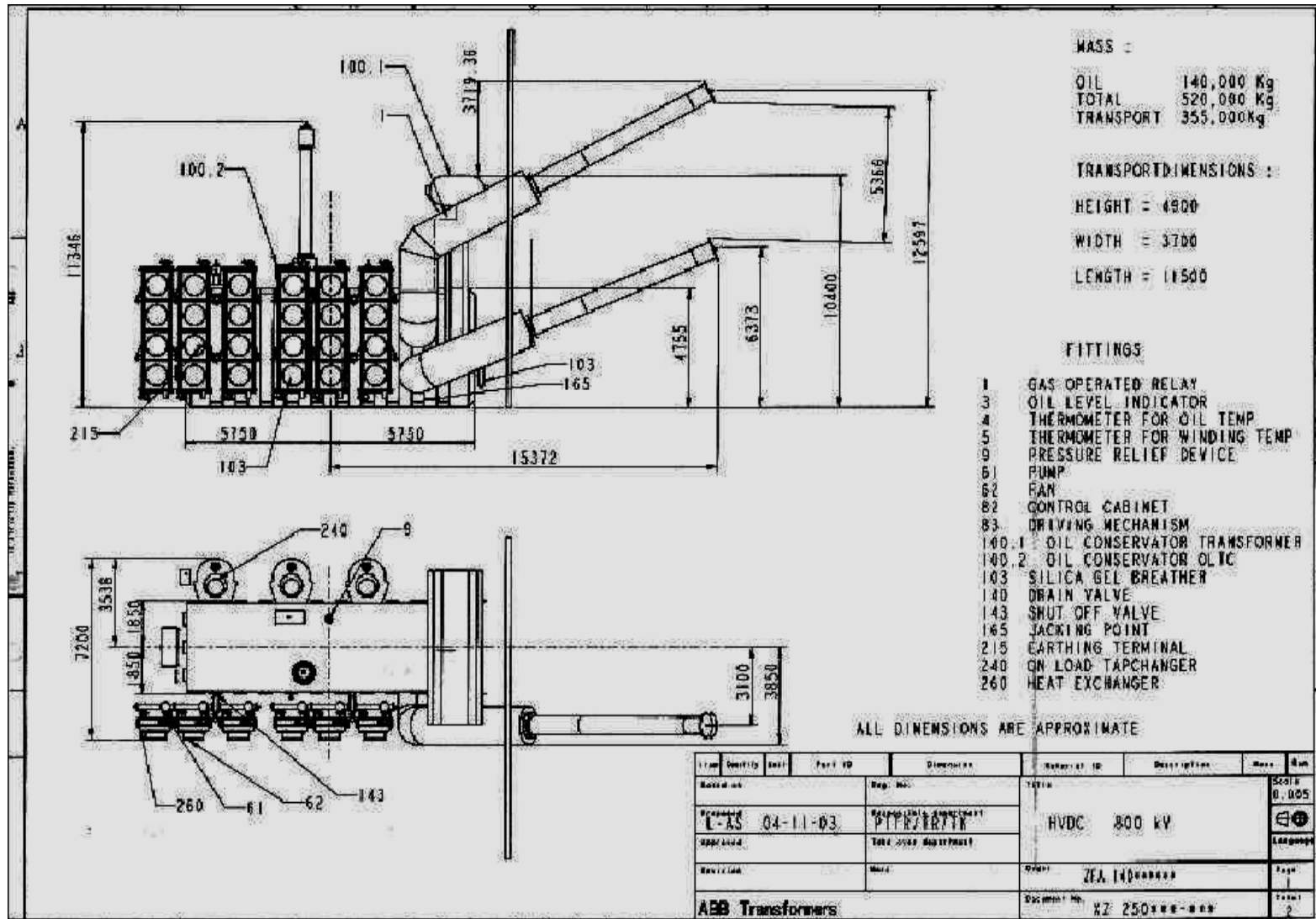


Converter transformer

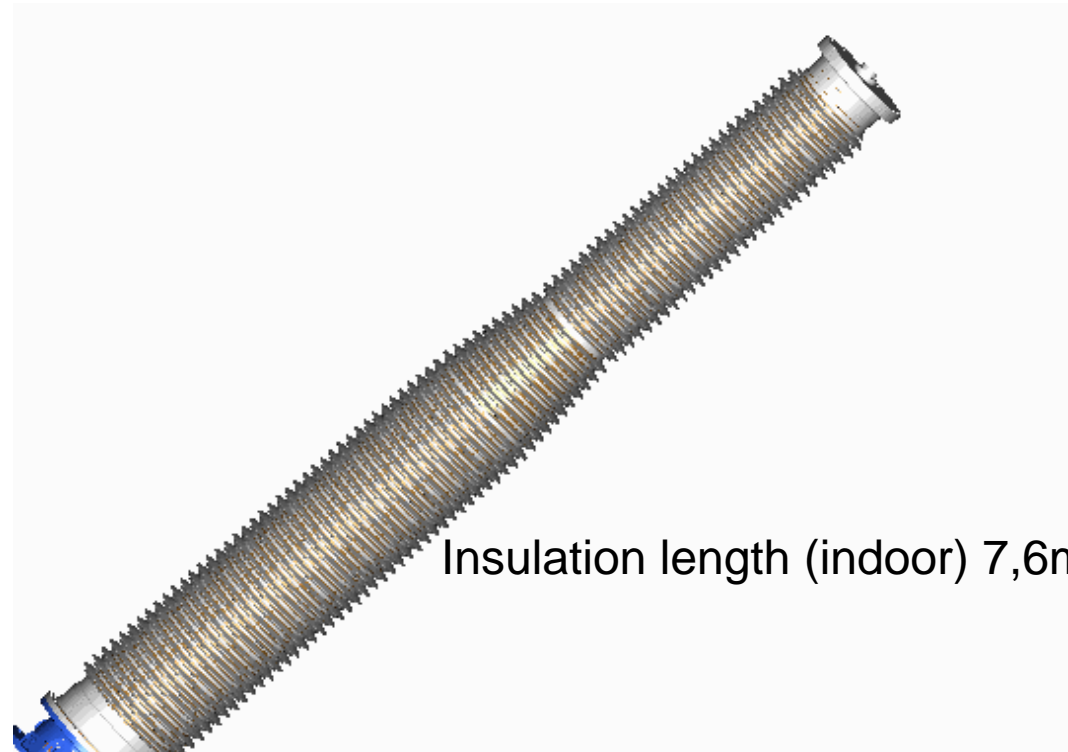
- **Prototype manufactured**
- **First round of testing completed:**
 - **AC 800 kV 60 min**
 - **AC 900 kV 5 min**
 - **DC 1100 kV 60 min**
 - **DC 1250 kV 6 h**



