INTRODUCTION

The design of HVDC requires Careful study coordination , which must be achieved in compliance with the Owner's requirements.

To achieve these objectives, number of highly interactive system studies is performed using digital computer programs.

Figures 1 & 2 show a simplified SLD of an HVDC and block diagram for the system studies required for the HVDC scheme.

The System Design Studies are divided in four major groups as shown in the following Table:

	Study Group
A	Main Data & Reactive Power
B	AC Filters & Harmonics
C	DC Filters & Harmonics
D	Ins. Coordination and Arresters

The tools for all these studies are digital programs in Basic Language running on personal computers (PC) or portable notebooks. The Software is suitable for XP, Vista and Windows 7, however license is required.

The description of these digital programs is given in **Part 1**.

In addition to the software digital programs, different documentations are required in order to complete the system studies for HVDC.

The description of these documentations is given in **Part 2**.

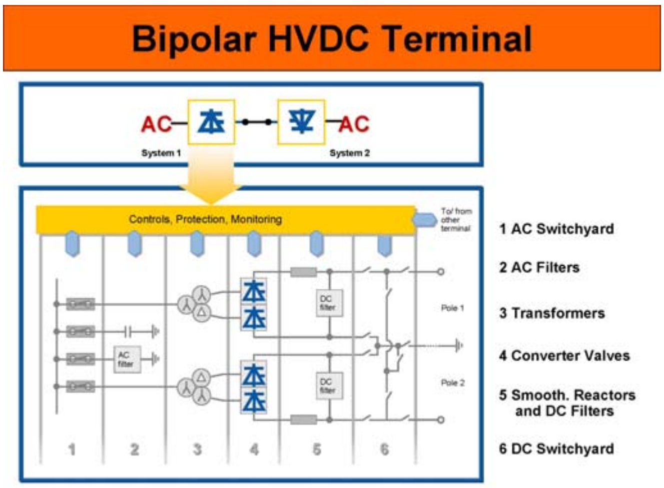

Figure 1 : SLD for HVDC (Bipolar)

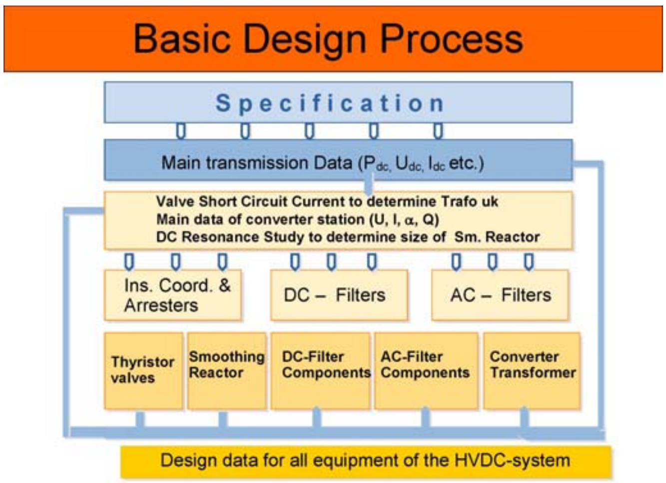

Figure 2 : System Design Studies

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Part 1 : Software

A) Main Data and Reactive Power Study

The study includes the calculation of the steady state characteristics as function the transmitted power for different operating modes of the converter station:

- Bipolar Operation
- Monopolar Operation
- Metallic Return Operation ,

For nominal as well as for reduced dc voltage conditions.

At first the type of thyristor element should be selected. The most suitable thyristor is the 5 " Thyristor with rated dc current 3000 – 3200 A with short circuit level of 36 to 38 kA, which define the impedance of the converter transformer.

The following values will be calculated:

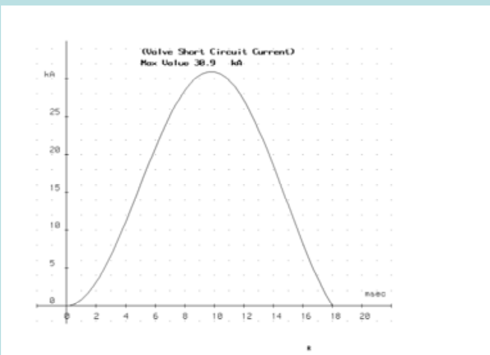
- Dc current & Voltage
- Firing, extinction & overlap Angle
- Converter Reactive Power
- P-Q diagrams
- Converter Transformer Rating
- Tap-changer Range

The next step is to calculate the value of the smoothing reactor. This will be done using the DC-RES program, as described later under dc resonance study.

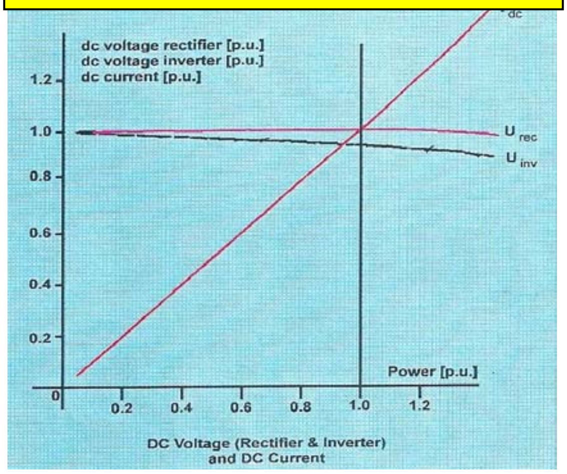
A reactive power compensation concept is established to satisfy the requirements of customer's requirements. This includes the following :

- Determination of the necessary design data of the reactive power supply and absorption requirement
- Determination of switching sequences of the reactive power equipments
- Calculation of the reactive power exchange at ac system bus

Program : MAINDATA (Ivalve)



Program : MAINDATA



B) AC Filters & Harmonics

B1)AC / DC Harmonics Study

The study includes the calculation of the characteristic and non- characteristic harmonics on both ac and dc side for different operating modes including:

- Representation of each converter terminal including dc line and smoothing reactors
- Representation of ac system incl. ac voltage neg. Sequence
- Converter transformer commutating reactances incl. unbalances between the individual phases
- Non-ideal firing pulses with asymmetries due to jittering and due to dc current ripple.

