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3. TECHNICAL DATA

3.1. Dimensions and weight

Weight:

The converter cubicle according to chapter 1 should have a maximum weight of 3.5 t + 0%, including chassis and oil, but without oil pump. The weight of the converter has to be minimized!

Dimensions:

Drawing No. 3EHN110250

3.2. Converter cubicle

3.2.1. General construction

Assembly:

The converter cubicle is mounted in the machine room.

Components of the converter cubicle:

The converter cubicle is composed of a valve set module, an apparatus module, a series-resonant-circuit module and an expansion tank for the oil circuit.

Valve-set module

Main parts within the valve set module are four plugable valve sets, three of type 2 x ZV24 and one of type ZV24+MV23.

The valve set type 2 x ZV24 contains two branch valve sets at the two-point-Undeland-principle. The valve set ZV24+MV23 contains one branch valve set at the same principle and an overvoltage chopper (MUB-chopper), each with RCD snubber circuit. The NSR requires two valve sets of type 2 x ZV24, the ASR and MUB require together one valve set of type 2 x ZV24 and one of Type ZV24 + MV23.

The Gate units are placed next to the related valve sets. The DC link capacitors are placed behind. The connection to the valve sets should minimize the stray inductance. The oil circuit monitoring sensor is inserted into the oil supply pipe. Furthermore an expansion tank with oil level indication is placed upon the valve-set module. Oil filling and draining devices is located close to the oil inlet flange (Drawing No. 3EHN110250).

Apparatus module:

The apparatus module with the small electrical equipments and the control electronics is built aside the valve set module. The enumeration of the included apparatus is found under chapter 1 (piece numbers, apparatus module). The DC-link earthing switch must stay in operation with closed cabinet door. (switching and pushing in or pulling out of the key).

Series resonant circuit module:


The series resonant circuit is partially built into the converter cubicle. The capacitors are placed within the converter cubicle and the chokes within the main transformer tank.

Cooling:

The converter cubicle has its own, independent cooling system. For forced oil cooling of the valve sets, the modules are connected to the pipework with rapid action couplings. The parts within the apparatus module are cooled by convection.

Protection of people:

The three doors of the converter cubicle open with the E-key from the key multiplier Pos. 1004.6 only. The voltage indicator shall stay visible but not touchable with cabinet doors closed (LED under high voltage, construction with a window). The converter has to be cased in a way, that live parts cannot be touched during operation.

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Inscription:

Within the converter cubicle all apparatus have to be inscribed with their schematic position number according to the documentation. The rating plate has to be placed beside the assembled apparatus. All mechanically connected and exchangeable main parts (e.g. valve set) should be inscribed in such a way, that they can be identified clearly. This requires at least a series number and an identification number.

The inscriptions must be durable (carved or stamped, riveted, glued or bolt on) and placed in a way, that easy reading is possible, without any dismantling. Scale and location of warnings and instruction rules must be chosen according to requirements.

Form and type of warning rules in english, as per assembly drawings.

Protection:

No IP class specified for machine room.

Shock - and vibrational stress

Component	Vibration	Shock
Valve sets	ABB document HIET 615104	ABB document HIET 615104
Control electronics, Gate Units, GUSP, voltage and current sensors	IEC 571, Draft pr. EN 50155	IEC 571, Draft pr. EN 50155
Contactors, resistors	IEC 77	IEC 77
Capacitor banks	IEC 68-2-6	IEC 68-2-27

Non-detachable electrical connections

Preferably pressed-on or bolt-on.

Inflammability and toxicity of materials

- Materials must not contain PCB (polychlorinated biphenyls).
- Inflammability according to standard NF F16/101.

EMI-requirements:

Standards: according Draft pr. EN 50155

Additional documents (internal working instructions):

3EHN 600313	(EMI-domain plan)
3EHN 600314	(EMI wiring)
3EHN 600317	(Earthing and screening)

Painting:

Oil pipes : RAL 7030

All components needing a protective coat should be painted with clear varnish or varnish tone RAL 7030.

The demanded warranty of 5 years concerning corrosive protection has to be taken into account!

3.2.2. Loco data

Designation	: WAP5/WAG9
Axle arrangement Bo'Bo' (WAP5)	: bogie-selective drive, 2 motors
Axle arrangement Co'Co' (WAG9)	: bogie-selective drive, 3 motors
Traction sharing	: 1 converter cubicle per bogie
Hourly power at wheel rim	: 4500 kW
Continuous power at wheel rim	: 4500 kW under environmental conditions as mentioned in chapter 5

3.2.3. Traction winding data

Values at operational temperature of transformer, $T_{Cu} = 75^{\circ}\text{C}$.

Frequency	:	50 Hz	± 1.5 Hz
Operational voltage	nom.:	1269 V _{eff}	(full traction power, $U_{\text{prim}} = 25 \text{ kV}$)
	max.:	1396 V _{eff}	(full traction power, $U_{\text{prim}} = 27.5 \text{ kV}$)
	min.:	1142 V _{eff}	(full traction power, $U_{\text{prim}} = 22.5 \text{ kV}$)
	min_k:	888 V _{eff}	momentary ($U_{\text{prim}} = 17.5 \text{ kV}$)
	max_k:	1523 V _{eff}	momentary ($U_{\text{prim}} = 30 \text{ kV}$)
Operational current per winding	nom.:	1142 A _{eff}	continuous at $U_{\text{sek}} = 1269 \text{ V}_{\text{eff}}$
	max.:	1142 A _{eff}	
Self-inductance	:	2.1 mH	± 15 %
Internal resistance	:	< 34 mΩ	(calculated value; no guarantee)

For more informations see engineering-specifications "Transformer and magnetic components", documents 3EHP510054 (Bo'Bo') and 3EHP551108 (Co'Co').

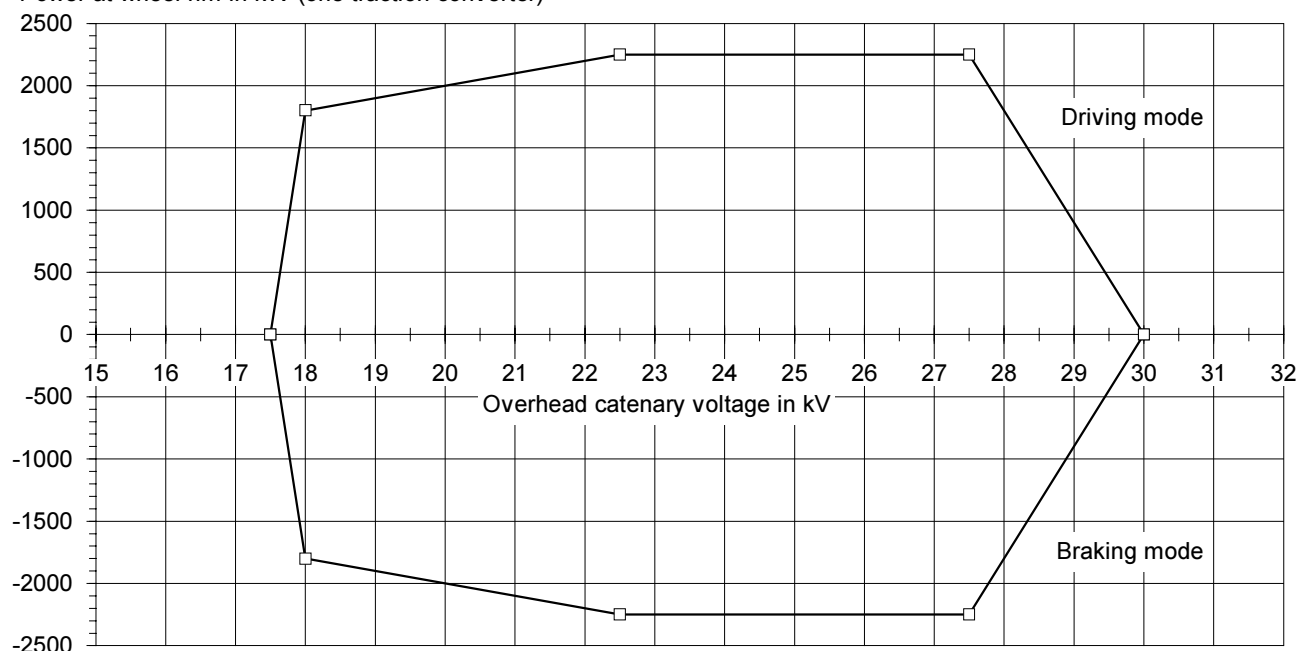
3.2.4. Converter data

Converter cubicle:

Max. obtained mechanical power P_{wheel} at wheel rim per converter cubicle (bogie) as a function of the line voltage U_L (fundamental component).

	Driving mode	Braking mode
P_{Wheel} at $U_L = 17.5 \text{ kV}$ (min)	: 0 kW	0 kW
P_{Wheel} at $U_L = 18 \text{ kV}$ (min)	: 1800 kW	-1800 kW
P_{Wheel} at $U_L = 22.5 \text{ kV}$: 2250 kW	-2250 kW
P_{Wheel} at $U_L = 25 \text{ kV}$ (nom)	: 2250 kW	-2250 kW
P_{Wheel} at $U_L = 27.5 \text{ kV}$: 2250 kW	-2250 kW
P_{Wheel} at $U_L = 30 \text{ kV}$ (max)	: 0 kW	0 kW


Power at wheel rim in kW (one traction converter)



Line converter (NSR):

Transformer windings per converter cubicle	:	2
NSR switching frequency	:	250 Hz ($k = 5$)

Series-resonant circuit:

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Resonant frequency	:	100 Hz	
Capacity, series resonant circuit	:	4.34 mF \pm 3%	
Inductance, series resonant choke	:	0.551 mH \pm 15%	(according to transformer specification)
	:	0.569 mH \pm 3%	(according to measurements on existing transformers)

Note:

Measurements on existing transformers have shown a value of the series resonant choke as 0.569 mH \pm 3%. To ensure a resonant frequency of 100 Hz at lower inductance an additional capacitor (560 μ F) may be mounted on the converter cubicle.

DC-link circuit:

Nominal link circuit voltage	:	2800 V \pm 5%
Max. transient (protective turn off)	:	3400 V
Capacity link circuit capacitor	:	11.41 mF
MUB-resistor	:	2.5 Ω \pm 5%
Inductivity min.	:	10 μ H
Inductivity max.	:	50 μ H
Clock frequency max.	:	200 Hz

At operation, the DC-link voltage is temporarily reduced.

Motor converter (ASR):

	Bo'Bo'	Co'Co'
Motors per converter cubicle	: 2	3
Motor type frequency	: 80 Hz	65 Hz
Line to line voltage	: 2180 V	2180 V

Losses per converter cubicle:

Converter cubicle losses (NSR + ASR)	:	116 kW + 0%	(oil cooled)
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Testing voltages:

Main circuit against case/auxiliary and battery circuit:
 $U_p = 9 \text{ kV}_{\text{rms}}, 50 \text{ Hz}$ (for initial testing without valve sets)

Battery circuit against case/main and auxiliary circuit:
 $U_p = 1.5 \text{ kV}_{\text{rms}}, 50 \text{ Hz}$

Auxiliary circuit against case/main and battery circuits:
 $U_p = 1000 \text{ V}_{\text{rms}}, 50 \text{ Hz}$

First the valve sets are tested separately.

3.2.5. Motor data

	Bo'Bo'	Co'Co'
Type :	6 FXA 7059	6 FRA 6068

For motor data and characteristics see documents:

3EHM 426602, 3EHM 426605, HBAM 94013 (Bo'Bo') and
 3EHM 426603, 3EHM 426606, HBAM 94014 (Co'Co')

Additional informations are given in engineering specification "Traction motor", documents 3EHW500451 (Bo'Bo') and 3EHW500452 (Co'Co').

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3.2.6. Cooling data

Oil cooling circuit:

Type	:	Forced oil cooling
Input oil temperature	max. :	65 °C
Oil flow rate	per module :	4 l/sec
	per converter cubicle :	16 l/sec at 65 °C inflow temperature
Pressure drop conveter cubicle	max. :	2700 mbar at 16 l/sec and 65 °C
Pressure drop oil cooling unit	max. :	600 mbar at 16 l/sec and 65 °C
Type of oil pump	:	Plumettaz TC10-2185/29
Power dissipation per converter cubicle	max. :	116 kW + 0 %

Coolant:

Type	:	Mineral oil
Make	:	Shell Diala DX
Oil quantity per valve set	:	62 l
Oil quantity per converter cubicle	:	300 l (without oil cooling unit)

Air cooling:

Converter control electronics:

Cooling air is drawn in from the vehicle bodyside via the Machine Room Blower, and ducted to the Traction Converter. To cool the control electronics an air/air heat exchanger has to be attached to the backside of the screening case. The temperature difference between the control electronics screening case inner air and cooling air should never exceed 5 K.