800 kV HVDC converter transformer and transformer bushings



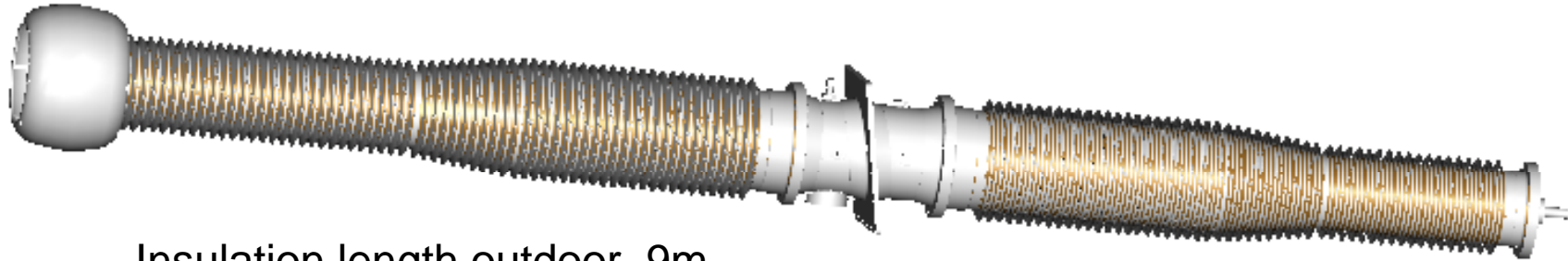
800 kVdc transformer bushing



- Based on proven design used in 3G projects in China
- Hollow core composite insulator
- Silicon rubber sheds with proven profile
- SF₆ enhanced insulation
- "Explosion safe" – no porcelain



800 kV DC wall bushing



Insulation length outdoor 9m

Insulation length indoor 6,7m

- Enlarged 3G-concept
- SF₆ filled bushing
- "Explosion safe" – no porcelain
- Positioning ~10 degrees to horizon beneficial for electrical performance
- Silicon rubber sheds with proven profile

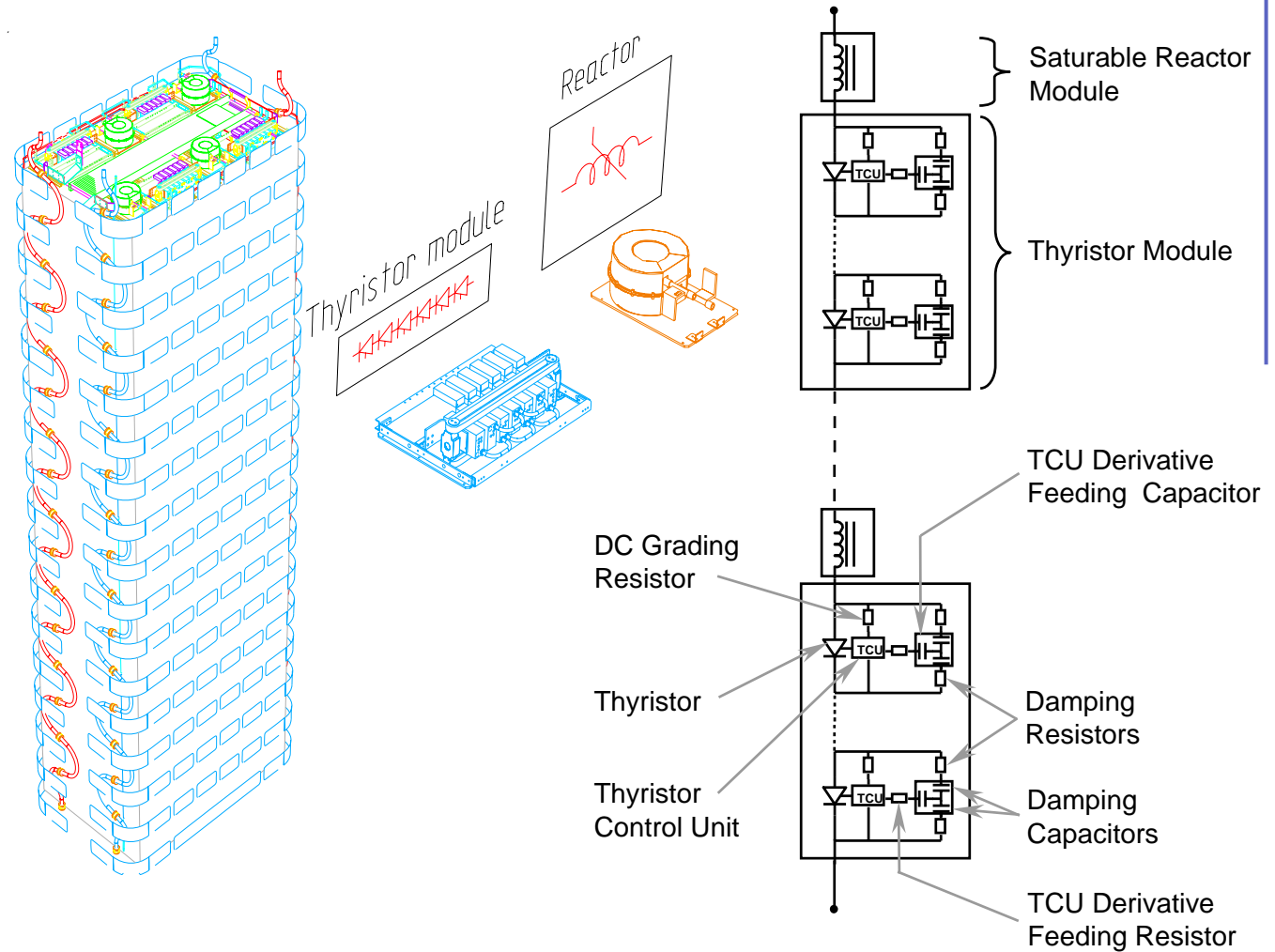
800 kV Wall Bushing



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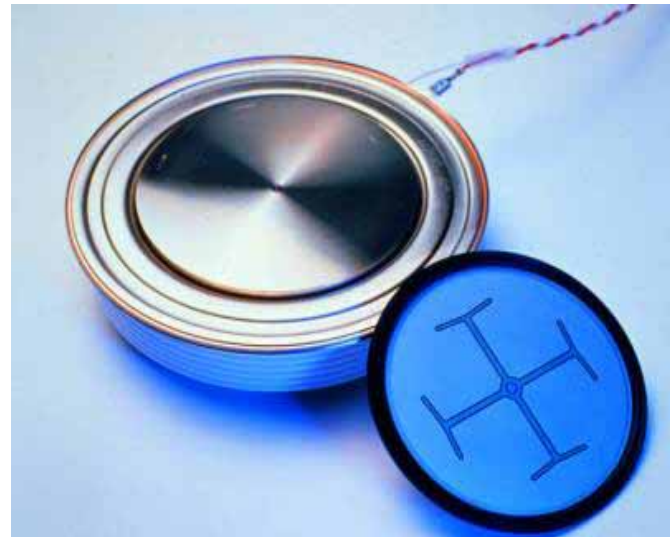


Thyristor Valve Layout



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 has 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



Experience of 14000 5” thyristors

Project	Power Transmitted, MW	Number of thyristors	Commissioned 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 Project USA	3100	2016	2004	3100	3650 @20°C

One thyristor failed during commercial operation reported (Garabi 2002)