A Fourier analysis of ac currents, dc voltages and dc currents of both rectifier and inverter will be done.

Program : ACFILTER (HARM)

B2) AC Filters, Performance & Rating Studies

The study includes the calculation of the ac filter performance and rating considering the following specific parameters:

- Detuning effects due to frequency and ambient temperature deviation, initial detuning and capacitor can outages
- Required number of filters for the reactive power compensation
- Resonance with the ac system impedance as specified by customer
- Emergency conditions with filter sub-banks out of service
- Back-ground harmonics from the ac system (only for Rating calculations)
- Variation of ac system voltage

1) AC Filter Performance

This study includes the following :

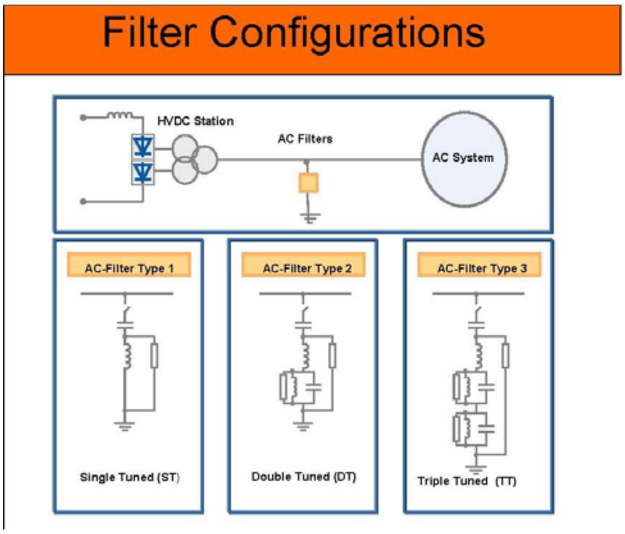
- Calculation of ac filter impedance
- Calculation of resonance
- Calculation of individual distortion
- Calculation of total harm. distortion
- Calculation of Telefon Interference Factor (TIF) or Telefon Harmonic Form Factor (THFF) or IT

Program : ACFILTER (PERF)

2) AC Filter Steady State Rating

The calculations in this study are carried out in the whole range of operation of the converter stations to determine the highest steady state current and voltage stresses for each individual filter component including the arresters. Resonance conditions are assumed between ac filters and ac system.

Program : ACFILTER (RATING)



3) AC Filter Transient Rating

The calculations in this study are carried out to determine the highest transient stresses and insulation levels of the ac filter components.
Following cases are included :

- Ground fault with pre-fault voltage corresponding to the switching surge protective level of the ac bus arrester
- Switching surge overvoltage from ac side corresponding to the switching surge protective level of the ac bus arrester
- AC filter energization at the instant of max. ac bus voltage
- Fault recovery after 3-phase ground fault incl. saturation effects and resonance conditions with ac system at low order harmonics

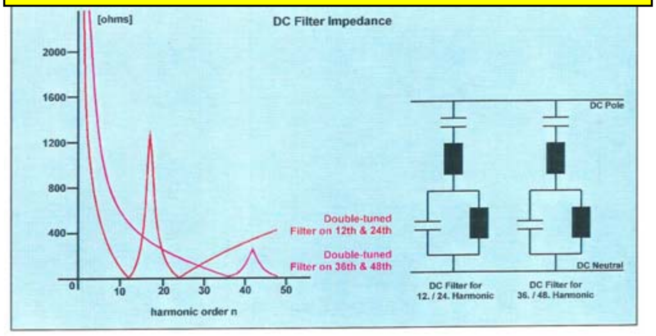
Program : ACFILTER (TRANS)

C) DC Filters & Harmonics

C1) DC Resonance

- The study includes the calculation of the resonance conditions on the dc side between smoothing reactor, dc filters and dc line/cable. Following cases are included :
- Variation of smoothing reactor size and calculation of resonances
- Calculation of resonances with all dc filters in & out of service
- determination of min. value of the smoothing reactor required

Program : DCFILTER (RESON)



C2) DC Filters, Performance & Rating Studies

The study includes the calculation of the dc filter performance and rating considering the following specific parameters:

- Detuning effects due to frequency and ambient temperature deviation, initial detuning and capacitor can outages
- Required number of filters to meet the performance values
- Resonance with the dc system impedance including dc line/cable
- Emergency conditions with filter sub-banks out of service

1) DC Filter Performance

This study includes the following :

- Calculation of dc filter and dc line/cable impedance
- Calculation of triple harmonic currents along the dc line/cable
- Calculation of induced voltage (mV/km) & eq. dist. Current (mA)

Program : DCFILTER (PERF)

2) DC Filter St. State Rating

The calculations are carried out in the whole range to determine the highest steady state stresses for all dc filter components including filter arresters

Program : DCFILTER (RATING)