Gate units:

The Gate units are cooled from the lower side of the converter.

3.3. Valve sets

3.3.1. Valve set type 2 x ZV24-2830

Scheme position	:	12
Required number	:	3

Short description:

A valve set of type 2 x ZV24-2830 contains two branch valve sets at the 2-point-Undeland-principle.

Detail:

Manufacturer	:	Adtranz
Type	:	2 x ZV24-2830
Minimum oil temperature at operation	:	0 °C
Minimum oil temperature at storage	:	0 °C

3.3.2. Valve-set ZV24+MV23-2830

Scheme position	:	13
Required number	:	1

Short description

A valve set of type ZV24+MV23-2830 contains a branch valve set at the two-point-Undeland-principle and an overvoltage chopper (MUB-chopper), each with RCD snubber circuit.

Detail:

Manufacturer	:	Adtranz
Type	:	ZV24 + MV23-2830
Minimum oil temperature at operation	:	0 °C
Minimum oil temperature at storage	:	0 °C

3.4. Gate unit / Gate unit-power-supply

3.4.1. Gate unit

Scheme position : 227, 228, 229
Required number : 15

Design specification:

Manufacturer : ABB
Type : GVA 587 A01

3.4.2. Gate unit power-supply (GUSP)

Scheme position : 219
Required position : 1

Electrical data:

Supply voltage : 110 V_{DC} (range: 77 till 137.5 V)
Power output : 1000 W to $T_A \leq 25^\circ\text{C}$
Minimal efficiency : 0.9

Detail:

Manufacturer : ABB
Type : KY A924 C01
Design : with plugable print and cover

3.4.3. Precharge-resistor to GUSP

Scheme-position : 219.1
Required number : 1

Electrical data:

Resistance : 47 Ω , 250 W
Allowed dissipation power : 250 W continuous at $T_A \leq 25^\circ\text{C}$

Detail:

Manufacturer : Danotherm
Type : GRF 30/265-401284

Cooling/assembly

Cooling : convection
Maximum surface temperature : 300 $^\circ\text{C}$ at $T_A = 50^\circ\text{C}$

Free flow of cooling air must stay unaffected.

3.5. Series resonant circuit capacitor

Scheme-position : 15.4
Required number : 7 single capacitors + 1 single adjustment capacitor

Electrical data:

Capacitiy per capacitor : 560 μ F \pm 5%
total : 4.34 mF \pm 3%

Electric strength : 4000 V_{DC}

While selecting the capacitors it has to be ensured, that their tolerances within the converter cubicle compensate each other as accurately as possible, not to exceed the range of the adjustment capacitor. If necessary, 1 single capacitor has to be added to ensure the adjustment of the 100 Hz resonant frequency.

Detail:

Manufacturer : ERO
Type : Gfp 3.8 / 560 μ F

3.6. Capacitor DC-link


Scheme position : 15.5
Required number : 14 single capacitors

Electrical data:

Capacity : 11.41 mF + 5 / - 5%
Nominal electrical strength : 2940 V_{DC}
Maximal electrical strength : 3090 V_{DC}

Detail:

Manufacturer : Condis SA
Type : CDM 15230 A 0815
Nominal data : 815 μ F +;_ 5 % / 2940 V

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3.7. Contactors

3.7.1. Precharge contactor

Scheme-position : 12.3
Required number : 1

Electrical data:

Current : 50 A
Voltage : 3000 V
Operation : electro-magnetically, 110 V_{DC}

Detail:

Design : single contactor
Manufacturer : Sécheron SA
Type : HS_m
Special requirement : with transzorb+diode snubber and auxiliary contacts;
arc-blow-out-coil to be designed for 30 A

3.7.2. Main contactor

Scheme position 12.4 : Identification HSBA433691 R1485
Required number : 1

Required data:

Voltage : 2 x 1500 V
Current : 2 x 1500 A
Operation : electro-pneumatically, 110 V_{DC}

Detail:

Design : Double contactor
Manufacturer : Sécheron SA
Type : BPS 15.15 C/2
Special requirements : with transzorb+diode snubber and auxiliary contacts

3.7.2. GUSP contactor

Scheme position : 218.4
Required number : 1

Electrical data:

Nominal current (at 124 V_{DC}) : 8 A
Operation : electro-mechanically, 110 V_{DC}

Detail:

Design : closing contactor with auxiliary contacts
Manufacturer : Schaltbau München
Type : S163C1DT/110V
Special requirements : with transzorb+diode snubber circuit

3.8. Precharge-resistor and MUB-resistor

3.8.1. Precharge-resistor

Scheme-position 14 : Identification 3EHN424095 P1250
Required number : 1

Electrical data:

Resistance : $50 \Omega \pm 10\%$
Voltage : $1517 V_{RMS}$

Detail:

Manufacturer : Microelettrica
Type : 150 KWs / 50Ω

Cooling/assembly

Cooling : convection
Maximum surface temperature : 300°C at $T_A = 50^\circ\text{C}$

Free flow of cooling air must stay unaffected.

3.8.2. MUB-resistor

Scheme-position 15.1 : Identification 3EHN424091 P0025
Required number : 1

Electrical data:

Resistance : $2.5 \Omega +;_- 5\%$
Voltage : $2800 V$

Detail:

Manufacturer : Microelettrica
Type : Res* 1MWs- 2.5Ω

Cooling/assembly:

Cooling : convection
Max. surface temperature : 500°C at $T_A = 60^\circ\text{C}$

Free flow of cooling air must stay unaffected.

3.9. Measuring devices

3.9.1. Primary voltage transformer module

Scheme-position 224 : Identification HIET401147 R0001
Required number : 1

Electrical data:

Primary rated voltage : 200 V_{eff}
Frequency : 50 Hz
Transforming ratio : 1:50
Secondary rated voltage : 4 V_{eff}
Circuit : passive
Special requirement : circuit is connected to the primary voltage transformer (scheme position 3)

Detail:

Manufacturer : ABB/BAL
Type : UU A225 A11

3.9.2. NSR voltage sensor

Scheme-position 18.2 : Identification 3EHN424026 P0002
Required number : 4

Electrical data:

Primary rated current : 2000 A
Transforming ratio : 1:5000
Circuit : active
Test winding : yes

Specification:

Manufacturer : LEM
Type : LEM LT2000-S/SP20

3.9.3. Voltage sensor DC-link

Scheme position 15.6 : Identification 3EHL300358 R0001
Required number : 2

Electrical data:

Designation : voltage transformer 4 kV
Input clamps : 4 kV connections
Supply voltage : ± 15 V or ± 24 V
Special requirement : no shunt needed
Manufacturer : KUK Elektronik AG
Type : PV C000 A01

3.9.4. ASR-current sensor

Scheme position 18.5 : Identification 3EHN424026 P0002
 Required number : 3

Electrical data:

Primary rated current : 2000 A
 Ratio of transforming : 1:5000
 Circuit : active
 Test-winding : yes

Detail:

Manufacturer : LEM
 Type : LEM LT2000-S/SP20

3.9.5. Earth fault detector

Scheme position 89.4 : Identification 3EHL300358 R0001
 Required number : 1

Electrical data:

Designation : voltage transformer 4 kV
 Input clamps : 4 kV-connectors
 Supply voltage : ± 15 V or ± 24 V
 Special requirement : no shunt needed

Detail:

Manufacturer : KUK Elektronik AG
 Type : PV C000 A01

3.9.6. Oil circuit monitoring

Scheme position 210.61 : Identification 3EHN 424142 R5000
 210.62 : 3EHN 424144 R5000
 Required number : 1

Short description:

The oil circuit monitoring consists of two sensors. The system measures oil temperature and oil pressure difference simultaneously.

Pressure difference sensor:

Manufacturer : Baumer Electric
 Type : PDRB K005 W22 B240

Oil temperature sensor:

Manufacturer : Allmetra
 Type : 2 x PT100
 (double wire circuit)

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3.10. Earthing

Earthing is done asymmetrically.

3.10.1. Earthing resistor DC-link

Scheme-position	: 90.61, 90.62
Required number	: 3 + 3
Circuit	: according to specification

Electrical data:

Resistors R1 to R3	: 22 k Ω , 250 W
Resistors R4 to R6	: 6.8 k Ω , 250 W
Allowed dissipation power	: 250 W continuous at $T_A \leq 25^\circ\text{C}$
Connection	: series connected

Detail:

Manufacturer	: Danotherm
Type	: GRF 30/265-401284

Cooling/assembly

Cooling	: convection
Maximum surface temperature	: 300 °C at $T_A = 50^\circ\text{C}$

Free flow of cooling air must stay unaffected.

3.11. Safety devices

3.11.1. Earthing switch DC-link

Scheme-position	: 15.82
Required number	: 1

Short description of the interlocking concept

Operating the earthing switch is only possible, if the key C from key-multiplier Pos. 1004.2 is pushed in. As soon as earthing is o.k., the key D can be pulled off. With all keys D one get the keys E from key-multiplier Pos. 1004.6. The keys E open the cabinet doors of the converter cubicle.

Electrical data:


Voltage	: 3 kV
Current	: 400 A
Operation	: manually

Detail:

Manufacturer	: Sécheron SA
Type	: 07-03.04/2

Assembly:

The DC-link earthing switch shall work without opening of the cabinet doors as mentioned earlier (switching and pushing key in or pulling out).

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3.11.2. Voltage indicator

Scheme position : 15.7
Required number : 1

Electrical data:

Voltage indication : from 40 V onwards
Voltage max. : 3500 V continuous
max. : 4000 V during 120 ms
Flashing frequency : proportional to voltage

Detail::

Manufacturer : B+Z Elektronik
Type : BVW 3230A

Assembly:

The voltage indicator shall be visible but not touchable (due to LED high voltage), if the cabinet doors are closed (e.g. door construction with a window).

3.12. Converter bus station

3.12.1. Supply

The bus station is supplied from the vehicle battery.

Battery voltage : 110 V_{DC}
Operational range : 77 V (- 30 %) to 137.5 V (+ 25 %)

Max. allowed power consumption is 120 W (continuous power).

Overvoltage protection according to Draft preliminary EN 50155.

3.12.2. Interface list

The external signals as speed sensing, temperature-measuring and so on are listed in the interface lists

3EHW410054 (Bo'Bo')
3EHW410055 (Co'Co')

3.12.3. Plug coding

Front plugs and backplane-coding have to be assigned for the converter control electronics.

4. STANDARDS / QUALITY

4.1. Standards

IEC 850	: Supply voltage of traction systems
IEC 77	: Electrical traction equipment
IEC 411-5	: Rules for electronic power converters
NF.F.16.101	: Rolling stock; Fire behaviour; Materials choosing
NF.F.16.102	: Rolling stock; Fire behaviour; Effects on electrical equipment
Draft pr. EN 50155	: Railway applications-electronic equipment used on rolling stock
IEC 801	: Electromagnetic compatibility for industrial process measurement and control equipment
3EHN 600 359	: Insulation coordination
3EHN 600 385	: Min. insulation distance for basis insulation within air
3EHN 600 388	: Min. insulation distance for basis insulation within oil

4.2. QA-qualification

According to Quality Management Manual 3EHQ 600 002:

Converter without control electronics	: Q-Class 2
Converter control electronics	: Q-Class 4

4.3. Quality assurance

An ISO 9001 compatible quality assurance system has to be used.

5. REQUIREMENTS ON RELIABILITY

5.1. Environmental conditions

Environmental condition within the machine room:

Air circulation	: Weak forced cooling
Operational temperature	: 0 ... +65 °C
Environmental air	: salty, dusty
Air humidity	: Condensation possible

Conditions around the oil cooling:

Air circulation	: Forced cooling
Operational temperature	: 0 ... +47 °C
Environmental air	: salty, dusty
Air Humidity	: Condensation possible

5.2. Operational conditions

Operational time

Daily approx.	: 16 hours (approx. 330 days per year)
Yearly approx.	: 5'280 hours
Within 30 years approx.	: 158'400 hours

Environmental conditions

Rated values for environmental temperature and air humidity according to chapter 5.1; "Conditions within the machine room and around the oil cooling".

5.3. Reliability

Operational conditions	: according to chapter 5.2
Availability rate	: 98 %
Lifetime of the loco	: min. 30 years (Maintenance, spare parts, lifetime)

5.3.1. Failure rate

Failure classification:

The following MTBF are estimated:

Cat. 1: Critical failure	MTBF: $2.0 \cdot 10^6$ h
Cat. 2: Operational failure	MTBF: $1.4 \cdot 10^4$ h

The indication of failure classes and the related MTBF is required.

6. TEST CONDITIONS

Type test:

According to IEC 411-5 and test specification. Indian Railways prescribes a type test for every component. Exceptions are only made, if the concerned component has been tested earlier, used as a strictly identical item (down to the smallest screw) and run under identical conditions (e.g. leading the cooling airflow). Therefore, a type test is required. The type test planning shall be submitted to the technical project management and the Indian Railways representatives for approval.