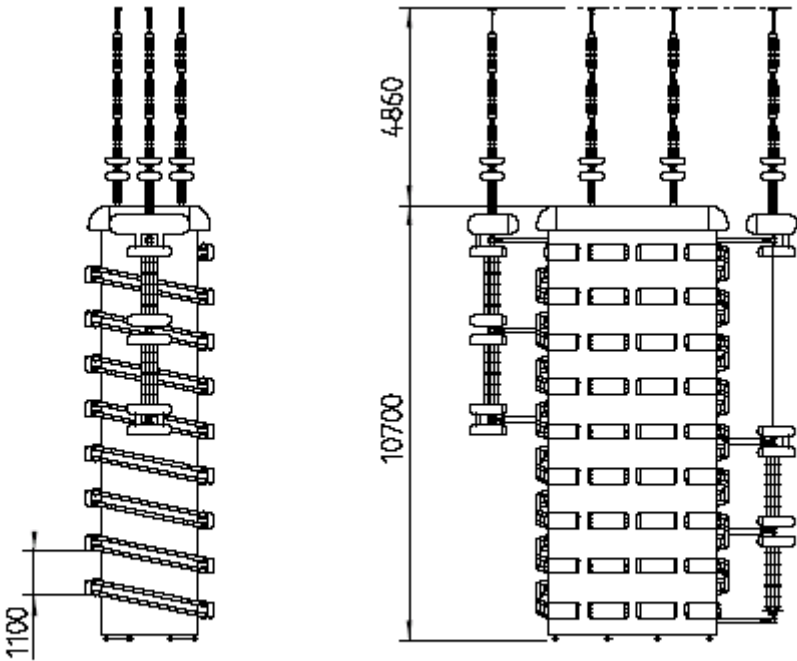


Valve

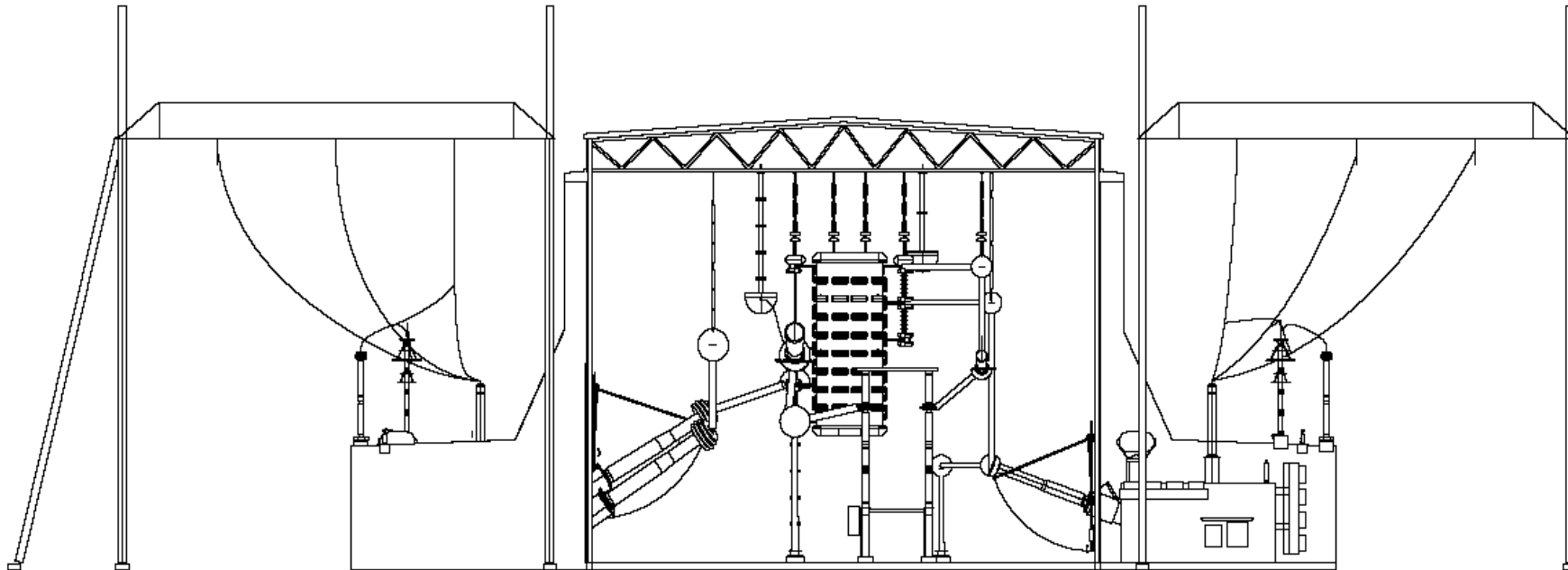
- New valve design to include 800 kV and 6" thyristors
- Conceptual design ready
- Modular prototype testing ready



Quadruple thyristor valve



Valve hall, quadruple 400 kV Valve



Dimensions valve halls, LxWxH:

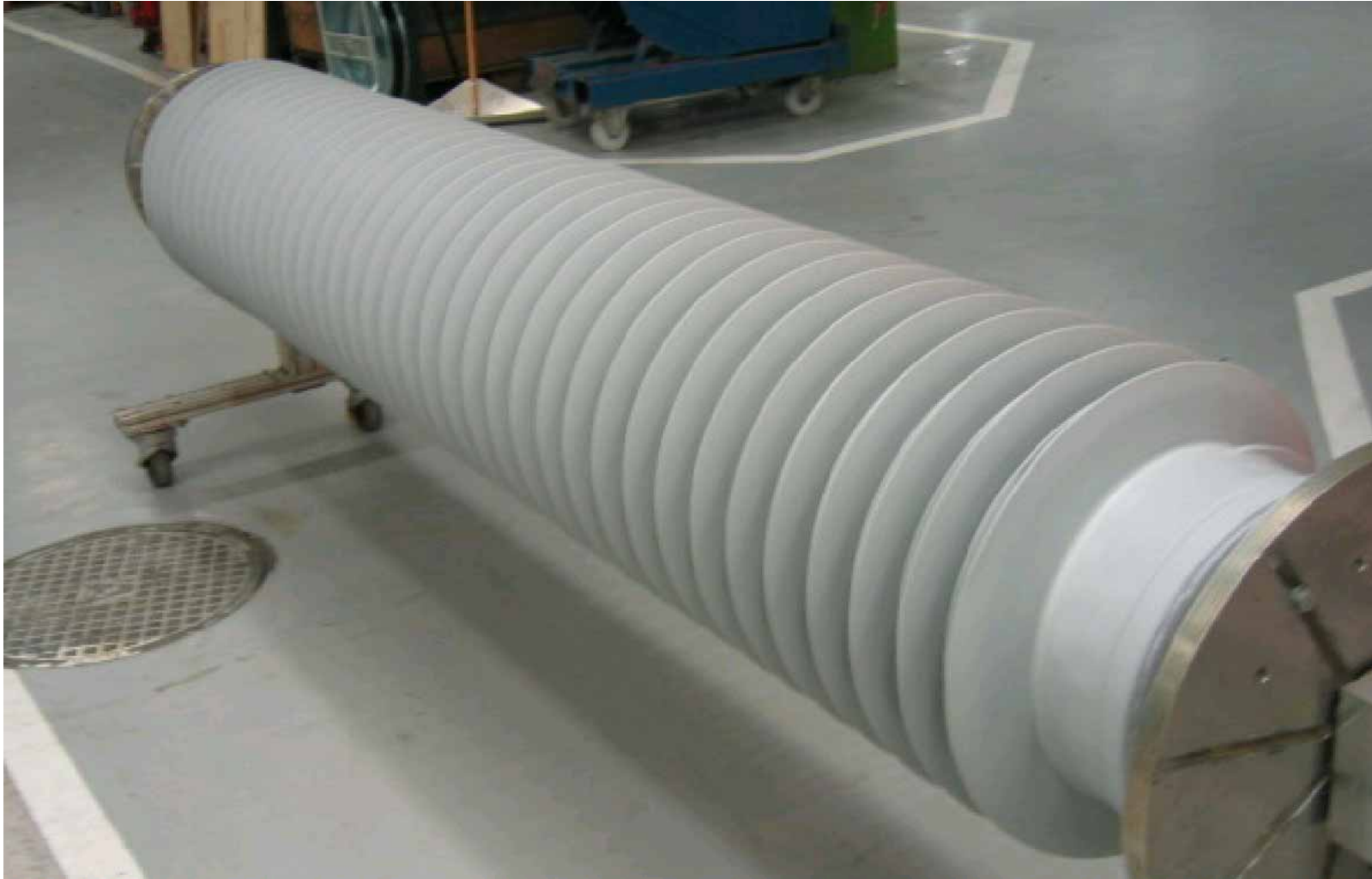
High voltage group: 46.3x31.8x23.6 m, top of roof 27.3