3) DC Filter Transient Rating

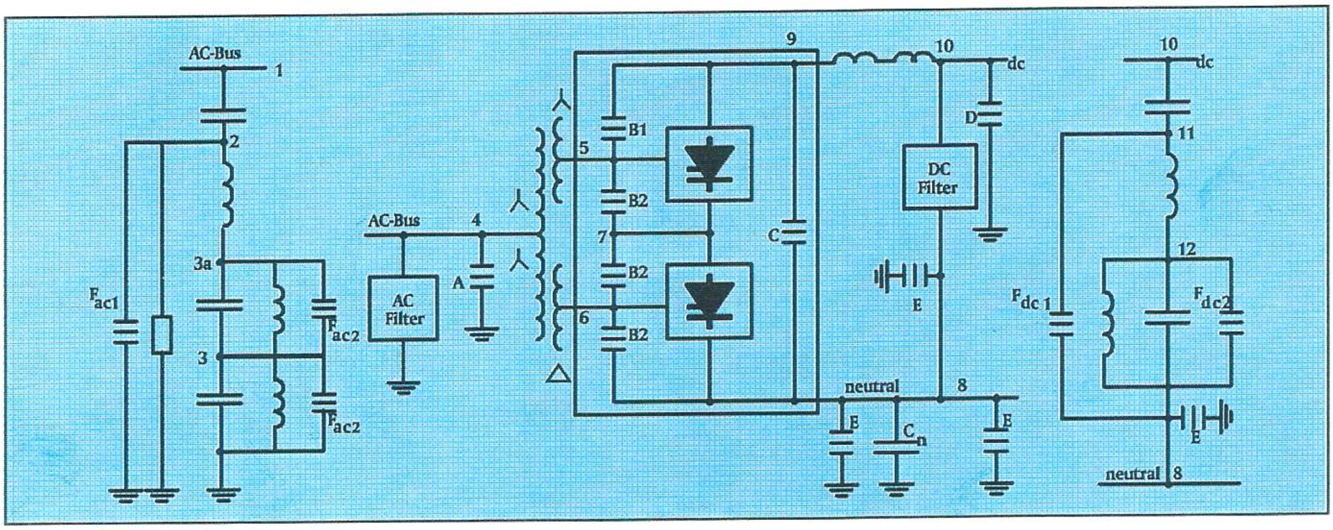
In this study the highest transient stresses and insulation levels of the dc filter components are determined.

The decisive fault cases are :

- Ground fault with pre-fault voltage corresponding to the switching surge protective level of the dc bus arrester type 'D'
- Switching surge overvoltage from dc side corresponding to the switching surge protective level of the dc bus arrester type 'D'

Program : DCFILTER (TRANS)

D) Insulation Coordination & Arresters



The converter station is protected by the following Zno-Arresters (s. Figure):

- AC bus arrester type 'A'
- Valve arrester type 'B'
- Valve group arrester type 'C'
- DC line arrester type 'D'
- Neutral bus arrester type 'E'
- AC filter arrester type 'Fac'
- DC filter arrester type 'Fdc'

Following steps are necessary to determine the insulation levels of the converter station:

1. Definition of the Max. Continuous Operating Voltages (MCOV) for each arrester type
2. Determination of arrester protective levels, current and energy duties at following worst cases fault conditions:
   - Ground fault on the ac bus for arrester 'A' and 'Fac' as well as on dc bus for arrester 'Fdc'
   - Ground fault on HV valve side trans-former bushing, LV valve side transformer bushing and on dc bus for arrester 'E' for the operation in metallic return mode (worst case)
   - Ground fault on HV valve side trans-former bushing for arrester 'B1'
   - Transferred switching surge from ac and dc side for arresters 'B', 'C', 'D' & 'Fdc'
3. Determination of protective levels and insulation levels for all components (Term-Term & Term-ground) considering the specified margins
4. Determination of arrester rating (MCOV, protective levels at associated coordinating currents)
5. Summary of results

Program : INS-COORD

Part 2 : Documentation

Table of Content

1. Summary of Techn. Spec. (s. Attachment 1)

This doc gives a summary of all important data relevant to the system design of the HVDC scheme. This document must be produced before starting the system studies.

2. Component Data Sheets (s. Attachment 2)

All the calculated design data of each component will be documented in these data sheets, which are the technical data needed in the component spec's (s. next Item 3)

3. Component Specifications for Sub-suppliers

- Simplified Single Line Diagram
- Specification for Converter Transformers (Rectifier & Inverter side)
- Specification for Smoothing Reactors (Rectifier & Inverter side)
- Specification for AC Filter Components (Rectifier & Inverter side)
- Specification for DC Filter Components (Rectifier & Inverter side)
- Specification for AC & DC Arresters (Rectifier & Inverter side)

4. Word documents (9 Reports)

- Prel. Basic Design Report for the HVDC Scheme (90 pages)
- Report on Main Data & Reactive Power (80 pages)
- Report on AC/DC Harmonics (25 pages)
- Report on AC Filters -Rectifier side (65 pages)
- Report on AC Filters -Inverter side (65 pages)
- Report on DC Filters Rectifier & Inverter (45 pages)
- Report on Reactive Power Management -Rectifier side (45 pages)
- Report on Reactive Power Management -Inverter side (45 pages)
- Report on DC Resonance Study (15 pages)

5. Time Schedules for the system studies

A prel. Time schedule for the work on system studies for HVDC is given :

	Study Group & Activities	Week 1&2	Week 3&4	Week 5&6	Week 7&8
A	Main Data				
B	AC Filters & Harmonics				
C	DC Filters & Harmonics				
D	Ins. Coordination and Arr.				
E	Summary of Technical Spec				
F	Component Data Sheets				
G	Components Specifications				
H	Word Reports (Text)				

ATTACHMENT 1 (Summary of Techn. Spec.)

