A1 APPENDIX 1: INFRASTRUCTURE DATA AND RELATED INFORMATION

This appendix contains more detailed infrastructure data for Norway and Sweden based on requests from the ESC Infobank. The appendices also include a list of existing vehicles.

The data and values shall be regarded as information which can be changed without notice, hence the values shall not be considered as exact stipulated data. More specific information can be given by the authority in each country respectively.

Another source for information about the infrastructure and traffic may be the Network Statements.

A1.1 Main data

Data	Norway	Sweden
Owner	Norwegian National Rail Administration	Swedish National Rail Administration
Power supply system	15 kV, 16 2/3 Hz	15 kV, 16 2/3 Hz
Length of railway network	4000 km, of which 220 km double track	9882 km, of which 1734 km are double track or more (11 697 km track length)
Length of electrified railway network	2500 km, of which 220 km double track	7638 km, of which 1734 km are double track or more (9543 km track length)
Map	See appendix 2	See appendix 3
Modifications planned in future	Rebuilding of weak main lines and construction of some new lines (double track) that will increase capacity and cut travel time between existing railway destinations around Oslo	New single track lines on the east coast in the north of Sweden (Botniabanan and Haparandabanan) New city lines double track in Stockholm and Malmö Strengthening of some weak lines. Further away: High speed lines Stockholm-Mjölby and Gothenburg-Norway. Upgraded lines Stockholm-Sundsvall, Stockholm- Gothenburg, Stockholm-Malmö, Gothenburg-Malmö.
Other	The traction power supply is generally weak.	-

A1.2 Power generation

Data	Norway	Sweden
Direct supply from public network	No	No
Supply from public utility via rotary frequency converters	Yes	Yes
Supply from public utility via static frequency converters	Yes	Yes
Railway owned power stations / generators	Yes, but one hydro power station owned by other company (Statkraft SF)	No
Supply network structure	Decentralized, but a small centralized 55 kV network exists in the region south west of Oslo	Decentralized, including a 132 kV-feeding system which connects 8 converter stations
Frequency and phase stiffness	Synchronous to public utility. See section 6.1.2 in the report. Transient deviation in frequency may occur due to changing load. Phase: For both rotary and static converters phase angle depends on load demand. For a load at cos(φ) = 1.0 the phase normally lags 36º at converters at rated load.	Synchronous to public utility. See section 6.1.2 in the report. Transient deviation in frequency may occur due to changing load. Phase: For both rotary and static converters phase angle depends on load demand. For a load at cos(φ) = 1.0 the phase normally lags 36º at converters at rated load.

A1.2.1 Connection to public utility

Data	Norway	Sweden
Voltage level at connection point (PCC= point of common coupling)	min: 11 kV typ: 66 kV max: 130 kV	min: 70 kV typ: 130 kV max: 220 kV
Short circuit power at connection point (PCC= point of common coupling)	min: 70 MVA typ: 250 MVA max: 2500 MVA	min: 594 MVA typ: 2-3000 MVA max: 9260 MVA
Short circuit power at substation input	Not calculated	Without any contribution from rotary converters: min: 45 MVA

		typ: 150-200 MVA max: 480 MVA
Modifications planned in future	No information available.	Increased feeding capacity when new converters are commissioned.

A1.2.2 Power stations

Data	Norway	Sweden
Number of power stations	1	None
Number of generators per station	min: 2 typ: 2 max: 2	N.A. (= not applicable)
Rate generator power	min: 600 kW typ: 600 kW max: 600 kW	N.A.
Typical short circuit impedance of generator [%]	Unknown	N.A.
Typical short circuit impedance of transformator [%]	3.09+j0.978	N.A.
Modifications planned in future	Increasing generator capacity to 2500 kW	N.A.