Low voltage group: 35.4x26.6x16.6 m, top of roof 20.3

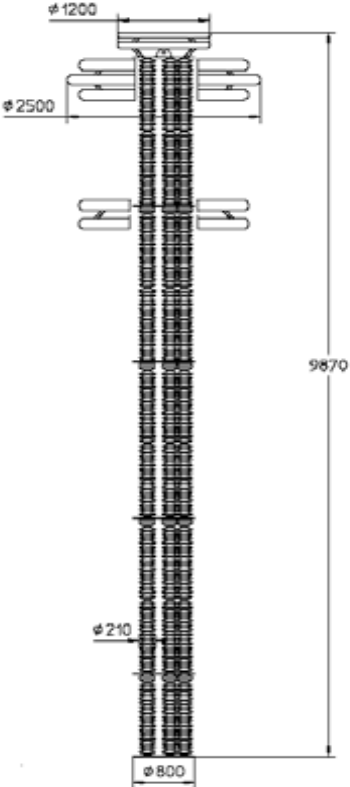
Height increase with 3 meter if single 12 pulse bridge for 800 kV



ABB Composite support insulator



Pole arrester



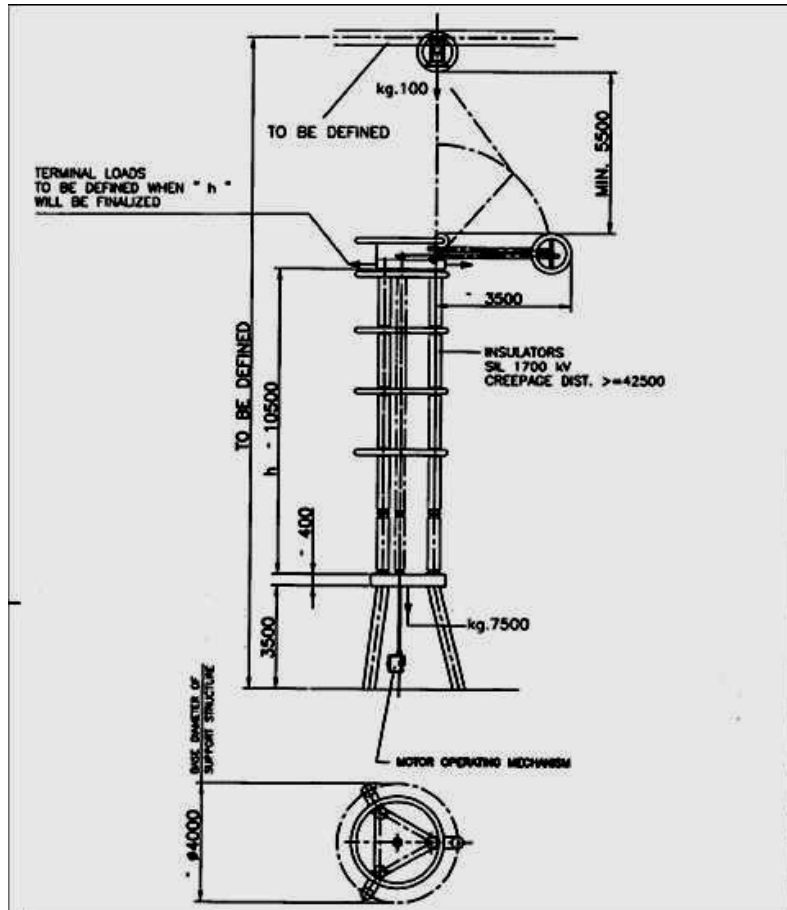
By pass switch

	1	2	A	3	V	4	5	6																									
<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th colspan="2">MASS IN KGS</th> <th colspan="2">MASSA I KG</th> </tr> <tr> <td>BREAKER BRYTTARE</td> <td>OPERAT.MECH. MANÖVERDON</td> <td>SF6-GAS *)</td> <td>TOTAL MASS *)</td> </tr> <tr> <td></td> <td></td> <td>0,5 MPa 0,7 MPa</td> <td>0,5 MPa 0,7 MPa</td> </tr> <tr> <td>3x2824</td> <td>3x460</td> <td>3x19 3x26</td> <td>3x3303 3x3310</td> </tr> </table>		MASS IN KGS		MASSA I KG		BREAKER BRYTTARE	OPERAT.MECH. MANÖVERDON	SF6-GAS *)	TOTAL MASS *)			0,5 MPa 0,7 MPa	0,5 MPa 0,7 MPa	3x2824	3x460	3x19 3x26	3x3303 3x3310	<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>DEFINITE DIMENSION PRINT</td> <td>Your nL/Er ref.</td> </tr> <tr> <td>BINDANDE MÅTTSKISS</td> <td>Din referens ref.</td> </tr> </table>		DEFINITE DIMENSION PRINT	Your nL/Er ref.	BINDANDE MÅTTSKISS	Din referens ref.										
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<p>*Vid blandgas se märkskylt/At mixed gas see ratingplate.</p>				<p>① Cable inlet size FL33. Kabelintag storlek FL33.</p> <p>② Terminal of aluminium. Anslutningsplatta av aluminium.</p> <p>③ Holes for earthing clamp. On all legs. Hål för jordningsklämma. På samtliga ben.</p> <p>④ Terminal load: max 3000 N in any direction. Belastning i anslutning: max 3000 N i vilken riktning som helst.</p> <p>⑤ Max resulting loads on foundation: Vertical load Fv=±74000 N Horizontal load Fh=±14000 N Moment on foundation M=±52000 Nm Max resulterande krafter på fundament: Vertikal kraft Fv=±74000 N Horisontell kraft Fh=±14000 N Moment på fundament M=±52000 Nm</p> <p>⑥ Max vertical load on any bolt ±120000 N Max horizontal load on any bolt ±11000 N Max vertikal kraft på någon bult ±120000 N Max horisontell kraft på någon bult ±11000 N</p> <p>⑦ Clear spacing for revision. Fritt avstånd för revision.</p> <p>⑧ Break chamber insulator. Brytkammarisotant.</p> <p>⑨ Post insulator. Stödsotant.</p>																													
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				<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>Prepared R Magnusson</td> <td>2005-05-04</td> <td>Responsible department PTHVP/BDB</td> <td>Title SF6-BREAKER</td> <td rowspan="2"> </td> </tr> <tr> <td>Approved</td> <td></td> <td>Takes over department</td> <td>SF6-BRYTTARE</td> </tr> <tr> <td>Revision</td> <td></td> <td></td> <td></td> <td>Language 82</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td>Sheet 1</td> </tr> <tr> <td colspan="3"> ABB Power Technologies AB </td> <td>Document no. 1HSB100001M781</td> <td>Cart -</td> </tr> </table>						Prepared R Magnusson	2005-05-04	Responsible department PTHVP/BDB	Title SF6-BREAKER		Approved		Takes over department	SF6-BRYTTARE	Revision				Language 82					Sheet 1	ABB Power Technologies AB			Document no. 1HSB100001M781	Cart -
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ABB Power Technologies AB			Document no. 1HSB100001M781	Cart -																													
				<p>Foundation bolt M30, Lmin=110 mm Fundamentsbult M30, Lmin=110 mm</p>																													
				<p>SF₆ -BREAKER HPL 800B2 HIGH SPEED DC BYPASS SWITCH OPERATING MECHANISM BLG 1002A SF₆ -BRYTTARE HPL 800B2 HÖGHASTIGHETS DC-FÖRBIKOPPLARE MANÖVERDON BLG 1002A</p>																													