1 General Description

A bipolar 12-pulse HVDC transmission of a total rated power capacity of **3000** MW (**500**kV,**3000** A) measured on the DC side of the rectifier is required.

2 Summary of Technical Information

	Unit	Station A (REC)	Station B (INV)
• **AC Voltage**			
Nominal System Voltage	kV	535	500
Normal Operating Voltage Range			
Maximum (steady state)	kV	550	515
Minimum (steady state)	kV	500	490
Extrem Operating Voltage Range			
Maximum (steady state)	kV	550	525
Minimum (steady state)	kV	475	475
• **AC Side Insulation Level**			
a) Converter Transformer			
- LIWL (1.2/50)	kV	1425	1425
- SIWL (250/2500)	kV	1175	1175
b) Other Components			
- LIWL (1.2/50)	kV	1550	1550
- SIWL (250/2500)	kV	1175	1175
• **AC Short-Circuit Level**			
a) Maximum	MVA	45000	56000
b) Minimum	MVA	9000	26000
c) Max. Circuit Breaker Current	kA	63	63
• **AC Frequency**			
a) Nominal	Hz	50	50
b) Maximum (Performance)	Hz	50.2	50.2
Maximum (Rating)	Hz	50.5	50.5
c) Minimum (Performance)	Hz	49.8	49.8
Minimum (Rating)	Hz	49.0	49.0

• **AC System Impedance**	Unit	n=2	n=3	n>3	n=2	n=3	n>3
a) Max Imp (Zmax)	Ω	100	130	400	35	35	200
b) Min Imp (Zmin)	Ω	20	30	10	0.3	0.3	2.3
c) Max Angle (Perf/Rat)	deg	88/89	85/89	88/89	85/89	85/89	80/85
d) Min Angle (Perf/Rat)	deg	30/88	20/88	82/88	85/88	85/88	80/88

		Station A (REC)	Station B (INV)
• **AC Negative Sequence**			
a) Performance	%	1.0	1.0
b) Rating	%	2.0	2.0
• **DC Transmission Data**			
a) Rated DC Power	MW	3000	
b) DC Current			
- Rated	A	3000	
- Minimum	A	300	
- Overload (Cont.) without red. cooling	A	3300	
- Overload (2 hrs),	A	**NA**	
- Overload (3 sec), without red. cooling	A	4500	
c) Normal DC Voltage			
- Rated	kV	**± 500**	
- Maximum	kV	**± 515**	
- Minimum	kV	**± 485**	
d) Reduced DC Voltage for Current Range **300** A to **3000** A depending on the reactive power capability of the ac System			
- without red. Cooling	KV	400	
-- with red. Cooling	kV	350	
• **Reactive Power Compensation**			
a) at rated Load			
-to ac system	MVAr	-	-
-from the ac system	MVAr	700	-
b) at min. Load			
-to ac system	MVAr	250	230
-from the ac system	MVAr	-	-
c) normal range	MVAr	**± 180**	**± 230**

		Station A (REC)	Station B (INV)
• **Insulation Coordination**			
a) Zno - Arresters			
b) Margins (Switching/Lightning/Steep Front)			
- Valves	%	**15/15/20**	**15/15/20**
- Converter Transformers	%	**15/20/25**	**15/20/25**
- Smoothing Reactors	%	**20/25/25**	**20/25/25**
- Filter Reactors	%	**20/25/25**	**20/25/25**
- Filter Capacitors	%	**20/25/25**	**20/25/25**
- AC - Switchgear	%	**20/25/25**	**20/25/25**
- DC - Switchgear	%	**20/25/25**	**20/25/25**
• **Radio Interference**			
Level at 1 MHz and 450 m	uV/m	**100**	**100**
• **PLC - Interference**			
a) Minimum Frequency	kHz	-	-
Signal to Noise Ratio	dBm	-	-
a) Maximum Frequency	kHz	-	-
Signal to Noise Ratio	dBm	-	-
• **AC - Filters**			
a) Max. Size (sub-bank/bank)	MVAr	**180 / 360**	**230 / 690**
b) Max. Voltage Change	%	**2.0**	**2.0**
c) Perf. Requirements			
- Indiv. Distortion	%	**1.0**	**1.0**
- Tot. Distortion (rms)	%	**1.5**	**1.5**
- TIF	-	**NA**	**NA**
- THFF	-	**1.0**	**1.0**
• **DC - Filters**			
a) Perf. Requirements			
- Induced Voltage (Bip.)	mV/km	**NA**	**NA**
- Induced Voltage (Mon.)	mV/km	**NA**	**NA**
- Eq. Dist. Current (Bip.)	mA	**400**	**400**
- Eq. Dist. Current (Mon.)	mA	**800**	**800**

3 DC Transmission Data

The following transmission data are defined on the DC side :

a) DC Power

rated	**2x1500** MW at rectifier
maximum	as per overload capability
minimum	**2x150** MW (**10** % of rated)

b) DC Voltage

rated	**± 500** kV at rectifier
maximum	**± 515** kV (**1.03** pu of rated)
minimum	**± 485** kV (**0.97** pu of rated)
80 %	**± 400** kV (**without redundant cooling**)
70 %	**± 350** kV (**with redundant cooling**)

c) DC Current

rated	**3000** A
maximum	as per overload capability
minimum	**300** A (**10** % of rated)