The acceptance test takes place in the presence of the Inspecting Officer from Indian Railways. For client's information, a definite timetable must be submitted to the project management at least 7 weeks before start of the test.

Routine tests:

According to IEC 411-5 and test spec. Part UW 2423-2810. They have to be submitted to the technical project management for approval.

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7. DOCUMENTATION

7.1. General

Project Designation : Indian Railways, WAG9 Locomotive

7.2. Contents

7.2.1. Drawings, tracings and descriptions

All drawings and descriptions which are necessary for design, assembly and commissioning of the traction converter. A parts list / components list to each drawing has to be given. Within the individual lists all parts of the corresponding drawing have to be mentioned, including consumable items.

A family-tree has to be given, including all drawings, parts lists and other relevant documents which are part of the documentation. Also a complete list of all documents and a complete list of all components („Bill of Materials“) form part of the documentation.

7.2.2. Manual

The manual includes all necessary information for correct operation, maintenance, fault finding and repair of the traction converter, including spare parts catalogue and instructions for assembly, dismantling and replacement of the individual components.

7.3. Language

All documents, including reference documents, have to be given in english. For translation the document 3EHP620108 „Index of English and German Abbreviations and Designations“ has to be used. Other ideas and short forms may only be used with approval by the responsible documentation department within the project organisation.

7.4. Structure

7.4.1. Drawings, tracings and descriptions

The documentation shall be structured by the following order:

1. Family tree
2. List of drawings (sorted by Ident-No.)
3. Bill of Materials (sorted by Ident-No.)
4. Drawings, etc. (sorted by subassembly components, corresponding to the family tree)

All documents have to be given in proper folders. Loosen documents will not be accepted.

7.3.2. Manual

An overview of function and work order has to be given. The chapters of the manual must belong to the individual subassembly components. All drawings and documents, which are used as reference documents have to be given as annexure to the manual.

7.5. Standards / Units

Only IEC-Standards will be accepted. Internally used BBC/ABB/Adtranz-Standards may only be mentioned together with the corresponding IEC-Standard. Only SI-Units will be accepted.

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7.6. No. of documents

7.6.1. Drawings, tracings and descriptions

6 sets of copies	(according to 7.3.1.),
1 set of reproducibles	(only drawings; sorted by Ident-No.),
1 set of microfilms	(only drawings; sorted by Ident-No.)

7.6.2. Manuals

4 sets of copies	(according to 7.3.2.)
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7.7. Type-/Routine-Test documentation / Special documents

7.7.1. Converter cubicle

Documents
Test specification, part testing
Test record, part testing
Test specification type test
Test records type test
Thermal characteristics of the GTO an the GTO cooling elements (heat sinks)
Data sheets GTOs and Diodes
Documentation design oil cooling
Documentation design power circuit
Diagrams of efficiency and power dissipation as a function of TE-speed characteristics.

7.7.2. Converter Control Electronics

Document
Test program type test
Test program routine test
MTBF-values per apparatus and bus station
<i>Maintenance related documents:</i>
Assembly drawing for rack
Wiring schematics for backplane
Complete parts list for rack
<i>Documentation per PCB</i>
Data sheet
Apparatus schematics
Parts list
In-line assembly drawing (plan)*
Test instructions*

* dependent on maintenance concept

7.8. Quality proof

Document
Standard test plan for oil cooled converters
Standard-test plan for valve set 2 x ZV24-2830
Standard-test plan for valve set ZV24 + MV23-2830
Standard-test plan for series resonant circuit capacitor cubicles
Test plan for converter control electronics

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8. DELIVERY REQUIREMENTS

- Acceptance : Yes
- Delivery schedule : according to MPS of project IR WAP5
ABB Daimler Benz Transportation (Switzerland) Ltd,
Dept. BBG-IR
- Packing : according to supplier instructions
- Delivery address : Tramont
- Type test : Yes
- Routine test : Yes
- Purchasing specification : according to the special purchasing conditions for the
Indian Railways project No. IR GP-140

8.1. Scope of Supply

Material:

- Converter cubicle, tested
- Expansion tank with oil level indications
- Oil filling and draining devices

Work:

- General engineering without SLG-software
- Construction
- Documents
- Assembly of the converter cubicle
- External wiring and laying of pipes of the converter cubicle
- Load test

9. REFERENCE DOCUMENTS

No.	Title	Pages	Ident.-No.
1	TE/BE-speed-diagrams	4	HBTB 490730 HBTB 490726 HBTB 490731 HBTB 490727
2	General scheme main current Bo'Bo' General scheme main current Co'Co'	2	3EHP 281101 3EHP 281141
3	Overall scheme, auxiliary devices Bo'Bo' Overall scheme, auxiliary devices Co'Co'	2	3EHP 281102 3EHP 281142
4	Schematics valve set 2 x ZV24		HIET 310430
5	Schematics valve set ZV24+MV23		HIET 310431
6	Interlocking concept	1	3EHP 510209
7	Motor characteristics	2	3EHP 426605 3EHP 426606
8	Motor data sheet	2	3EHP 426602 3EHP 426603
9	Vibration and shock testing of the converter		HIET 615104
10	Outline drawing converter cubicle	1	3EHP 110250
11	Technical Specification IR GP-140	83	Annexure No. 5 to Contract No. 92/RSF/459/1
12	Interface list, Converter control electronics <-> Environment	2 2	3EHP 410054 3EHP 410055
13	Standards NF.F.16.101, NF.F.16.102		
14	Test specification type test of the converter cubicle UW 2423-2810	28	3EHP 610307
15	Technical data sheet for asynchronous traction motor IR Loco. type GP-140/R. Passenger locomotive Bo'Bo'	4	HBAM 94013
16	Technical data sheet for asynchronous traction motor IR Loco. type GP-140/R. Freight locomotive Co'Co'	4	HBAM 94014
17	Inspection and test prescription for the customer	1	Supply Contract No. 92/RSF/459/1

Note: The latest revision status of the above reference documents should be utilised.

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ADtranz		ABB Daimler-Benz Transportation (Schweiz) AG			3EHW 500453
Responsible department: BEM2		Take over department: -	Revision: H 96-12-09 Hack	Doc.-type: ES	File no.:
Prepared: 93-01-25 A. Müller		Checked: 93-03-02 A. Trümpi	Approved: 93-03-03 F. Laczo		Language: Page: en 23/22
Valid for: IR WAP5 / WAG9		Derived from:	Replaces:	Classify no.:	File: file.doc

Punch: ☒ 2 holes ☐ 4 holes ☐ spiral-boundStaple: ☒ 1 x ☐ 2 x ☐ glue-boundCopies: ☒ single-sided ☐ double-sided**Distribution:**

Loc.	Department	Names	Copies	Updates	Remarks
Oe	BASP	Lehmann	1		
Tu	BALP1	Sumpf	1		
Oe	BEM2	H.Hack	2		
Oe	BES1	F. Buzzelli	1		

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ABB		ABB Transportation Systems Ltd		3EHN 420 456	
Responsible department: BASP		Take over department:		Revision: A / 95-09-15, 11	Doc.-type: DOK
Prepared: 95-05-23 Imhof		Checked: 95-06-02 Mesic		Approved: 95-06-27 Schmid	
Valid for: IR WAP-5 / WAG-9		Derived from:		Replaces:	File no.: 420456EA.DOC
				Language: en	Page: 1/21

WAP-5 / WAG-9 Converter:

Electrical Design Calculations

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1. GENERAL

1.1 Documents

[1]	Motor Data Sheet for Motor 6FXA7059 (Bo'Bo')	3EHM 426 602 Rev.: d
[2]	Motor Diagram for Motor 6FXA7059 (Bo'Bo')	3EHM 426 605 Rev.: a
[3]	Motor Data Sheet for Motor 6FRA6068 (Co'Co')	3EHM 426 603 Rev.: d
[4]	Motor Diagram for Motor 6FRA6068 (Co'Co')	3EHM 426 606 Rev.: a
[5]	Guidelines for the Design of the DC-link	TN BAS 91.24.045
[6]	Calculation of the RMS DC-link Current in 2 State Converters	TN BAS 93.24.044
[7]	Engineering Specification Converter IR GP-140/R	3EHW 500 453 Rev.: e
[8]	Engineering Specification Transformer IR GP-140/R	3EHP 510 054 Rev.: b
[9]	Isolation Coordination for IR GP-140/R	TN BAS 94.24.029
[10]	ALG Software Specification Bo'Bo', Part BEH	3EHP 551 009 Rev.: a
[11]	ALG Software Specification Co'Co', Part BEH	3EHP 551 010 Rev.: a

1.2 List of Abbreviations

AC	Alternating current
ASR	Motor converter
DC	Direct current
DSR	Direct self control mode
GTO	Gate Turn Off Thyristor
IdSAR	Current threshold for protective shut-down
ISR	Indirect self control mode
MUB	Overvoltage protection circuit
NSR	Line converter
R1	Free-wheeling resistor in the Undeland valve set
SR	Converter
UdMUB3	Overvoltage protection switch on threshold
UdMUB4	Overvoltage protection switch off threshold
UdSAR	Voltage threshold for protective shut-down
VDA	Valve device assembly
V1	GTO in the Undeland valve set
V5	Main diode in the Undeland valve set
ZK	DC-link
ZV	Phase (of a line or motor converter)
2P	2 state, converter DC-link with 2 voltage levels

1.3 Application Programs

- 2 state converter dimensioning program in the INTENS data base
- Program for the calculation of the DC-link capacitor current from Mr. Reichelt
- Program for the calculation of the possible reduction of the DC-link voltage from Mr. Mesic

2. DESIGN CALCULATIONS FOR THE COMPONENTS / MODULES

2.1 Transformation of the Mechanical Data into Electrical Quantities

The electrical motor data is given in the motor data sheets [1], [3] and in the motor diagrams [2], [4]. The power at the motor shaft (P_{2mot}) and $\cos\phi$ were derived from the motor characteristics for the calculations. P_{2mot} represents 2 motors (Bo'Bo') resp. 3 motors (Co'Co') in parallel. The required electrical output power (P_{2conv}) of the converter as it is needed according to engineering spec. [7] also is added in the last column of the tables of enclosure 2.1. The efficiency between converter (P_{2conv}) output and wheel axle (P_{wheel}) is assumed to be 95% ($P_{wheel} = 0.95 \times P_{2conv}$). This data is used for the motor converter and line converter calculations.

See enclosure 2.1:

- Table $\cos\phi = f(f_1)$, $P_{2mot} = f(f_1)$, $P_{2conv} = f(f_1)$, Bo'Bo'
- Table $\cos\phi = f(f_1)$, $P_{2mot} = f(f_1)$, $P_{2conv} = f(f_1)$, Co'Co'

2.2 Transformer

Datas from engineering specs. [7] and [8]

Number of secondary windings:	n	=	2	
Secondary voltage:	UNSR	=	1269	Vrms $\pm 10\%$
Transformation ratio:	\ddot{u}	=	19.7	
Nominal current per winding:	INSRn	=	1142	Arms
Max. current per winding:	INSRmax	=	1142	Arms
Leakage inductance per winding:	$L\sigma$	=	2.1	mH $\pm 15\%$
Resistance per winding:	RT	<	34	m Ω
Line frequency:	fN	=	50	Hz $\pm 1.5\text{ Hz}$

2.3 Line Converter

The calculations were only performed for the Co'Co' locomotive because its rated power is higher than for the Bo'Bo' locomotive (worst case). The most unfavourable values in motoring mode are given below and can be seen in the tables in enclosure 2.3.

Max. line converter input voltage:	UNSRmax	=	1523	Vrms
Max. secondary winding current:	INSRmax	=	1144	Arms
Max. periodic turn-off current:	Itqm	=	1803	A
Max. allowable periodic turn-off current:	ITQM	=	2250	A
Max. losses per phase:	PvZVmax	=	14.1	kW
Switching frequency:	fT	=	250	Hz
Ratio switching / line frequency:	fT/fN	=	5	

Max. DC-link power:	Pdmax	=	2368	kW
Max. DC-link current (at Ud = 2800 V - 5%):	Idmax	=	890	A

See enclosure 2.3:

- Table INSR = f(Uline, P2conv, LTr), Bo'Bo' and Co'Co'
Transformer secondary winding current INSR, rms value as a function of the line voltage, the electrical output power and the transformer leakage inductance (f1 = 45 Hz).
- Table Itqm = f(Uline, P2conv, LTr), Bo'Bo' and Co'Co'
Max. periodic turn-off current Itqm as a function of the line voltage, the electrical output power and the transformer leakage inductance (f1 = 45 Hz).