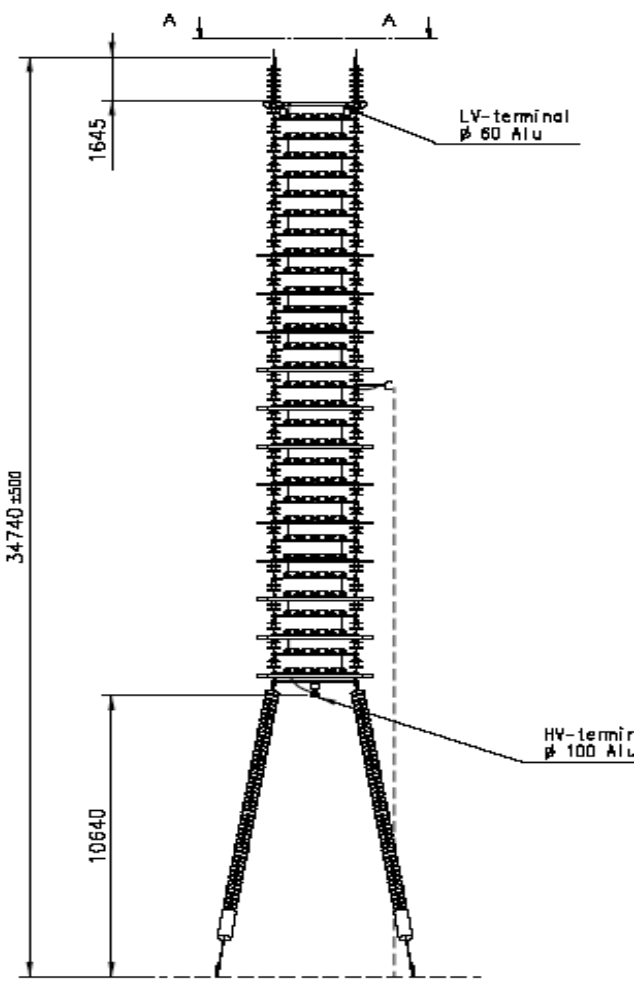
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DC disconnect

SPOL 800 kV, picture of the tests at FGH lab, Mannheim



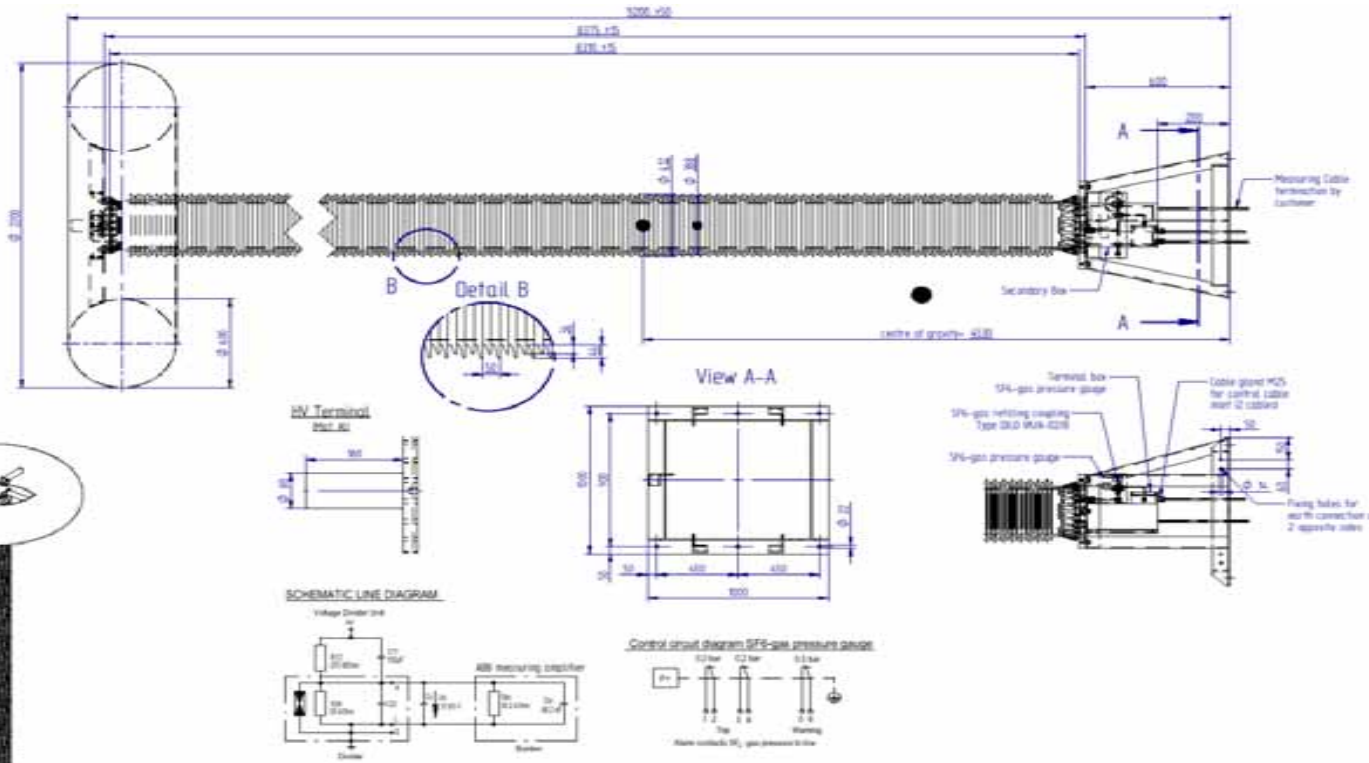
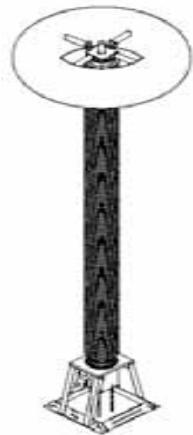
DC harmonic filter capacitor 800 kV