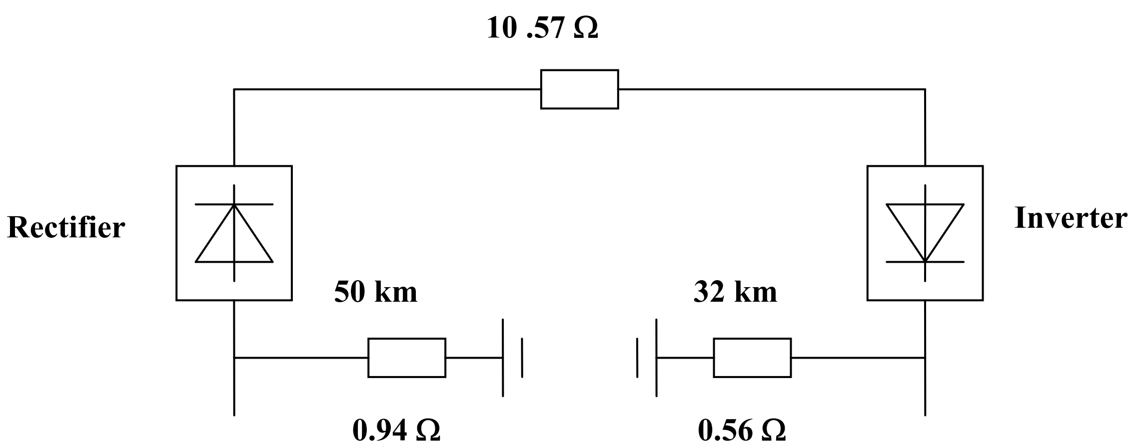
4 DC Line / Cable Data

Overhead Lines

Length	**890** km		
DC Resistance	**0.01176**	ohms/km	(max. value)
Inductance (0.1 Hz)	**0.85**	mH/km	
Capacitance	**13.1**	nF/km	

Electrode Lines & Grounding

Length	**50 / 32**	km Station A/B	
DC Resistance	**0,0144**	ohms/km (20 deg C)	
Inductance (0.1 Hz)	**2.2**	mH/km	
Capacitance	**13.1**	nF/km	



DC Resistance

The total DC resist. is given by Rdc = **10.57**ohms (Bipolar)
The total DC resist. is given by Rdc = **12.07**ohms (Mon.-1 Line)
The total DC resist. is given by Rdc = **6.79** ohms (Mon.-2 Lines)
The total DC resist. is given by Rdc = **21.14** ohms (Met. Ret.)

5 Operation Modes

The HVDC transmission scheme is designed for the following modes of operation:

a) Bipolar at DC voltage	**500 kV**	**400 kV**	**350 kV**
b) Monopolar (One Line) at DC voltage	**500 kV**	**400 kV**	**350 kV**
c) Metallic Return at DC voltage	**500 kV**	**400 kV**	**350 kV**
d) Monopolar (Two Lines) at DC voltage	**500 kV**	**400 kV**	**350 kV**

ATTACHMENT 2 (Component Data Sheets)

Sheets No 1 to 13

Sheet No	Description
1	Main Data needed to calculate AC Harmonis
2	DC Current and Voltages needed for Smoothing Reactor
3	AC Filter Data & Configuration
4	AC Filter Performance Results for different Loads
5	AC Filter Rating Results for different Loads
6	AC Filter Transients Results for different Filters
7	Main Data needed to calculate DC Harmonis
8	DC Filter Data & Configuration
9	DC Filter Performance Results for different Loads
10	DC Filter Rating Results for different Loads
11	DC Filter Transients Results for different Filters
12	DC Resonance Results Amplification Factor for different Cases
13	INS. COORD Results for Valve & E-Arresters

3000 MW HVDC
AC – DC HARM
100 % dc Voltage

Sheet No 1

Load [%]	Ud11(I) [kV]	Id11(I) [Amp]	Alf11(I) [deg]	Gam11(I) [deg]	Fload$(I) -
10	500	300			„SAD_H010.100“
20	500	600			„SAD_H020.100“
30	500	900			„SAD_H030.100“
40	500	1200			„SAD_H040.100“
50	500	1500			„SAD_H050.100“
60	500	1800			„SAD_H060.100“
70	500	2100			„SAD_H070.100“
80	500	2400			„SAD_H080.100“
90	500	2700			„SAD_H090.100“
100	**500**	**3000**	**15.0**	**18.0**	**„SAD_H100.100“**
110		3300			„SAD_H110.100“
120		3600			„SAD_H120.100“

3000 MW HVDC
AC – DC HARM for Sm. Reactor
100 % dc Voltage

Sheet No 2

Inductance	mH	20	40
Voltage Stresses			
a) DC	kV	0,036	0,072
b) Arith. Sum of Harm.	kV	4,326	8,652
c) Total Voltage	kV	4,362	8,724
Current Stresses			
a) DC	A	3600	3600
b) Geom. Sum of Harm	A	50,25	50,25
c) Total Current	A		
Insulation Levels			
Terminal – Terminal BIL / SIL	kV	450 / 350	450 / 350
HV-Term. to Ground BIL / SIL	kV	450 / 350	450 / 350
LV-Term. to Ground BIL / SIL	kV	450 / 350	450 / 350