2.4 DC-link, Resonant Circuit

DC-link voltage:	Ud	=	2800	V	± 5 %
DC-link capacitance:	Cd	=	11.41	mF	± 5 %
Max. DC-link capacitor current:	Icmax	=	860	Arms	
Min. resonant circuit capacitance:	Cskmin	=	4.21	mF	
Max. inductance of resonant circuit choke:	Lskmax	=	0.59	mH	
Max. resonant circuit current:	Iskmax	=	791	Arms	

See enclosure 2.4:

- Table Isk = f(Uline, P2conv, LTr), Co'Co'
Resonant circuit current Isk, rms value as a function of the line voltage, the electrical output power and the transformer leakage inductance (f1 = 45 Hz).
- Diagram Isk = f(f1), Bo'Bo' and Co'Co'
Resonant circuit current Isk, rms value as a function of the stator frequency f1.
- Diagramm Ic = f(f1), Bo'Bo' and Co'Co'
DC-link capacitor current Ic, rms value as a function of the stator frequency f1.

2.5 Overvoltage Protection Circuit (MUB)

It was calculated what the max. DC-link voltage is when a protective shut-down occurs at Id = Idmax. The MUB resistor is already switched on at this time.

Protective threshold voltage:	UdSAR	=	3350	V	
DC-link voltage:	Ud	=	2800	V	± 5 %
Protective threshold current:	IdSAR	=	2500	A	
Max. allowable periodic turn-off current:	ITQM	=	2250	A	
Leakage inductance of transformer:	Lσ	=	2.1	mH	
DC-link capacitance:	Cd	=	11.41	mF	± 5 %
Effective MUB resistance:	RMUB	=	2.5	Ω	± 5 %
Max. DC-link voltage after protective shut-down:	Udmax	=	3928	V	

2.6 Motor Converter

Calculations were carried out over the full speed range of the motors. The worst-case results are given below. Some values are different for the application in Bo'Bo' locomotives and Co'Co' locomotives:

Max. output current per phase:	IASRmax	=	953	Arms	(Bo'Bo', f1 = 40 Hz)
	IASRmax	=	971	Arms	(Co'Co', f1 = 30 Hz)

Max. periodic turn-off current:	I_{tqm}	=	2120	A	(Bo'Bo', $f_1 = 45$ Hz)
	I_{tqm}	=	2171	A	(Co'Co', $f_1 = 35$ Hz)
Max. allowable periodic turn-off current:	I_{TQM}	=	2250	A	
Max. losses per phase:	P_{vZVmax}	=	17,5	kW	(Bo'Bo', $f_1 = 45$ Hz)
	P_{vZVmax}	=	17,8	kW	(Co'Co', $f_1 = 35$ Hz)
Switching frequency:	f_T	=	250	Hz	

See enclosure 2.6:

- Diagram $I_{tqm} = (f_1)$
Max. periodic turn-off current I_{tqm} as a function of the stator frequency f_1 .

2.7 Line Harmonics

Dr. Skarpetowski has calculated the harmonic currents produced by the locomotives.

2.8 Protection

The protective thresholds and protective characteristics are given in enclosure 2.8. The datas are derived from the engineering spec. [7] and the busstation software spec. [10] and [11].

See enclosure 2.8:

- Protective characteristic 1A, Bo'Bo'
Input power P_{in} as a function of the line voltage U_{line}
- Protective characteristic 1A, Co'Co'
Input power P_{in} as a function of the line voltage U_{line}
- Protective characteristic 2A, Bo'Bo'
Torque T as a function of motor speed n
- Protective characteristic 2A, Co'Co'
Torque T as a function of motor speed n
- Protective characteristic 2B, Bo'Bo' and Co'Co'
Limitation of converter output current I_{asr} as a function of the stator frequency f_1
- Protective characteristic 4A, Bo'Bo' and Co'Co'
MUB characteristic in dependence on the DC-link voltage U_d .
- Protective threshold voltage U_{dSAR} , Bo'Bo' and Co'Co'
- DC-link voltage reduction characteristic $U_d = f(P_{in})$ for motoring mode, Bo'Bo' and Co'Co'
- DC-link voltage reduction characteristic $U_d = f(P_{in})$ for braking mode, Bo'Bo' and Co'Co'

2.9 RMS Currents in the Busbars and Cabling

The max. rms current values are given for Co'Co' locomotive in enclosure 2.9.

2.10 Rated Insulation Voltage

Insulation coordination

See insulation coordination [9].

Test voltages

- Power circuits - earth:	9.0 kV, 50 Hz, 1 s
- Battery circuits - earth:	1.5 kV, 50 Hz, 60 s
- Electronic circuits - earth:	1.0 kV, 50 Hz, 60 s

2.11 Cooling

Max. allowable oil inlet temperature:

$$t_{oilmax} = +65 \text{ }^{\circ}\text{C}$$

Max. allowable temperature difference between inlet and outlet:

$$\Delta t_{oil} = 5 \text{ K}$$

3. COMPONENTS

3.1 Components of Valve Device Assemblies

The power losses of the main components and the complete converter can be seen in enclosure 3.1. According to the engineering spec. [7] the max. power losses of the complete converter shall not exceed 116 kW.

See enclosure 3.1:

- Table of the main component power losses in a NSR, Co'Co':
The power losses of a GTO (V1), main diode (V5), snubber resistor (R1) and a whole phase (ZV) in a line converter are shown. The parameters for the different cases are the line voltage U_{line} , the corresponding required power and the leakage inductance of transformer secondary winding L_{tr} . The required power was derived from the engineering spec. [7] using a (bad) efficiency between DC-link and wheel axle of 85% (according to protection characteristic 1A, enclosure 2.8 with $P_{VNSR} = 0 \text{ kW}$). The calculation was only done for the more powerfull Co'Co' converter.
- Diagram of ASR, NSR and converter power losses, Bo'Bo' and Co'Co':
The power losses of the motor converter (P_{VASR}), the line converter (P_{VNSR}) and the complete traction converter (P_{VSR}) are shown as a function of the stator frequency f_1 . The power losses in ISR and DSR mode are given for a switching frequency of 250Hz.
- Diagram of the main component power losses in a ASR, Bo'Bo' and Co'Co':
The power losses of a GTO (P_{VV1}), a main diode (P_{VV5}), a snubber resistor (P_{VR1}) and a whole phase (P_{VZV}) in a motor converter are shown as a function of the stator frequency f_1 . The power losses in ISR and DSR mode are given for a switching frequency of 250Hz.
- Diagram of the main component power losses in a NSR, Bo'Bo' and Co'Co':
The power losses of a GTO (P_{VV1}), a main diode (P_{VV5}), a snubber resistor (P_{VR1}) and a whole phase (P_{VZV}) in a line converter are shown as a function of the stator frequency f_1 . The power losses in ISR and DSR mode are given for a switching frequency of 250Hz.

3.2 Capacitors

The graphs of the currents in the DC-link capacitor and series resonant circuit capacitor can be seen in enclosure 2.4.

3.3 Precharging Resistor

Max. line voltage:	$U_{linemax}$	=	30	kV
DC-link capacitance:	C_d	=	11.41	mF
Resonant circuit capacitance:	C_{sk}	=	4.34	mF
Resistance of precharge resistor:	R_l	=	50	Ω $\pm 10 \%$

The energy dissipated in the precharge resistor is 36.6 kJ each time the DC-link is charged.



3.4 MUB Resistor

Resistance of precharge resistor: RMUB = 2.5 Ω $\pm 5\%$

Motor efficiency: η_{FM} = 98 %

Efficiency motor converter: η_{ASR} = 97 %

The max. energy dissipated in the MUB resistor is 542.5 kJ for an protective shut-down and 606 kJ for pantograph bouncing.

3.5 Measurement Sensors

The rms currents are given in enclosure 2.9.

3.6 Contactors

The rms currents are given in enclosure 2.9.

4. ENCLOSURES

Motor Data Bo'Bo'

The data is derived from motor diagram [2]. The power datas correspond to two motors in parallel according to the configuration on the locomotive.

f1 (Hz)	cos(phi)	P2mot (kW)	P2conv (kW)	
10	0.85	418	383	type point
15	0.85	627	574	
20	0.85	836	765	
25	0.85	1045	957	
30	0.85	1255	1148	
35	0.85	1464	1339	
40	0.85	1673	1531	
45	0.85	1882	1722	
50	0.85	2091	1914	
55	0.85	2300	2105	
60	0.85	2300	2105	
65	0.86	2300	2105	
70	0.86	2300	2105	
75	0.86	2300	2105	
80	0.86	2300	2105	
85	0.87	2300	2105	
90	0.88	2300	2105	
95	0.88	2300	2105	
100	0.88	2300	2105	
105	0.88	2300	2105	
110	0.88	2300	2105	
115	0.88	2300	2105	
120	0.88	2300	2105	
125	0.86	2300	2105	
130	0.85	2300	2105	
135	0.84	2300	2105	
140	0.83	2300	2105	
145	0.82	2300	2105	
150	0.81	2300	2105	
155	0.79	2300	2105	
160	0.77	2300	2105	
165	0.76	2300	2105	
170	0.74	2300	2105	
175	0.72	2300	2105	
180	0.70	2300	2105	
181	0.70	2300	2105	

Motor Data Co'Co'

The data is derived from motor diagram [4]. The power datas correspond to three motors in parallel according to the configuration on the locomotive.

f1 (Hz)	cos(phi)	P2mot (kW)	P2conv (kW)	
10	0.87	567	526	type point
15	0.87	850	789	
20	0.86	1133	1052	
25	0.86	1417	1315	
30	0.86	1700	1579	
35	0.86	1983	1842	
40	0.86	2267	2105	
45	0.86	2550	2368	
50	0.86	2550	2368	
55	0.86	2550	2368	
60	0.86	2550	2368	
65	0.87	2550	2368	
70	0.88	2550	2368	
75	0.88	2550	2368	
80	0.88	2550	2368	
85	0.88	2550	2368	
90	0.88	2550	2368	
95	0.88	2550	2368	
100	0.86	2550	2368	
105	0.85	2550	2368	
110	0.84	2550	2368	
115	0.82	2550	2368	
120	0.81	2550	2368	
125	0.79	2550	2368	
130	0.77	2550	2368	
131	0.76	2550	2368	

Transformer secondary winding current INSR, Co'Co'

Uline UNSR P2conv	17.5kV 888V 0kW	18kV 914V 1893kW	22.5kV 1142V 2368kW	25kV 1269V 2368kW	27.5kV 1396V 2368kW	30kV 1523V 0kW
LTr = LTrmin (1.785 mH)	24 A	1144 A	1124 A	1002 A	905 A	14 A
LTr = LTrnom (2.1 mH)	24 A	1144 A	1123 A	1002 A	904 A	14 A
LTr = LTrmax (2.415 mH)	23 A	1144 A	1123 A	1002 A	904 A	14 A

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Max. turn off current Itqm in NSR, Co'Co'

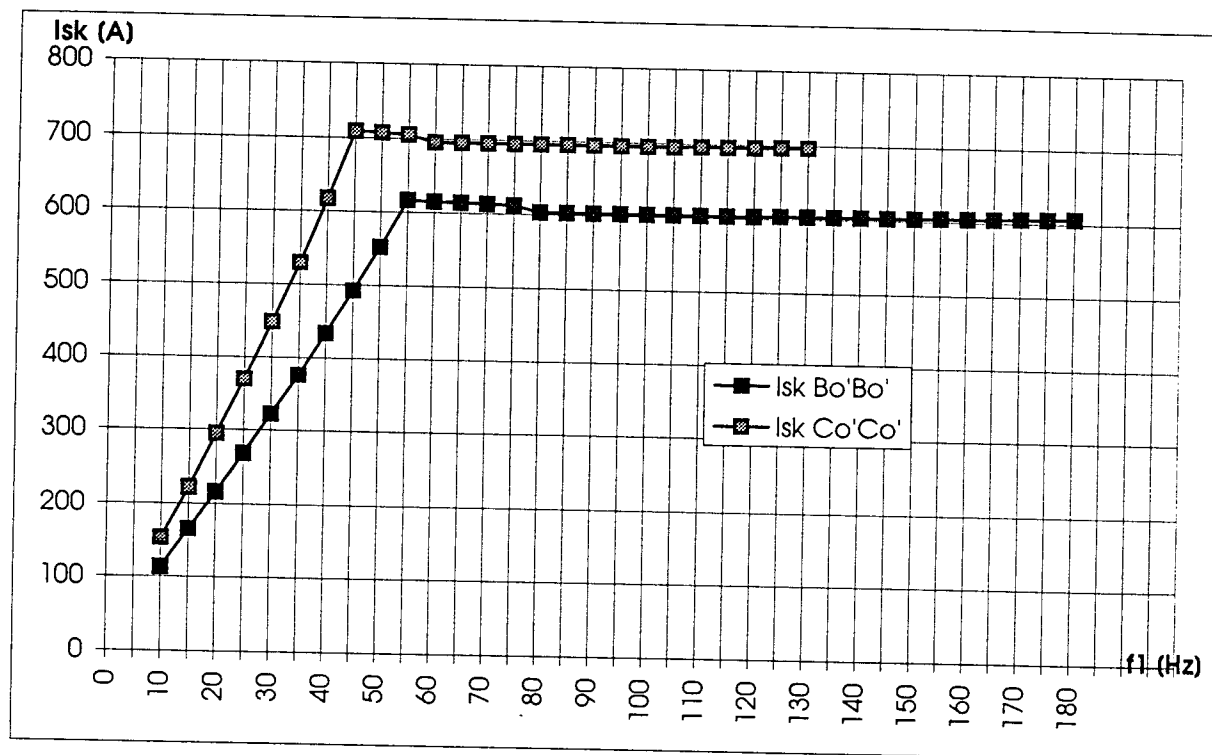
Uline UNSR P2conv	17.5kV 888V 0kW	18kV 914V 1893kW	22.5kV 1142V 2368kW	25kV 1269V 2368kW	27.5kV 1396V 2368kW	30kV 1523V 0kW
LTr = LTrmin (1.785 mH)	420 A	1797 A	1698 A	1559 A	1459 A	371 A
LTr = LTrnom (2.1 mH)	361 A	1801 A	1705 A	1482 A	1372 A	316 A
LTr = LTrmax (2.415 mH)	318 A	1803 A	1713 A	1487 A	1309 A	276 A