3GC 500 kVDC capacitor



DC-voltage divider



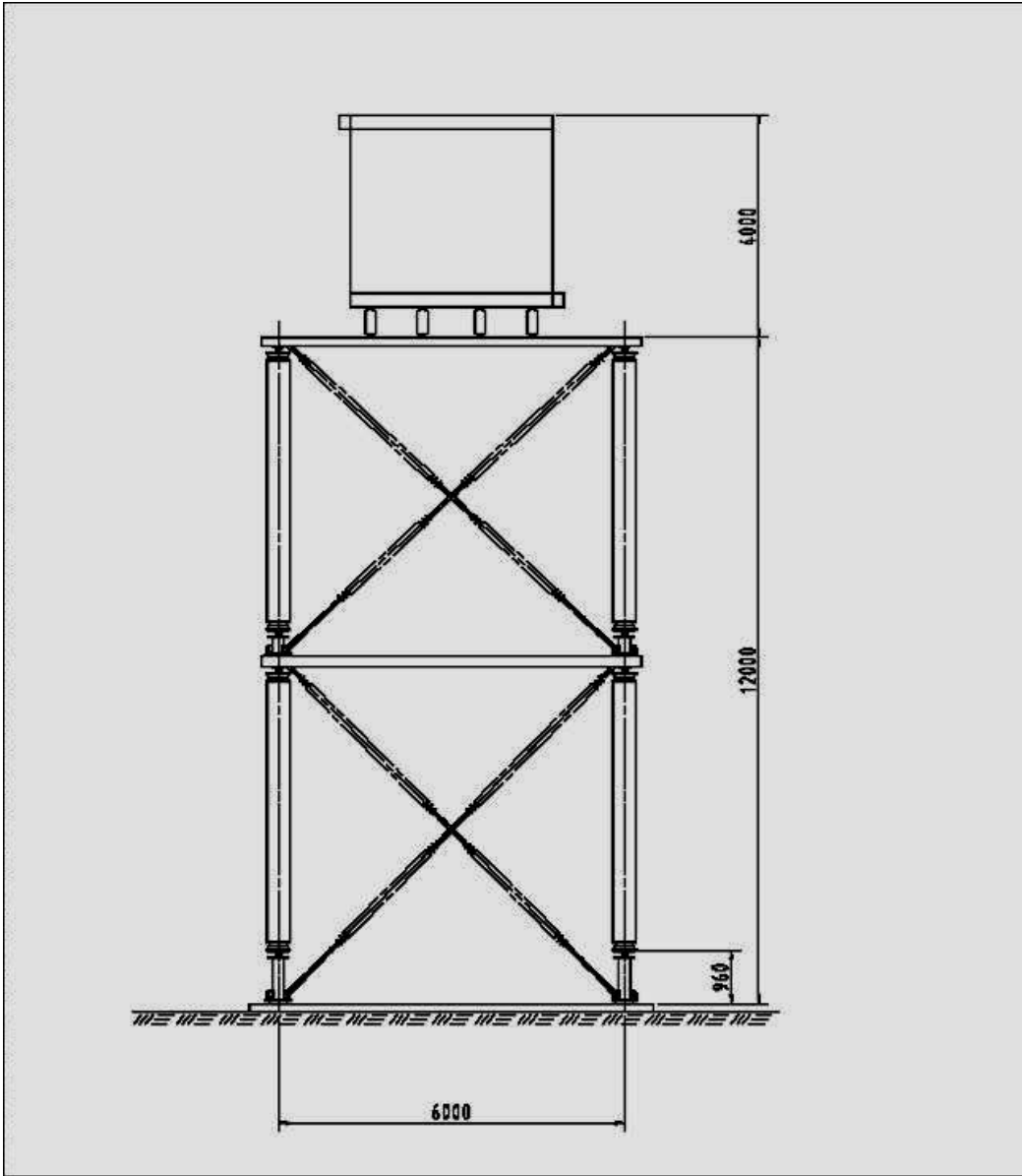
Steel support frame is hot-dip galvanized
 Colour of corona electrode: RAL 9006 silver grey
 Creepage distance - 29300 mm
 Terminal load max. 2000 N static, 2500 N dynamic
 Nominal pressure: 2.2 bar absolute / 1.2 bar over pressure

Colour of composite insulator: grey ANSI-Z70
 Net weight approx. 1300 kg
 Clearance distance - 7000 mm
 Insulation medium SF6-gas

Technical drawing of electrical equipment No. 10.017.016		Title: 10.017.016 Offer No.: 4064-1-025
Drawing No.: 10.017.016 Drawing Date: 2016-01-25 Drawing Version: 1.04.176.0.0		DC Voltage Divider 750 kV, 175 MW Outdoor Type
Drawing No.: 10.017.016 Drawing Date: 2016-01-25 Drawing Version: 1.04.176.0.0		1.04.176.0.0



Platform for smoothing reactor



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	N.A.	N.A.	N.A.	N.A.
	To ground	1950	1546	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 ABB Sweden (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	1400	1075

External Insulation

- **DC- LPE (Line Performance Estimator) work ongoing**
- **Expert team meetings to establish requirements on 800 kV insulators, ABB, NGK, CEPRI, Sediver, Xinghua University**
 - **Requirements for composite insulators agreed**
 - **Methods for high altitude correction agreed**
- **Pollution test station in operation in Yunnan**
- **Composite support insulator installed at TSQ site for verification**
- **All outdoor apparatus can be designed with composite insulators**

Next:

- **Evaluate test criteria for composite insulators**
- **Verification of DC-LPE based on experience from GeSha**
- **Tests on valve hall clearances in July**

Reliability of converters

Large power blocks ask for extremely high reliability!

100 % separation of poles, 3000MW each!

Far going separation of groups, 1500 MW each:

- Geographical
- Mechanical
- Electrical

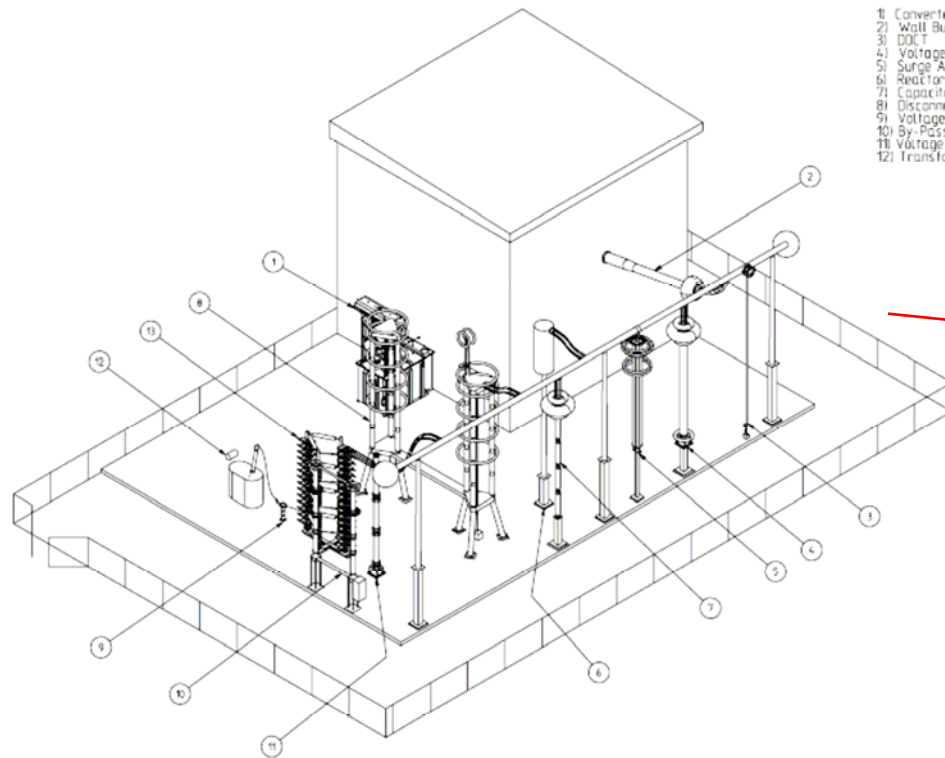
Example:

- AC-yard
- Auxiliary power
- Control
- Cabling
- AC-filters
- Cooling, water supply