Table 1 : Rating for Smoothing Reactors

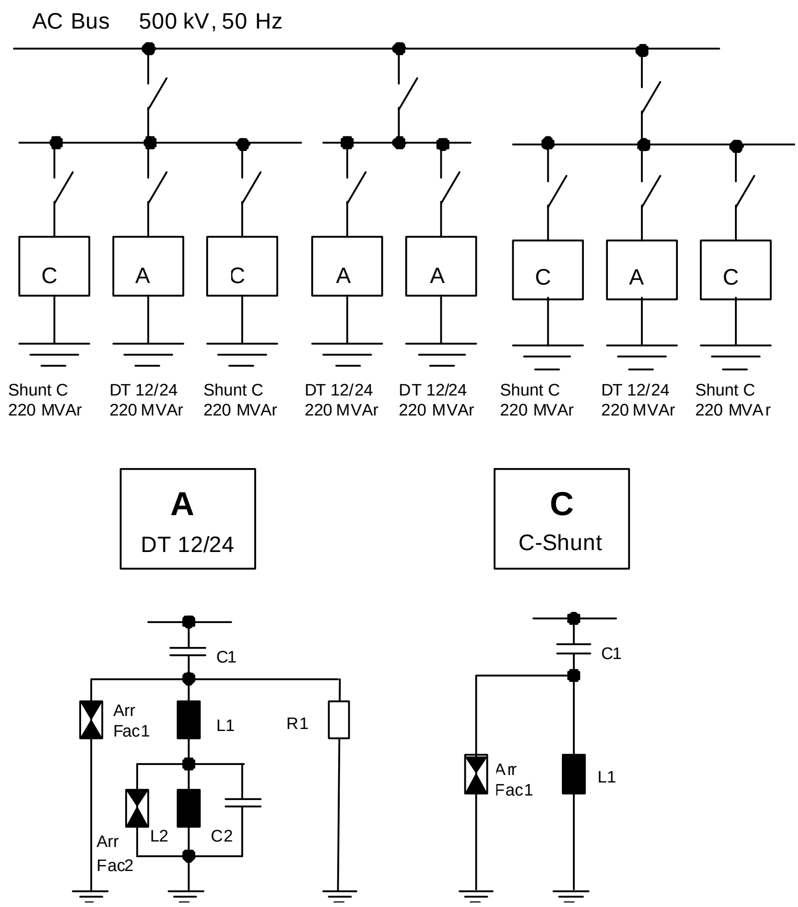
Ind. mH	20		40	
Harm. No.	kV	A	kV	A
dc	0,036	3600	0,072	3600
2	0,684	45,4	1,368	45,4
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	1,545	20,5	3,090	20,5
18	0	0	0	0
24	0,769	5,1	1,538	5,1
30	0	0	0	0
36	0,882	3,9	1,764	3,9
42	0	0	0	0
48	0,482	1,6	0,964	1,6
sum	4,362		8,724	

Table 2 : Rating for Smoothing Reactors (detailed Values)

3000 MW HVDC
AC Filter Data

Sheet No 3

AC Filters at Rectifier Station



AC FILTERS – INPUT - DATA

Nr	Q1 [MVAr]	Q2 [MVAr]	Q3 [MVAr]	N1 -	N2 -	N3 -	Rhp1 [Ω]	Rhp2 [Ω]	Rhp3 [Ω]
1									
2									
3									
4									

AC FILTER – Parameters

Nr	Qtot [MVAr]	C1 [uF]	L1 [mH]	Rhp1 [Ω]	C2 [uF]	L2 [mH]	Rhp2 [Ω]	C3 [uF]	L2 [mH]	Rhp3 [Ω]
1										
2										
3										
4										

	10 %			20 %			40 %			60 %			80 %			100 %			120 %		
n	min	nom	max	min	nom	max	min	nom	max	min	nom	max	min	nom	max	min	nom	max	min	nom	max
2																					
3																					
4																					
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23																					
25																					
29																					
31																					
35																					
37																					
41																					
43																					
45																					
47																					
THD																					
THFF																					

3000 MW HVDC
AC Filter Rating
100 % dc Voltage

Sheet No 5

		min detuning		nom detuning		max detuning	
		HV	LV	HV	LV	HV	LV
Ic	10 %						
	20 %						
	40 %						
	60 %						
	80 %						
	100 %						
	120 %						
Uc	10 %						
	20 %						
	40 %						
	60 %						
	80 %						
	100 %						
	120 %						
Pv	10 %						
	20 %						
	40 %						
	60 %						
	80 %						
	100 %						
	120 %						

3000 MW HVDC
AC Filter Transients

Sheet No 6

Location (see Figure 1)		FAULT CASE					
From	To	Component		Ground Fault (Lightning)	Switching Surge (Switching)	Filter Energization (Switching)	Fault Recovery (Switching)
1	G	Ac bus Arr.	kV				
			kA				
			kJ				
1	2	HV-Capacitor	kV				
			kA				
2	G	HV-Arrester	kV				
			kA				
			kJ				
2	3	HV-Reactor	kV				
			kA				
3	G	LV-Capacitor	kV				
			kA				
		LV-Reactor	kV				
			kA				
		LV-Arrester	kA				
			kJ				

Table 1 : Summary of ac Filter Transients for DT 11 / 24

Location (see Figure 1)		Protective and Insulation Levels					
From	To	LIPL kV	BIL kV	Margin %	SIPL kV	SIL kV	Margin %
1	G						
2	G						
3	G						
1	2						
2	3						