A1.2.3 Rotary frequency converters

Data	Norway	Sweden
Converter name	ASEA Q24, Q38, Q48 and NEBB 7 MVA and 10 MVA	ASEA Q24/Q25 ASEA Q38/Q39 ASEA Q48/Q49
Number of converter stations	29	25 and 3 which have both rotary and static converters
Number of converters units per station	min: 1 typ: 2 max: 3	min: 2 typ: 3 max: 5
Type of converter	Synchronous to synchronous	Synchronous to synchronous
Type of excitation and control	Electro-mechanical	Electro-mechanical
Damping	Damping windings in generator-machine, none in motor-machine	Damping windings in generator-machine, none in motor-machine
Railway side connected to	Contact line for all, but also to 55 kV distribution network in two stations	Contact line
Regeneration capability	Yes	Yes

Rated converter power per unit [MVA]	min (Q24): 2.4 typ (Q38): 4 max (Q48): 10	min (Q24): 2.4 typ (Q38): 4 max (Q48): 10
Continuous power per unit (respectively) [MVA]	min (Q24): 3.1 typ (Q38): 5.8 max (Q48): 10	min (Q24): 3.1 typ (Q38): 5.8 max (Q48): 10
Typical short circuit impedance of generator+ Transformer [Ohm]	min (Q48): j7.0 typ (Q38): j14.35 max (Q24): j33.1	min (Q48): j7.0 typ (Q38): j14.35 max (Q24): j33.1
Voltage regulation	Stiff or slightly declining with increasing reactive power demand.	Stiff or slightly declining with increasing reactive power demand.
Capacity	The number of active units in each station is adapted to hourly variation in power demand	The number of active units in each station is depending on the actual load and adaptive load statistics.
Overloading capacity	Up to +40 % of continuous power for 6 minutes and +100 % of rated power for 2 seconds	Up to +40 % of continuous power for 6 minutes and +100 % of rated power for 2 seconds
If overloaded	Converter is instantaneously disconnected	Converter is instantaneously disconnected
Modifications planned in future	Static and brushless excitation may be implemented. Maybe increasing the number of converters in each station.	Brushless exciters may be introduced in the future.

A1.2.4Static frequency converters

Data	Norway	Sweden
Converter name	ABB PWM converter ABB/Adtranz PWM converter: MegaMacs Siemens	ASEA Cyclo-converter: YOQC ASEA/ABB PWM-converter: TGTO ABB/ADtranz PWM-converter: MegaMacs ALSTOM PWM-converter
Number of converter stations	6	18
Number of converters units per station	min: 2 typ: 2 max: 3	min: 2 typ: 3 max: 4 6 in future
Type of converter	PWM converter: Line voltage converter (rectifier) and pulse width modulated	15 cyclo converters and 37 PWM conveters

	inverter connected together with DC-link	
Filters on railway side	Yes, broad band and psofometric filter	Normal filter configuration for cylco converters and MEGAMACS is a wideband filter. Normal filter configuration for other PWM converters is 6^{th} and 8^{th} and wideband
Other filters	DC-link: 2^{nd}, 4^{th}, 6^{th} and $8^{th}/9^{th}$. Utility grid: Yes	DC-link: 2^{nd}, 4^{th}, 6^{th} and 8^{th} and wideband in MEGAMACS converters Utility grid: Yes
Regeneration capability	Only one station, in others the phase angle is shifted to push regenerated energy forward to other trains or stations. Some stations have a resistor for taking care of short term feedback power.	All cyclo converters can regenerate to the 50 Hz-grid. 2 converter stations with PWM-converters can regenerate to the 50 Hz grid. (Alingsås and Järna). All other PWM converters have resistors to take care of short term feedback power.
Rated converter power per unit [MVA]	min: 6 typ: max: 15	min: 6 typ: 15 max: 15
Typical short circuit impedance of output transformer [%]	0.013+j0.0677 pu	0.83+j13.0 but can vary a lot: 0.83% > ur >1.49% 7.94% > ur >13.0%
Voltage regulation	Stiff or slightly declining with increasing reactive power demand. Static converters imitate the dynamical response of a rotary converter (ASEA Q48) due to software parameterisation. The 1~ phase voltage angle depends therefore of the 3~ phase angle.	Stiff or slightly declining with increasing reactive power demand. Static converters imitate the dynamical response of a rotary converter (ASEA Q48) due to software parameterisation. The 1~ phase voltage angle depends therefore of the 3~ phase angle.
Frequency regulation	Synchronization with the 50 Hz grid is kept by means for phase-locked loops	Synchronization with the 50 Hz grid is kept by means for phase-locked loops
Capacity	The number of active units in each station are automatically adapted to	The number of active units in each station is depending on the actual load and