Test Circuit

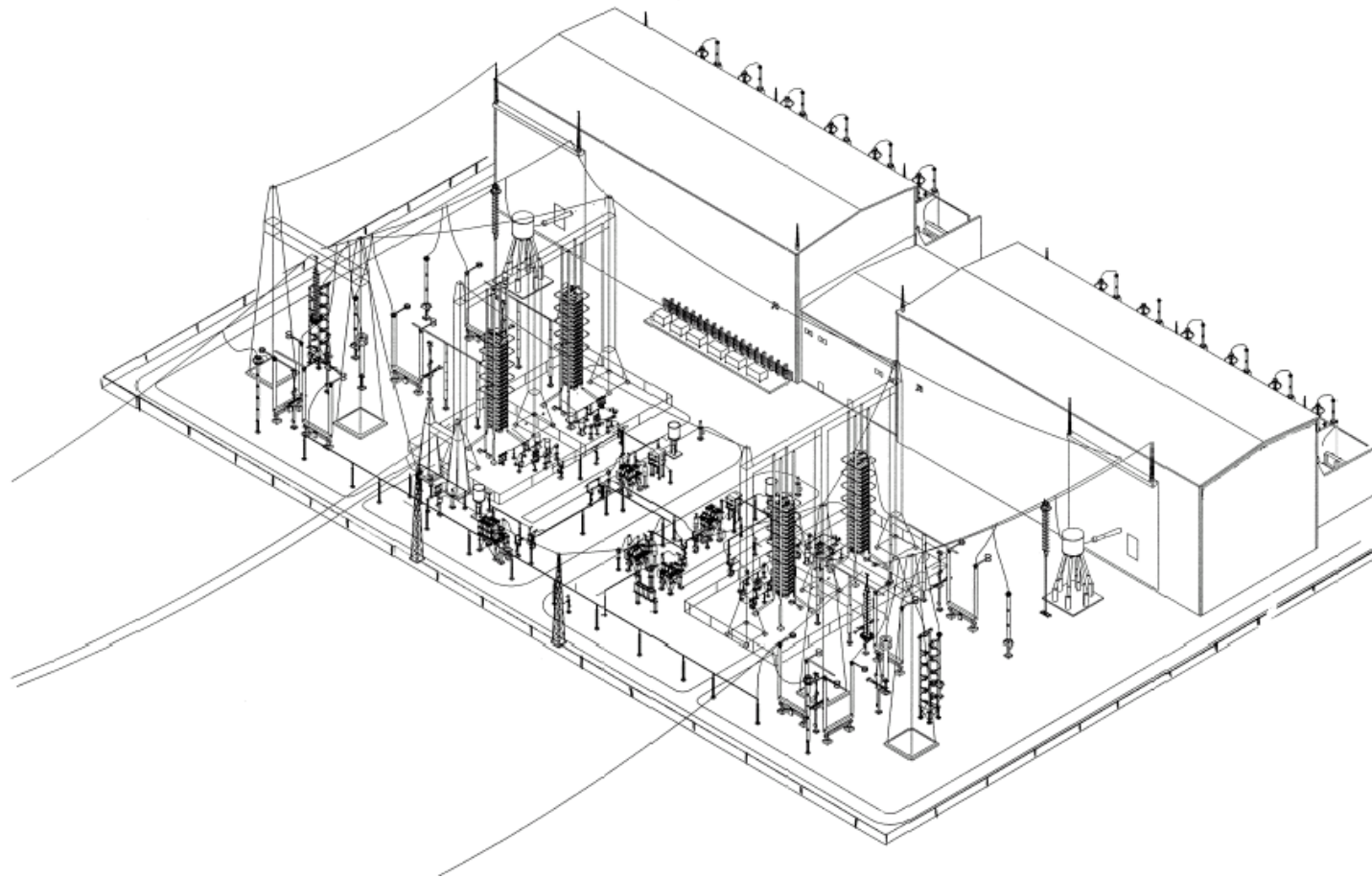
- The long term being built at STRI, Ludvika
- In operation October 2006



- 1) Converter Transformer
- 2) Wall Bushing
- 3) DOCT
- 4) Voltage Divider
- 5) Surge Arrester
- 6) Reactor
- 7) Capacitor
- 8) Disconnect
- 9) Voltage Divider, test equipment
- 10) Bypass Breaker
- 11) Voltage Divider, test equipment
- 12) Transformer, test equipment



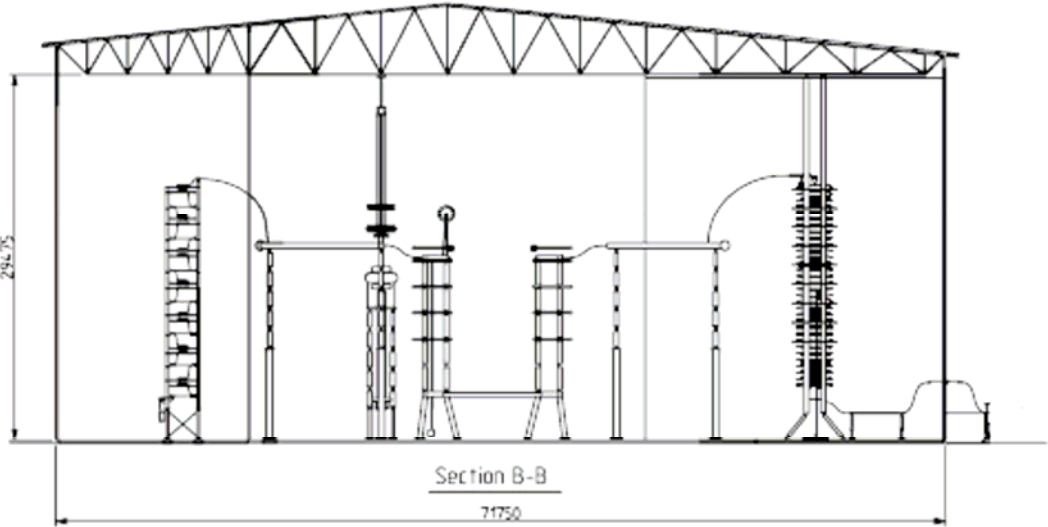
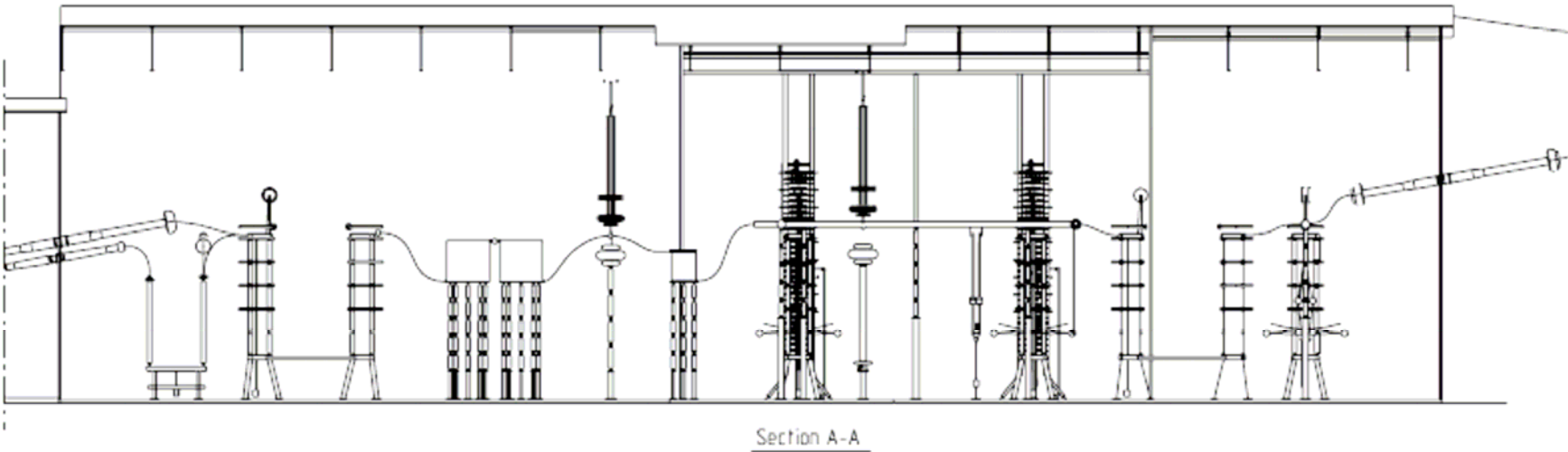
±800 kV, 3000-4500 MW Converter Station