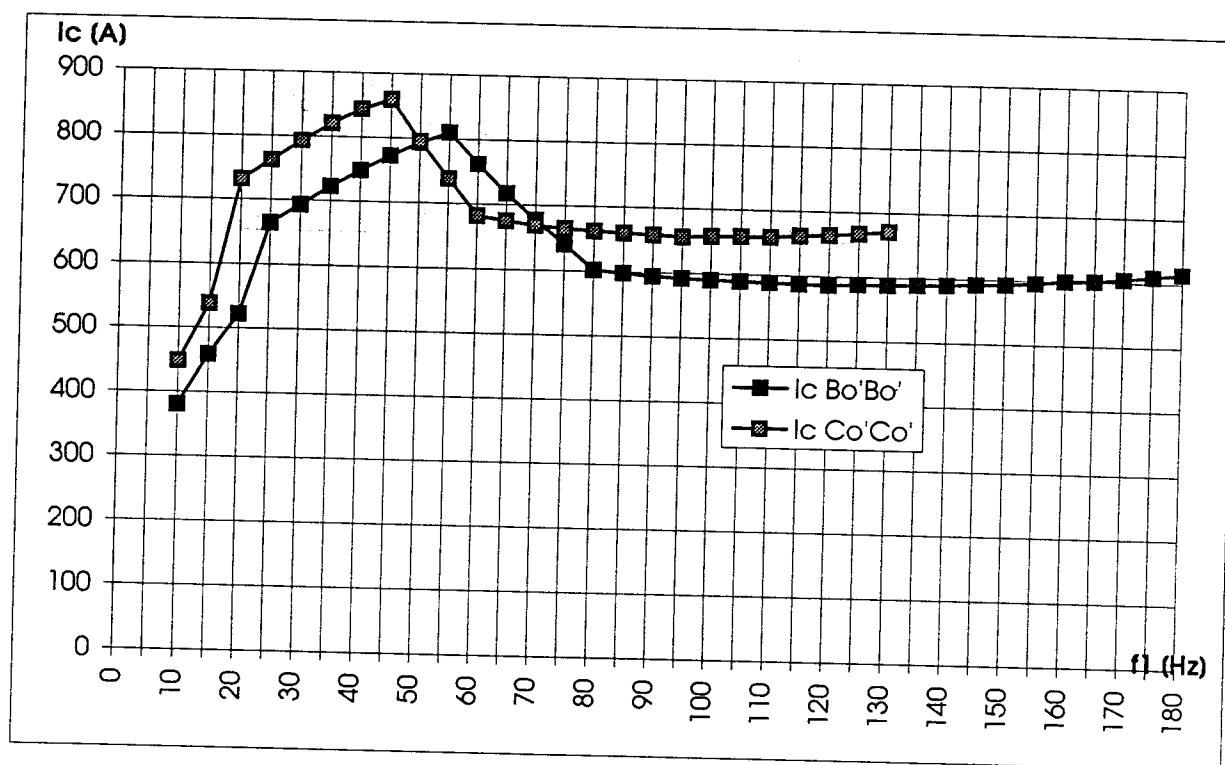
Resonant circuit current I_{sk} , Co'Co'

Uline UNSR P2conv	17.5kV 888V 0kW	18kV 914V 1893kW	22.5kV 1142V 2368kW	25kV 1269V 2368kW	27.5kV 1396V 2368kW	30kV 1523V 0kW
LTr = LTrmin (1.785 mH)	11 A	627 A	721 A	687 A	665 A	11 A
LTr = LTrnom (2.1 mH)	11 A	668 A	754 A	709 A	681 A	11 A
LTr = LTrmax (2.415 mH)	11 A	712 A	791 A	734 A	698 A	11 A

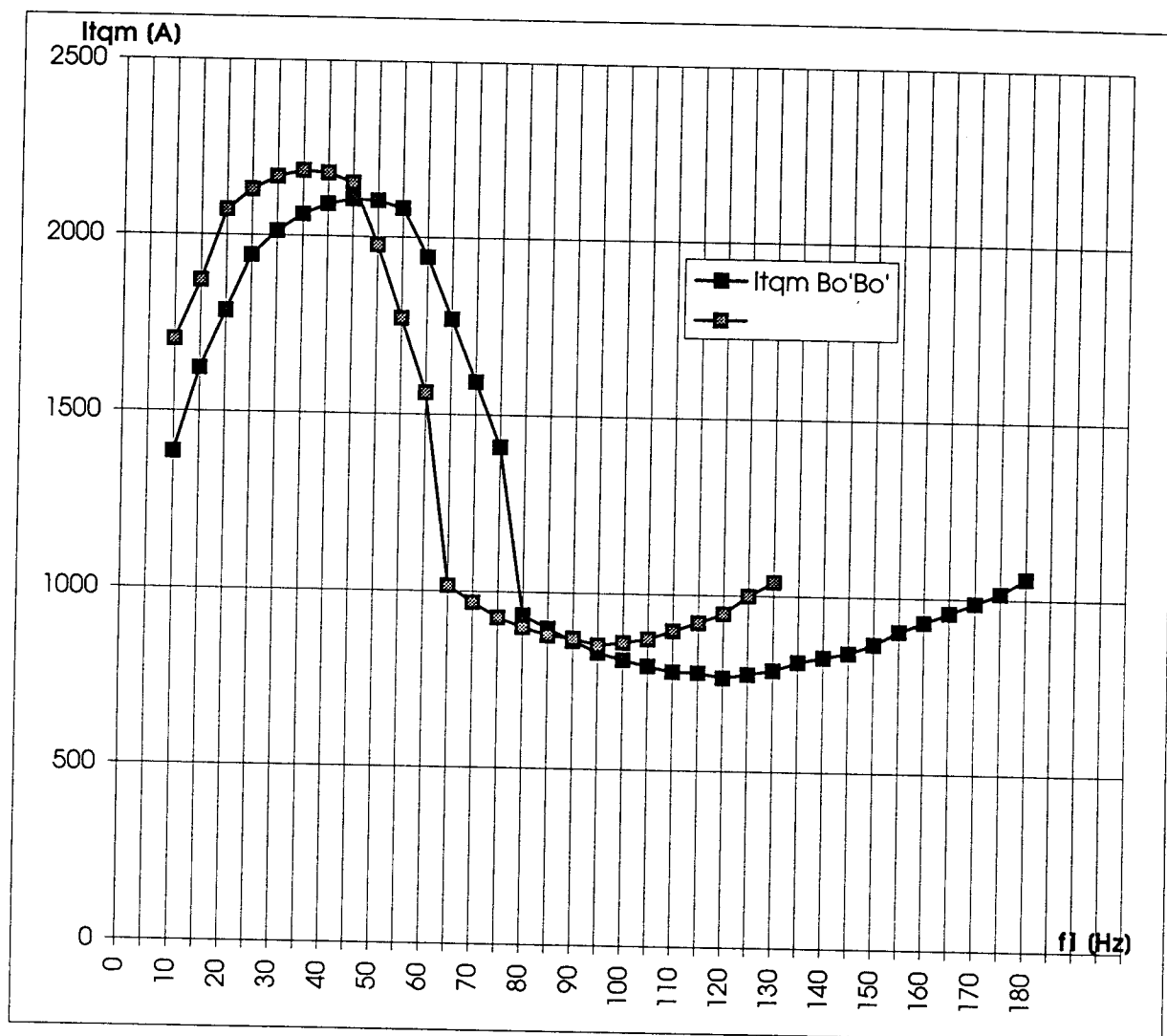
Resonant circuit current I_{sk} , Bo'Bo' and Co'Co'

14



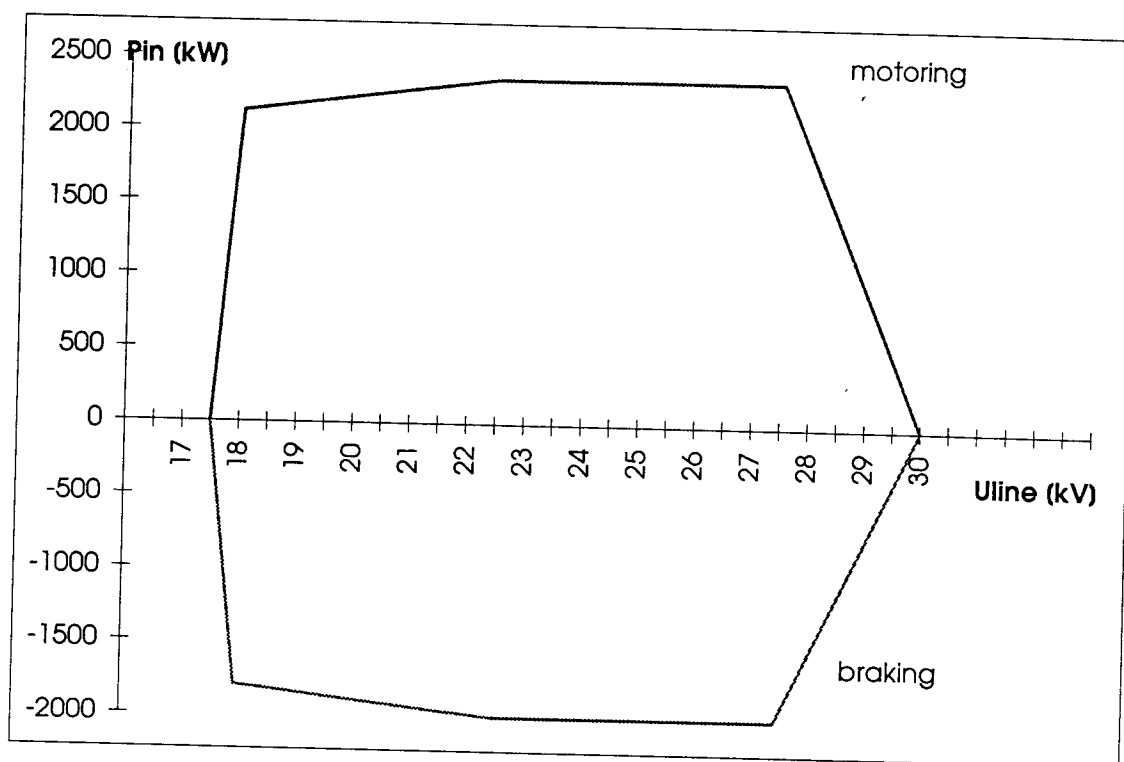
DC link capacitor current I_c , Bo'Bo' and Co'Co'

Max. turn off current I_{tqm} in the ASR, Bo'Bo' and Co'Co'