Table 2 : Insulation Levels of ac Filter Components for DT 11 / 24

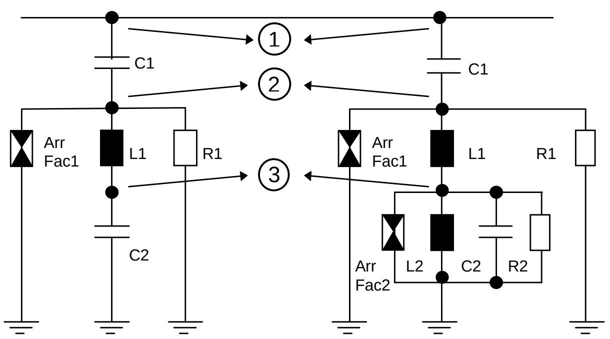


Figure 1 : Circuit Configuration for DT – Filters

3000 MW HVDC
DC Harmonics
100 % dc Voltage

Sheet No 7

Load [%]	Alf11 [deg]	Ue [deg]	F$ -	Usec [pu]
10			„DCHA_010.100“	
15				
20			„DCHA_020.100“	
25				
30			„DCHA_030.100“	
35				
40			„DCHA_040.100“	
45				
50			„DCHA_050.100“	
55				
60			„DCHA_060.100“	
65				
70			„DCHA_070.100“	
75				
80			„DCHA_080.100“	
85				
90			„DCHA_090.100“	1.00
95				
100	**15.0**	**22.3**	**„DCHA_100.100“**	**1.00**
105				
110			„DCHA_110.100“	1.00
115				
120			„DCHA_120.100“	1.00

3000 MW HVDC
DC Filter Data

Sheet No 8

DC Filters at Rectifier & Inverter

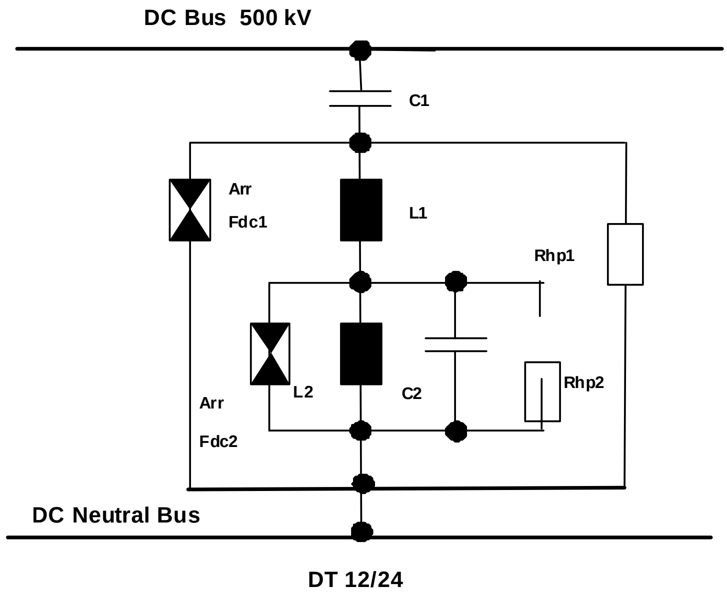


Figure 1: DC Filter Configuration

DC FILTERS – INPUT - DATA

Nr	C1 [MVAr]	N1 -	N2 -	Rhp1 [Ω]	Rhp2 [Ω]
1					
2					

DC FILTER – Parameters

Nr	C1 [uF]	L1 [mH]	Rhp1 [Ω]	C2 [uF]	L2 [mH]	Rhp2 [Ω]
1						
2						

3000 MW HVDC
DC Filter Performance
100 % dc Voltage

Sheet No 9

	10 %	25 %	40 %	55 %	70 %	85 %	100 %	110 %
n								
2								
3								
4								
5								
6								
7								
8								
9								
10								
12								
18								
24								
30								
36								
42								
48								
Ieq								

DC Filter Performance at different Loads (Ieq mA)

3000 MW HVDC
DC Filter Rating
100 % dc Voltage

Sheet No 10

		DT 12 / 24			
		HV		LV	
		Volts	Amp	Volts	Amp
Ic	10 %				
	20 %				
	40 %				
	60 %				
	80 %				
	100 %				
	120 %				
Uc	10 %				
	20 %				
	40 %				
	60 %				
	80 %				
	100 %				
	120 %				

3000 MW HVDC
DC Filter Transients

Sheet No 11

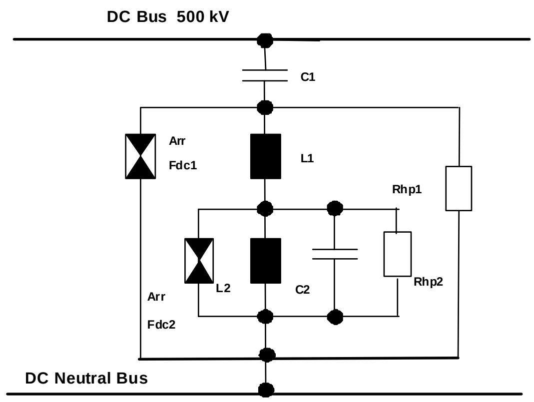
Location (see Figure 1)		FAULT CASE					
From	To	Component		Ground Fault	Switching Surge	Filter Energization	Fault Recovery
1	G	DC bus Arr.	kV				
			kA				
			kJ				
1	2	HV-Capacitor	kV				
			kA				
2	G	HV-Arrester	kV				
			kA				
			kJ				
2	3	HV-Reactor	kV				
			kA				
3	G	LV-Capacitor	kV				
			kA				
		LV-Reactor	kV				
			kA				
		LV-Arrester	kA				
			kJ				

Table 1 : Summary of ac Filter Transients for DT 12 / 24

Location (see Figure 1)		Protective and Insulation Levels					
From	To	LIPL kV	BIL kV	Margin %	SIPL kV	SIL kV	Margin %
1	G						
2	G						
3	G						
1	2						
2	3						