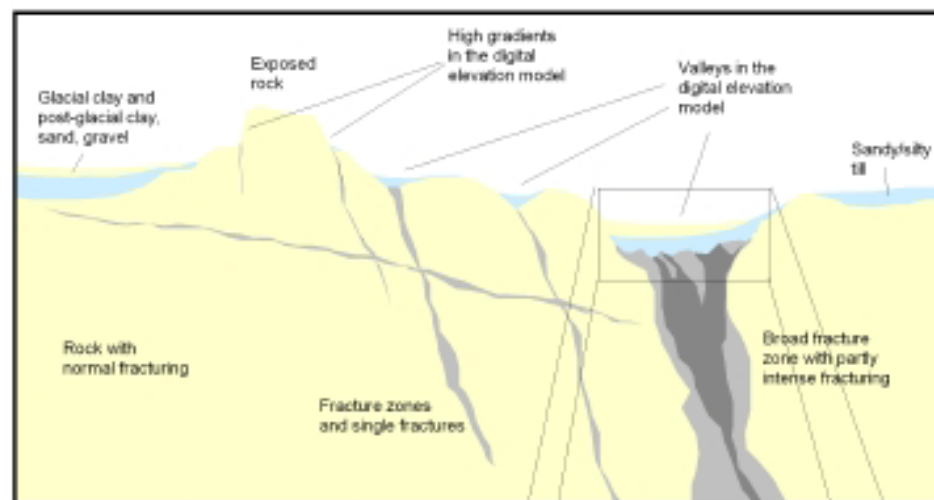
+/- 800 kV 6400 MW station



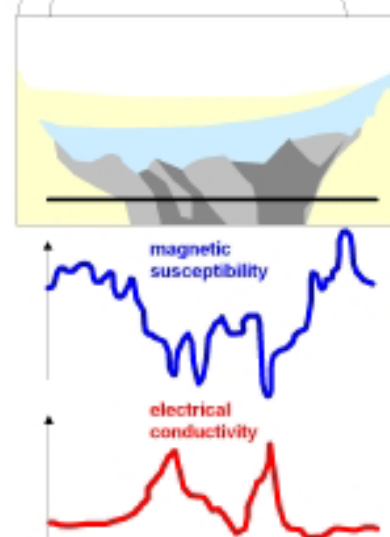
Indoor DC-yard



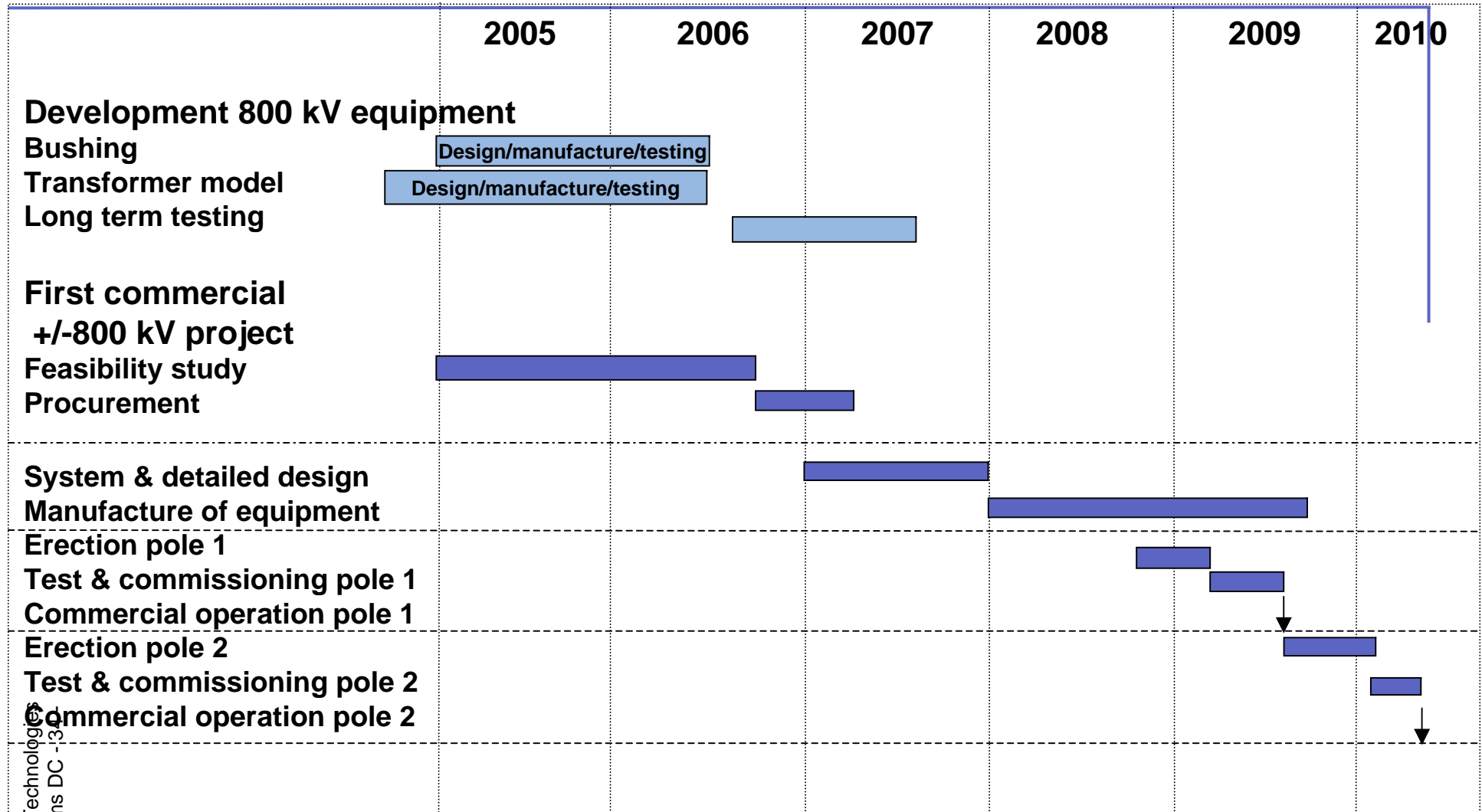
Ground electrode



Brittle fractures can be found in crystalline rock. The length of the fracture can be supposed to relate to its depth extent, i.e. a 50 km long fracture zone might extend to the mantle. Such zones are usually water-bearing and low-resistive.



Development of 800 kV equipment and first project execution.



Summary

- Project is on schedule
- Important knowledge obtained from service experience, calculations and pre-testing and integrated in 800kVdc design
- Design for transformer- and wall bushing prototypes ready and tests are ongoing
- Manufacturing of prototypes is on-going
- 800 kV test circuit- civil work ongoing
- Project is on track !





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