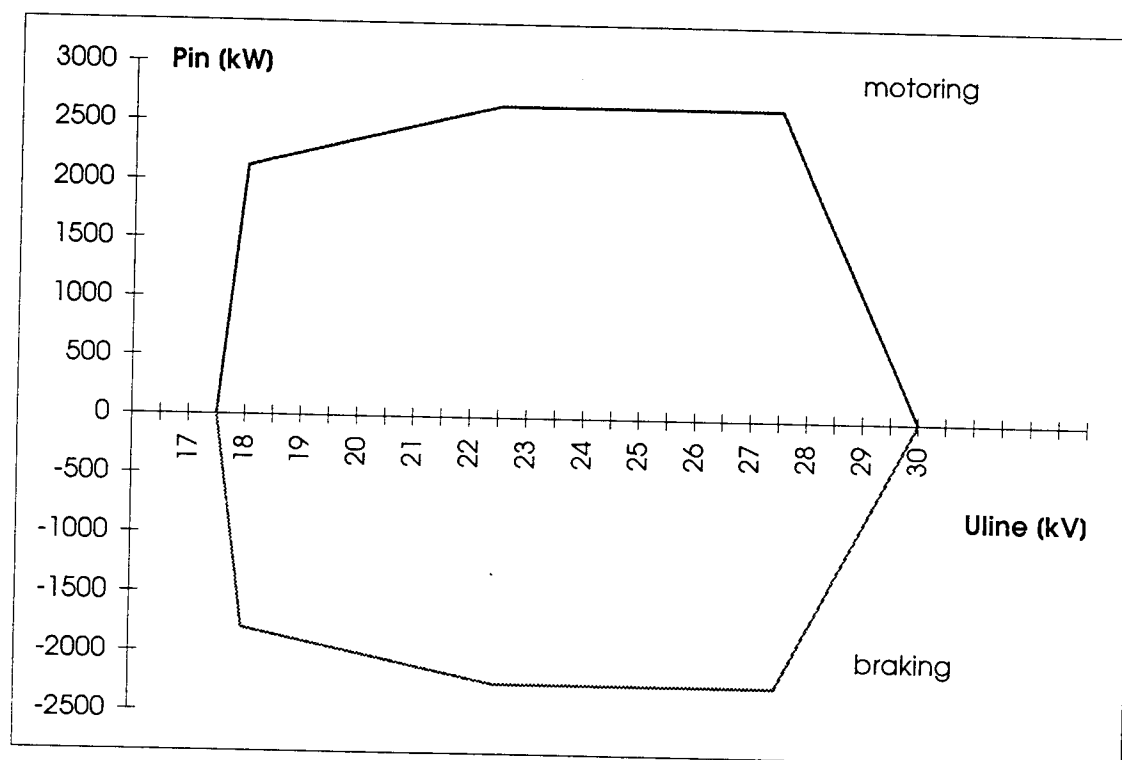
16

Protection characteristic 1A, Bo'Bo'



17

Protection characteristic 1A, Co'Co'

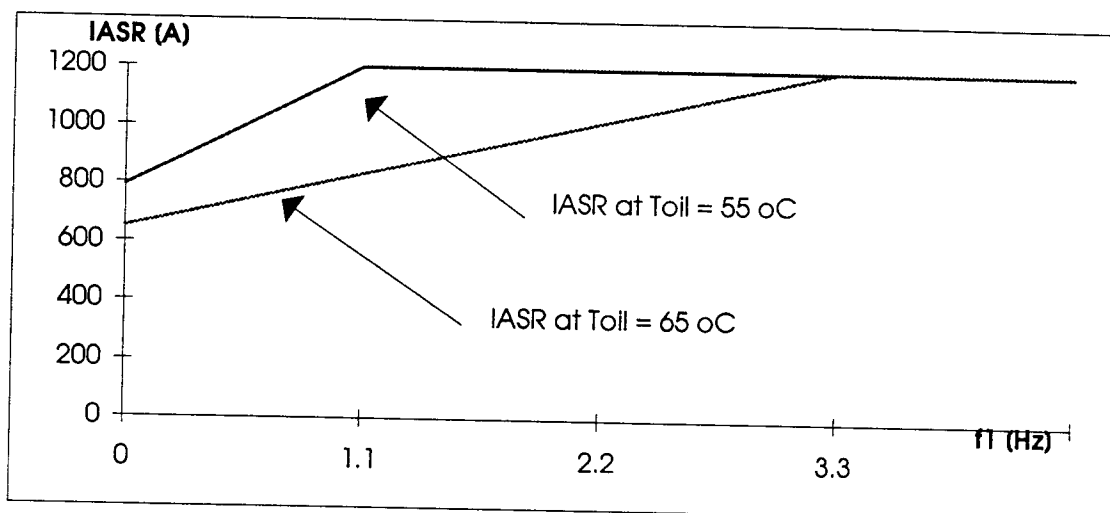


Protection characteristic 2A, Bo'Bo' and Co'Co'

Bo'Bo'	
Tmaxf	19610 Nm
Tmaxb	11400 Nm
nredf	3705 1/min

Co'Co'	
Tmaxf	26844 Nm
Tmaxb	18966 Nm
nredf	2948 1/min

Protection characteristic 2B, Bo'Bo' and Co'Co'



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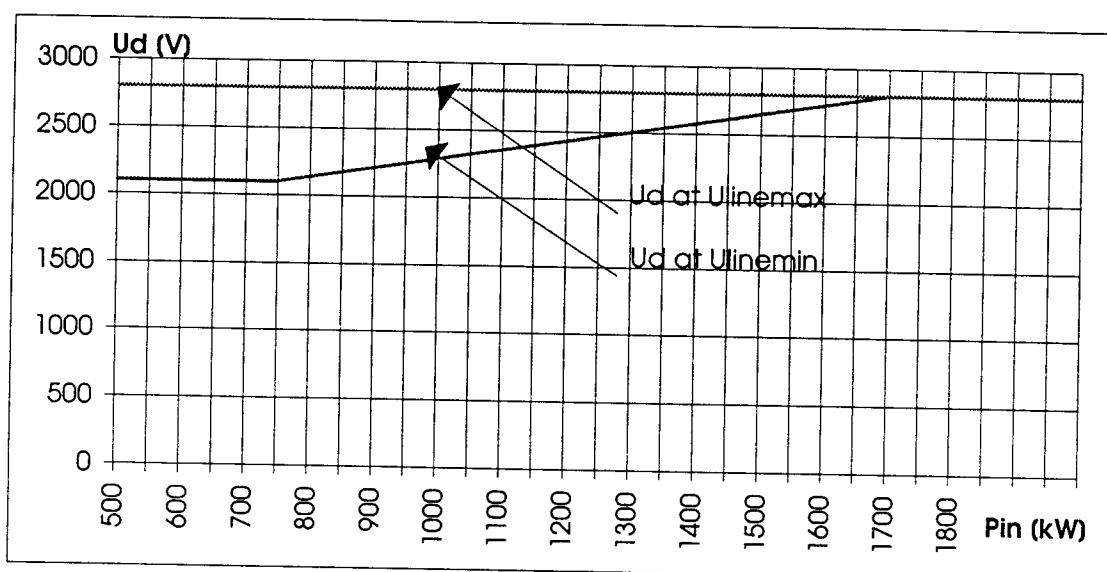
Protection characteristic 4A, Bo'Bo' and Co'Co'

UdMUB3	2800 V
UdMUB4	3200 V

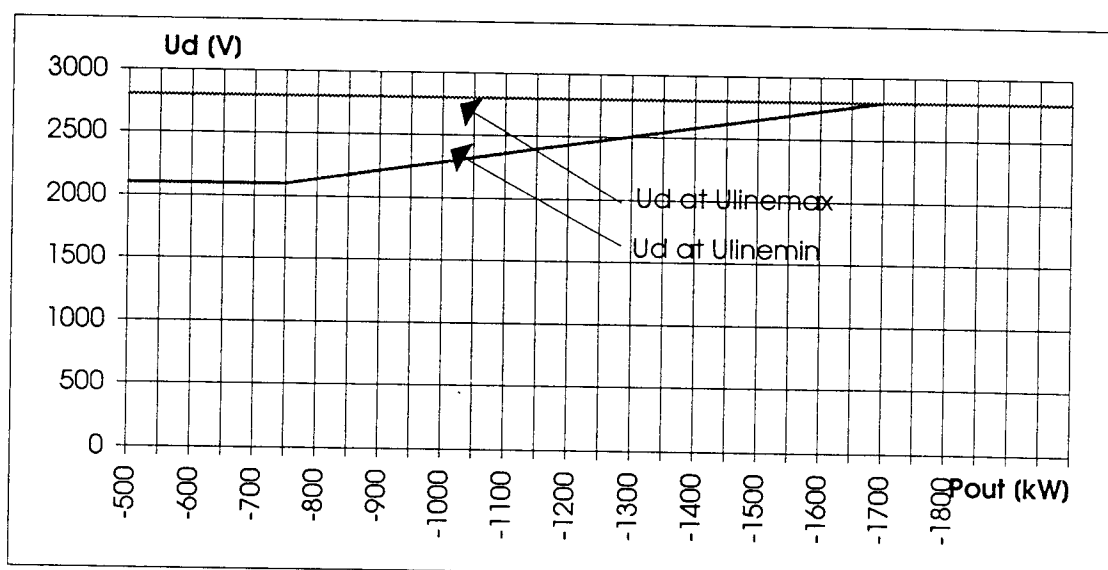
Voltage threshold for protective shut-down UdSAR, Bo'Bo' and Co'Co'

UdSAR	3350 V
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DC link voltage reduction Ud in motoring mode, Bo'Bo' and Co'Co'



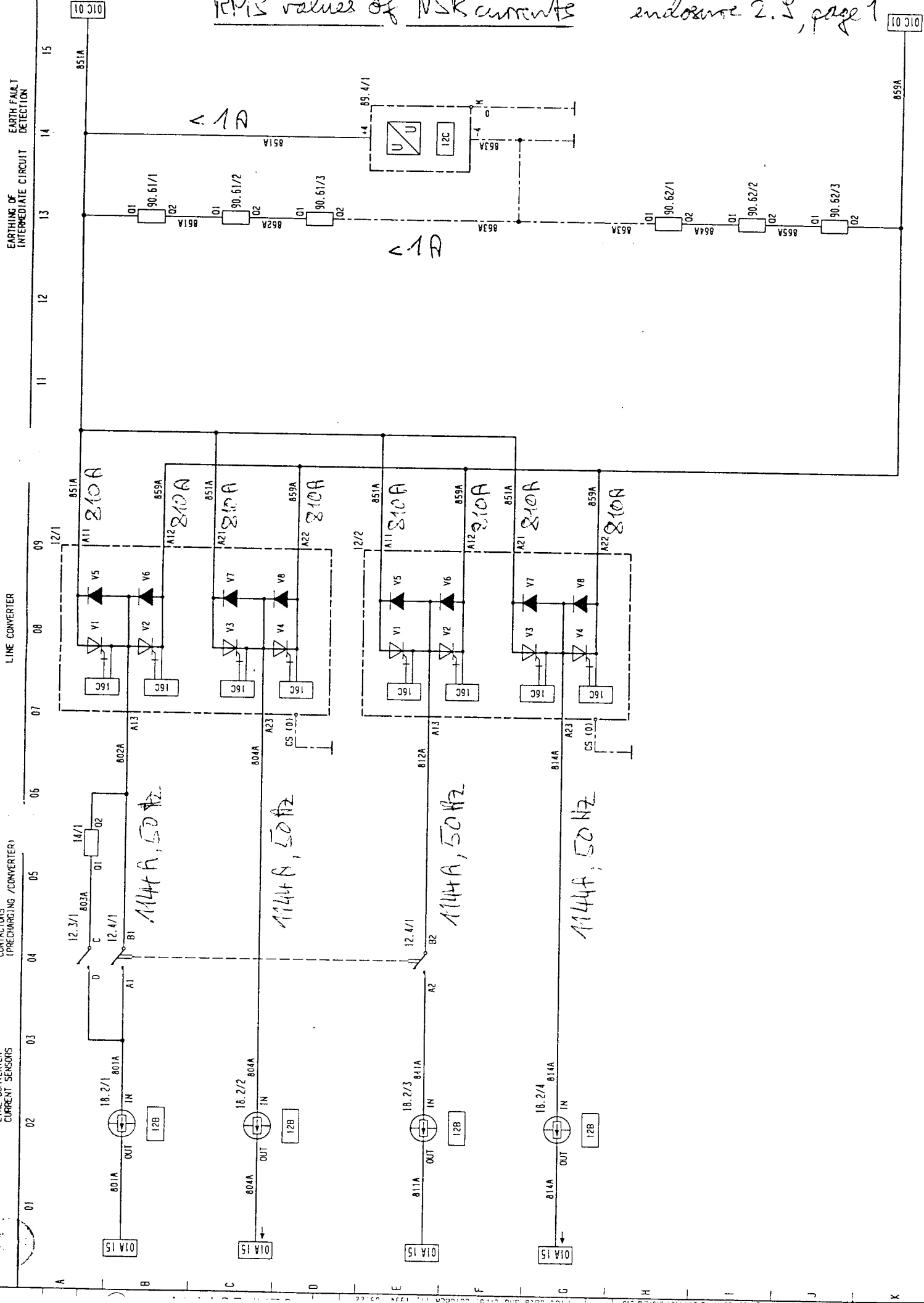
DC link voltage reduction Ud in braking mode, Bo'Bo' and Co'Co'