Table 2 : Insulation Levels of ac Filter Components for DT 12 / 24

DC Filters at Rectifier & Inverter



DT 12/24

Figure 1 : Circuit Configuration for DT – Filters

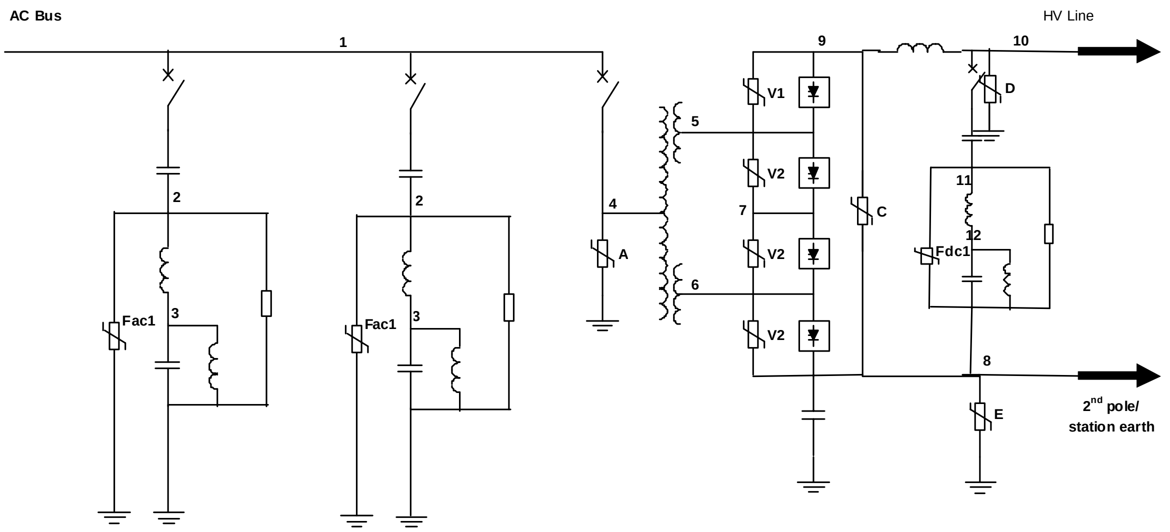
3000 MW HVDC
DC Filter Resonance

Sheet No 12

	10 %	25 %	40 %	55 %	70 %	85 %	100 %	110 %
n								
2								
3								
4								
5								
6								
7								
8								
9								
10								
12								
18								
24								
30								
36								
42								
48								
Ieq								

3000 MW HVDC
Insulation Coordination

Sheet No 13



LIPL: **L**ightning **I**mpulse **P**rotective **L**evel
SIPL: **S**witching **I**mpulse **P**rotective **L**evel

LIWL: **L**ightning **I**mpulse **W**ithstand **L**evel
SIWL: **S**witching **I**mpulse **W**ithstand **L**evel

Arrester Type		A	V1/V2	C	D	E	Fdc1	Fdc2	Fac1	Fac2	
MCOV	kV	318 rms	301 peak	571 peak	515 dc	< 50 dc	< 5 rms	< 5 rms	< 60 rms	< 30 rms	
Lightning											
- Prot. Level	kV	890	-	1033	1035	104	184	120	192	120	
- at Current	kA	10	-	5	30	30	40	10	20	10	
Switching											
- Prot. Level	kV	780	500	848	858	97	136	104	158	104	
- at Current	kA	1.5	0.8	1.0	2.0	15.8	2.0	2.0	2.0	2.0	
No of Colums	-	4	2	2	4	6*4	2	2	2	2	
No of Disks	-	103	67	126	114	13	17	13	20	13	
Energy Capability	MJ	8.2	3.3	6.3	11.6	6*1.3	0.85	0.55	1.0	0.55	

3000 MW HVDC
Insulation Coordination

Sheet No 13 A

Prot. Loc.	1	2	3		4	5	6	7	8	9	10	11	12
MCOV (kV)	318	< 60	< 60		318	571	301	301	<50	5719	515	<5	<5
LIPL (kV)	890	192	110		890	-	-	-	104	1033	1035	184	120
LIWL (kV)	1550	250	250		1425	1550	1050	1050	150	1425	1425	450	150
Margin (%)	**74%**	**30%**	**27%**		**60%**	**-**	**-**	**-**	**44%**	**37%**	**37%**	**44%**	**25%**
SIPL (kV)	780	170	159		780	1000	550	550	97	948	858	136	104
SIWL (kV)	1175	250	250		1175	1300	850	850	150	1300	1300	350	150
Margin (%)	**50%**	**47%**	**57%**		**50%**	**30%**	**54%**	**54%**	**54%**	**37%**	**51%**	**57%**	**44%**

Prot. Loc.	1 - 2	2 – 3		5&6 ph-ph	5 - 6	8 - 9	9 – 10*	9 - 10	10 - 11	11 – 12	Valves V1&V2
LIPL (kV)	780	192		-	-	1033	-	-	1035	184	-
LIWL (kV)	1050	250		1050	1550	1550	750	1300	1300	250	-
Margin (%)	**34%**	**30%**		**-**	**-**	**50%**	**-**	**-**	**25%**	**35%**	**-**
SIPL (kV)	742	144		550	1000	948	452	903	858	136	500
SIWL (kV)	1050	250		850	1300	1300	650	1175	1175	200	576
Margin (%)	**41%**	**73%**		**54%**	**30%**	**37%**	**43%**	**30%**	**37%**	**47%**	**15%**

Figure 1 : Insulation Coordination for Rectifier station