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RMS values of NSR currents

enclosure 2.9, page 1



RMS values of ASR currents

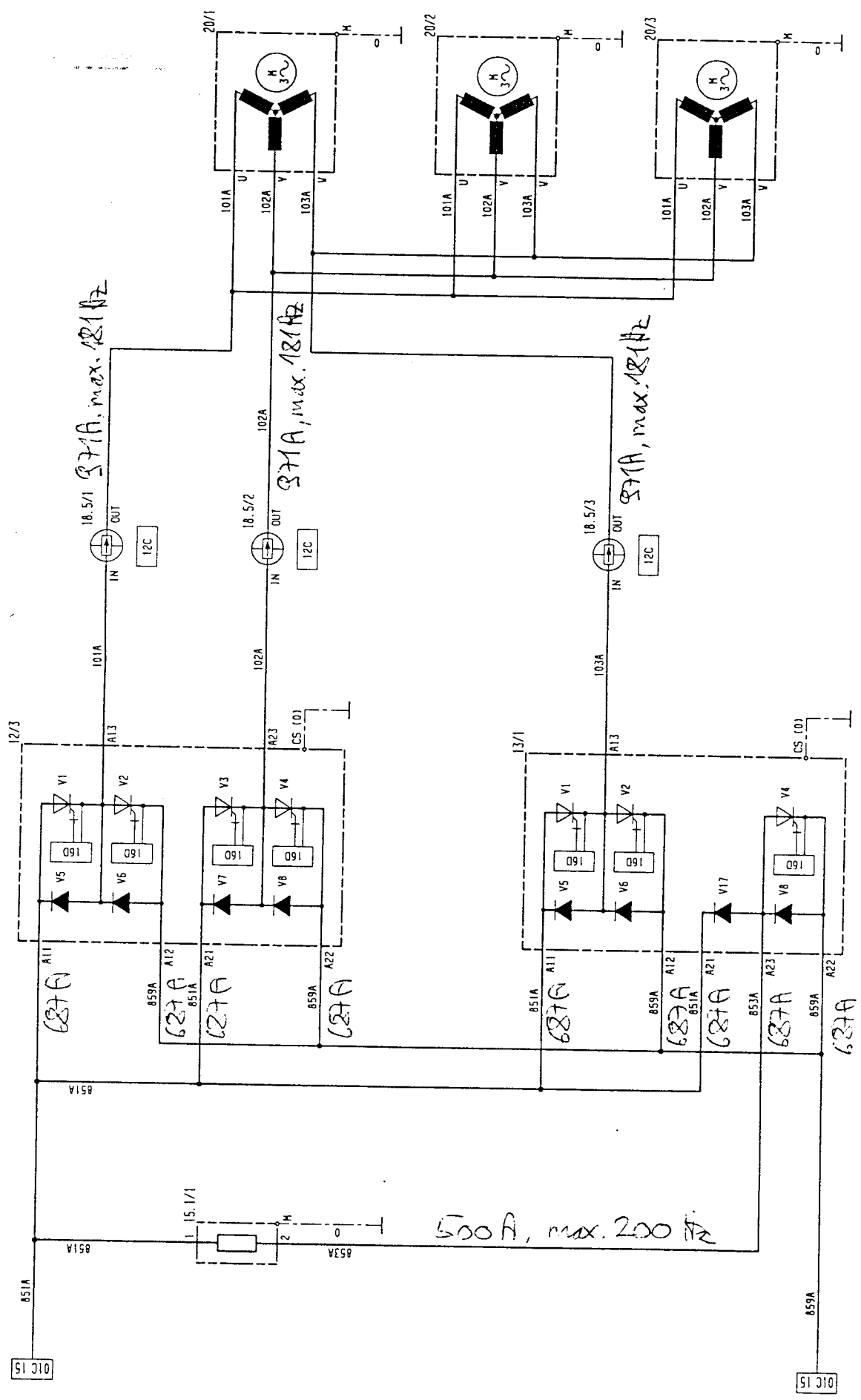
enclosure 2.2, page 3

TRACTION MOTORS BOGIE 1

DRIVE INVERTER CURRENT SENSORS

DRIVE INVERTER

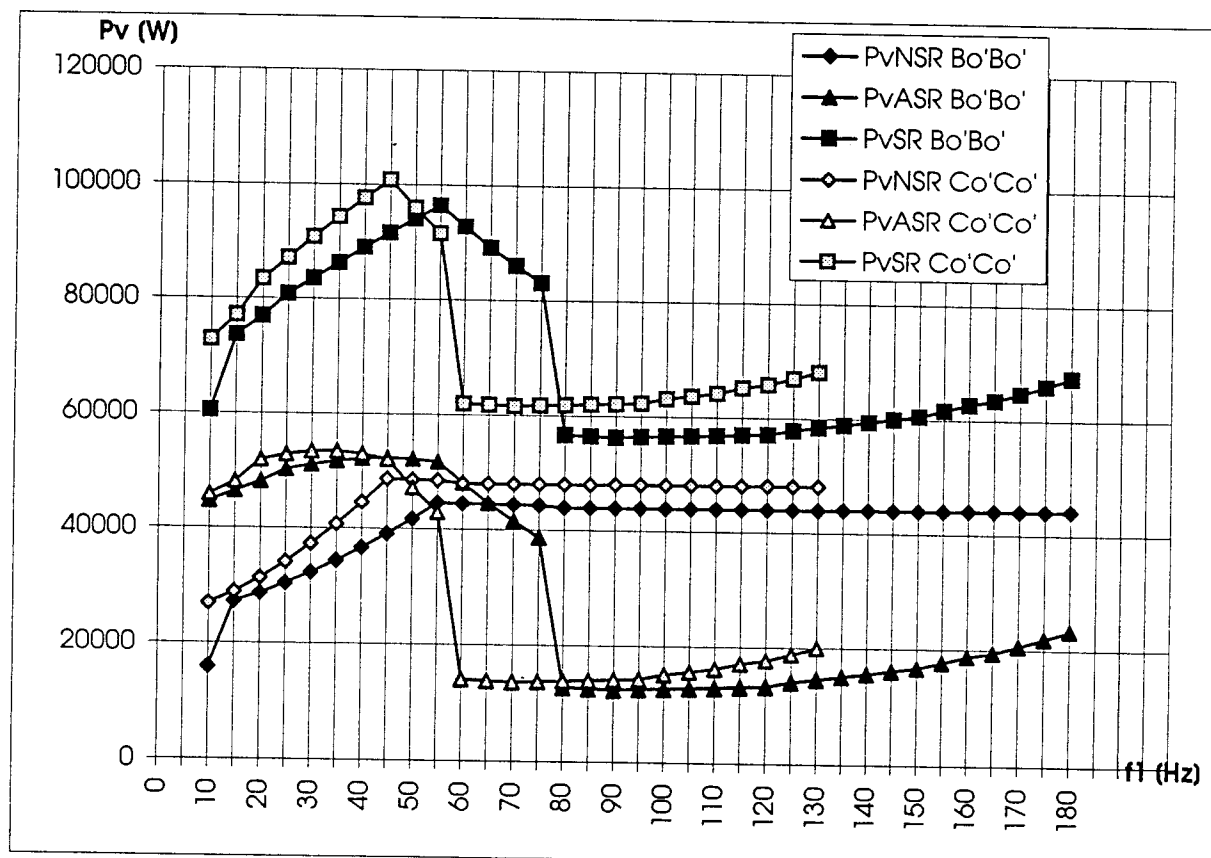
OVERVOLTAGE PROTECTION UNIT (MUB)



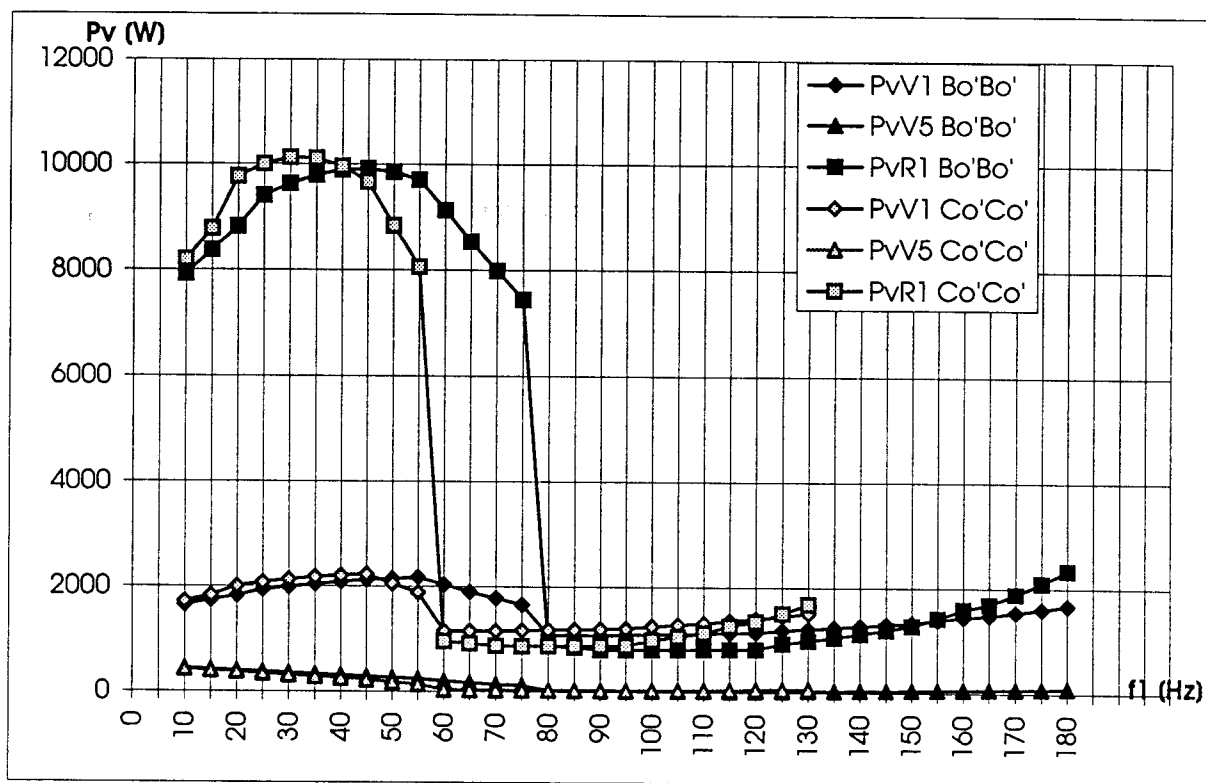
Power losses of main components in NSR phase, Co'Co'

Uline UNSR P2conv	17.5kV 888V 0kW	18kV 914V 1893kW	22.5kV 1142V 2368kW	25kV 1269V 2368kW	27.5kV 1396V 2368kW	30kV 1523V 0kW
LTr = LTrmin (1.785 mH)	V1: 559 W V5: 64 W R1: 2637W ZV: 3.9 kW	V1: 1659W V5: 687 W R1: 8314W ZV: 14.1kW	V1: 1542 W V5: 707 W R1: 8229 W ZV: 13.8 kW	V1: 1357 W V5: 630 W R1: 7606 W ZV: 12.4 kW	V1: 1213 W V5: 570 W R1: 7118 W ZV: 11.4 kW	V1: 551 W V5: 66 W R1: 2612 W ZV: 3.9 kW
LTr = LTrnom (2.1 mH)	V1: 499 W V5: 55 W R1: 2558 W ZV: 3.7 kW	V1: 1653 W V5: 685 W R1: 8125 W ZV: 13.9 kW	V1: 1539 W V5: 705 W R1: 8028 W ZV: 13.5 kW	V1: 1351 W V5: 627 W R1: 7424 W ZV: 12.2 kW	V1: 1204 W V5: 567 W R1: 6958 W ZV: 11.2 kW	V1: 492 W V5: 56 W R1: 2540 W ZV: 3.7 kW
LTr = LTrmax (2.415 mH)	V1: 453 W V5: 47 W R1: 2508 W ZV: 3.5 kW	V1: 1648 W V5: 683 W R1: 7998 W ZV: 13.7 kW	V1: 1537 W V5: 703 W R1: 7888 W ZV: 13.4 kW	V1: 1350 W V5: 625 W R1: 7295 W ZV: 12.0 kW	V1: 1200 W V5: 565 W R1: 6844 W ZV: 11.0 kW	V1: 447 W V5: 48 W R1: 2494 W ZV: 3.5 kW

Power losses in ASR, NSR and complete converter, motoring mode, Bo'Bo' and Co'Co'

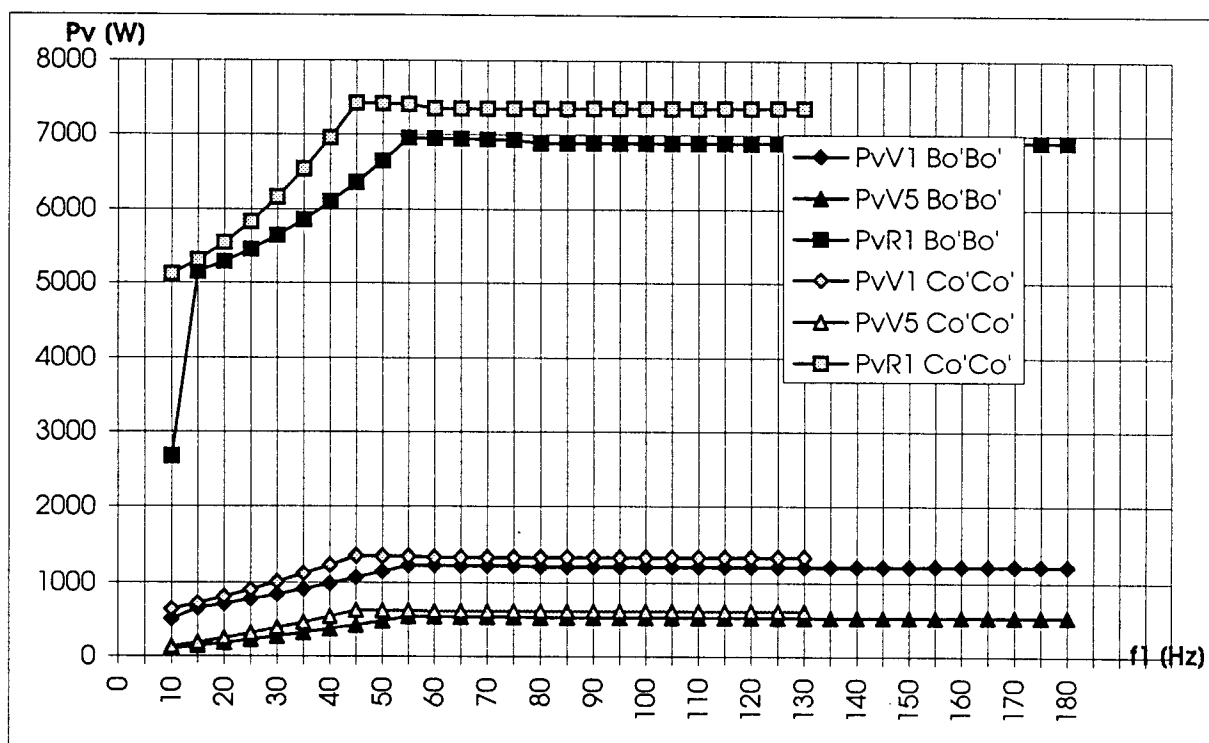


Power losses of main components in ASR, Bo'Bo' and Co'Co'



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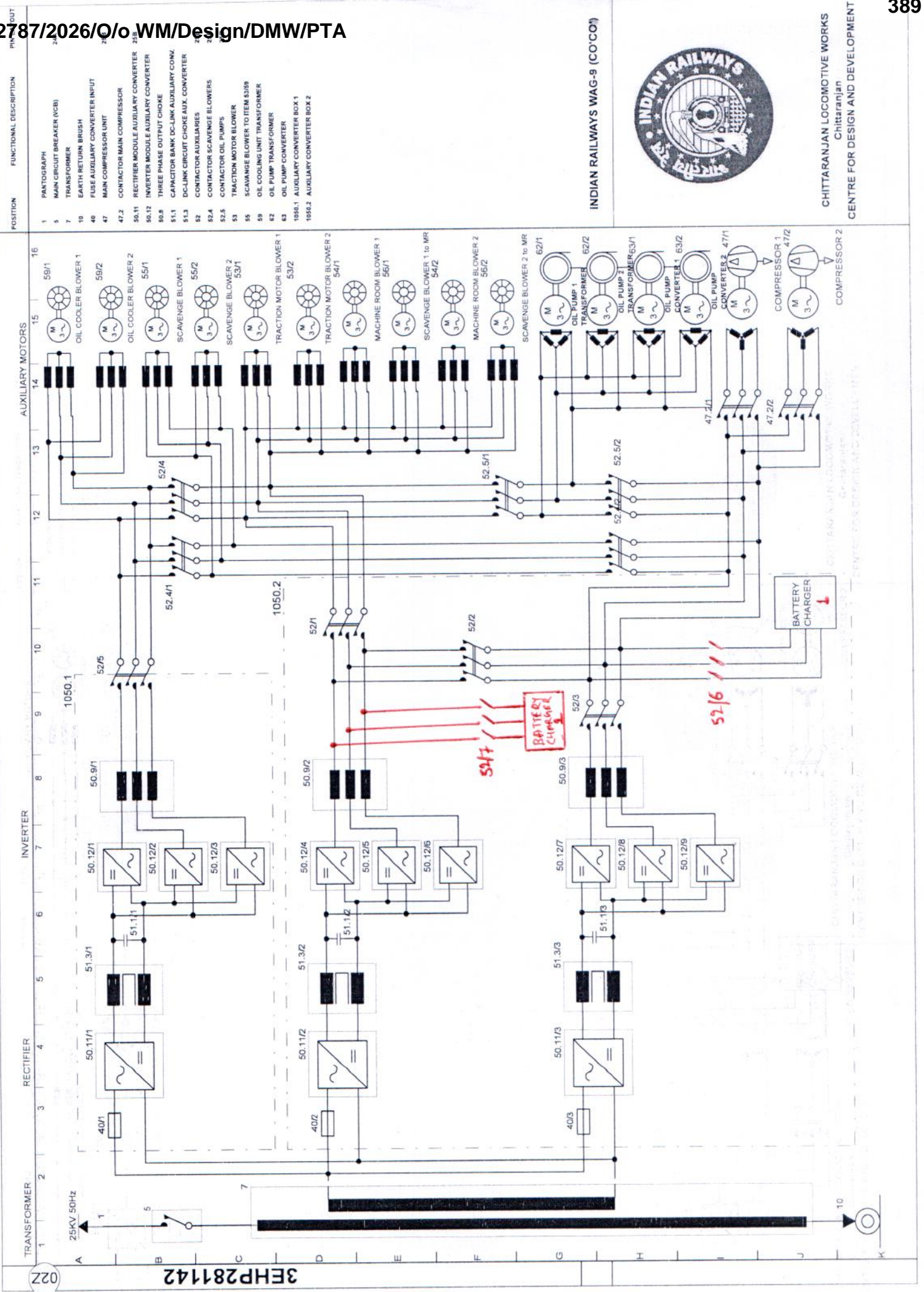
Power losses of main components in NSR, Bo'Bo' and Co'Co'



Scheme for additional hot redundant Battery charger in Auxiliary Converter-2, technically identical to the existing battery charger available in Auxiliary Converter-3

The redundant battery charger may have the following features:

- i. Battery charger-1 shall be connected to BUR-3 through a contactor (52/6) and Battery charger-2 shall be connected to BUR-2 through a contactor (52/7). The output of both the battery charger shall be terminated at common place.
- ii. When all BUR in service, battery charger-1 will be ON and battery charger-2 will be in OFF position. When battery charger-1 fails, battery charger-2 will come into service.
- iii. When BUR 3 will isolate, battery charger-2 will be ON.
- iv. The Auxiliary load distribution is prepared as per the current load distribution in three phase freight locomotive with energy saving scheme i.e. as per RDSO MS-0482, Rev.1. In addition to this, Pump for converter has been shifted from BUR-2 to BUR3.



POSITION	FUNCTIONAL DESCRIPTION	PHASE
1	PANTOGRAPH	2
5	MAIN CIRCUIT BREAKER (VCB)	2
7	TRANSFORMER	2
10	EARTH RETURN BRUSH	2
40	FUSE AUXILIARY CONVERTER INPUT	2
47	MAIN COMPRESSOR UNIT	2
47.2	CONTACTOR MAIN COMPRESSOR	2
50.11	RECTIFIER MODULE AUXILIARY CONVERTER	2
50.12	INVERTER MODULE AUXILIARY CONVERTER	2
50.9	THREE PHASE OUTPUT CHOKE	2
51.1	CAPACITOR BANK DC-LINK AUXILIARY CONV.	2
51.3	DC-LINK CIRCUIT CHOKE AUX. CONVERTER	2
52	CONTACTOR AUXILIARIES	2
52.4	CONTACTOR SCAVENGE BLOWERS	2
52.5	CONTACTOR OIL PUMPS	2
55	SCAVENGE BLOWER TO ITEM 53/59	2
59	OIL COOLING UNIT TRANSFORMER	2
62	OIL PUMP CONVERTER	2
100.1	AUXILIARY CONVERTER BOX 1	2
100.2	AUXILIARY CONVERTER BOX 2	2

INDIAN RAILWAYS WAG-9 (CO'CO')



CHITTARANJAN LOCOMOTIVE WORKS
Chittaranjan
CENTRE FOR DESIGN AND DEVELOPMENT

4792389/2026/O/o DMOES (D & M) / PW & R J

Additional redundant Battery charger in BUR-2

All BUR in service		When BC-1 in service	When BC-1 fails
BUR1 supply	Oil cooler blower-1	30 kw	30 kw
	Oil cooler blower-2	30 kw	30 kw
		60 kw	60 kw
BUR2 supply	Traction motor blower-1	25 kw	25 kw
	Traction motor blower-2	25 kw	25 kw
	Oil pump transformer-1	4.7 kw	4.7 kw
	Oil pump transformer-2	4.7 kw	4.7 kw
	Sc TMB-1	3 kw	3 kw
	Sc TMB-2	3 kw	3 kw
	Battery charger-2		12kw
		65.4 kw	77.4 kw
BUR3 supply	Compressor-1	15 kw	15 kw
	Compressor-2	15 kw	15 kw
	MRB-1	3 kw	3 kw
	MRB-2	3 kw	3 kw
	Sc MRB-1	0.75 kw	0.75 kw
	Sc MRB-2	0.75 kw	0.75 kw
	Battery charger-1	12 kw	
	Cab AC (Cab-1)	2.5 kw	2.5 kw
	Cab AC (Cab-2)	2.5 kw	2.5 kw
	Oil pump converter-1	11kw	11kw
	Oil pump converter-2	11kw	11kw
		76.5 kw	64.5 kw

When BUR1 Isolated

BUR2 supply	Oil cooler blower-1	30 kw	30 kw
	Oil cooler blower-2	30 kw	30 kw
	Traction motor blower-1	25 kw	25 kw
	Traction motor blower-2	25 kw	25 kw
	Sc TMB-1	3 kw	3 kw
	Sc TMB-2	3 kw	3 kw
	Battery charger-2		12 kw
		116 kw	128 kw
BUR3 supply	Compressor-1	15 kw	15 kw
	Compressor-2	15 kw	15 kw
	MRB-1	3 kw	3 kw
	MRB-2	3 kw	3 kw
	Sc MRB-1	0.75 kw	0.75 kw
	Sc MRB-2	0.75 kw	0.75 kw
	Battery charger-1	12 kw	
	Oil pump transformer-1	4.7 kw	4.7 kw
	Oil pump transformer-2	4.7 kw	4.7 kw
	Oil pump converter-1	11kw	11kw
	Oil pump converter-2	11kw	11kw
		80.9 kw	68.9 kw

When BUR2 Isolated

BUR1 supply	Oil cooler blower-1	30 kw
	Oil cooler blower-2	30 kw
	Traction motor blower-1	25 kw
	Traction motor blower-2	25 kw
	Sc TMB-1	3 kw
	Sc TMB-2	3 kw
		116 kw
BUR3 supply	Compressor-1	15 kw
	Compressor-2	15 kw
	MRB-1	3 kw
	MRB-2	3 kw
	Sc MRB-1	0.75 kw
	Sc MRB-2	0.75 kw
	Battery charger-1	12 kw
	Oil pump transformer-1	4.7 kw
	Oil pump transformer-2	4.7 kw
	Oil pump converter-1	11kw
	Oil pump converter-2	11kw
		80.9 kw

When BUR3 Isolated

BUR1 supply	Oil cooler blower-1	30 kw
	Oil cooler blower-2	30 kw
	Traction motor blower-1	25 kw
	Traction motor blower-2	25 kw
	Sc TMB-1	3 kw
	Sc TMB-2	3 kw
		116 kw
BUR2 supply	Compressor-1	15 kw
	Compressor-2	15 kw
	MRB-1	3 kw
	MRB-2	3 kw
	Sc MRB-1	0.75 kw
	Sc MRB-2	0.75 kw
	Battery charger-2	12 kw
	Oil pump transformer-1	4.7 kw
	Oil pump transformer-2	4.7 kw
	Oil pump converter-1	11kw
	Oil pump converter-2	11kw
		80.9 kw

*If any one BUR fails then CAB AC will not work