	variation in power demand	adaptive load statistics.
Overloading capacity	No short time exceeding of rated power	Normally no overload capacity but MEGAMACS have a short time capacity of 17 MVA
If overloaded	If current limit is reached, voltage will be reduced. The voltage will then not be sine adapted.	If current limit is reached, voltage will be reduced. The voltage will then not be sine adapted.
Extensions planned in future		7 new static converters are under commissioning, in operation 2007-2008

A1.3 Power distribution

A1.3.1 General data

Data	Norway	Sweden
Railway owned power distribution network exists	Yes at 16.7 Hz, in one limited area	Yes at 16.7 Hz
Nominal voltage [kV]	55 (2 x 27.5 kV)	132 kV (2x66 kV)
Number of phases	2	2
Purpose	Connecting one hydro power station, 2 rotary converters and 3 substations	To reduce number of converter stations and have a more even usage of the remaining converter stations
Network length [km]	Approx. 157	1925
Total cable length	No information available.	Cables north of Uppsala of length 6 km and south of Uppsala 3 km. (these are the longest existing cable sections)
Lowest network resonance frequency [Hz]	No information available.	Normally 100 -130 Hz. Resonance frequencies lower resonance frequencies can occur (combinations of lines and connected installed power).
Modifications planned in future	No significant modifications	No significant modifications planned

A1.3.2 Transformer stations

Data	Norway	Sweden
Number of transformer stations	3 plain transformers, 2 located together with converter stations	31 plain transformers substations, 8 transformer substations located together with converter stations
Nominal power rating [MVA]	min: 2x2.5 typ: max: 1x8	All plan transformer substations have one 16 MVA transformer Most transformer substations at converter stations have two 25 MVA transformers but normally only one operating.
Short circuit impedance [%]	min: typ: 6.3-6.5 max:	min: typ: 5 max:
Efficiency in nominal point [%]	typ: 98-99	> 99 at cos(φ) =1.0
Voltage regulation	Typically none, but one station has automatic tap changer	Only tap changers, no on load tap changers.
Modifications planned in future	None	No

A1.3.3 Transmission lines

Data	Norway	Sweden
Typical transversal section (cross section)	55 kV (2x27.5 kV) normally made up with concrete poles and with the phase height of 9.2 m and phase spacing of 3.5 m.	132 kV lines (2x66 kV) are normally built with wooden poles with a phase height of 10.8 m (sags included) and a phase spacing of 4m. Earthed top wires only close to substations and on some lines where old 3-pase 220 kV lines have been reused.
Conductor material(s)	Cu and FeAl	DOVE: 329 mm^2 FeAl
Conductor cross section (s) [mm2]	4x35, 4x50, 2x50 and 2x70	See above.
Specific impedance [Ohm/km]	0.34+j0.24 or 0.73+j0.28	Positive sequence: 0.1025+j0.126 Ω/km Zero sequence: 0.1349+j0.456 Ω/km

		Pos.seq. capacitance: 9.5862 nF/km Zero seq. capacitance: 6.4444 nF/km
Modifications planned in future	No significant modifications	No significant modifications planned.

A1.3.4 Cables

Data	Norway	Sweden
Specific impedance [Ohm/km]	0.1+j0.03 or 0.12+j0.28	Per phase: 0.1009 + j 0.026
Specific capacitance [nF/km]	Per phase: 0.16 µF/km	Per phase: 0.16 µF/km
Modifications planned in future	No significant modifications	None known.

A1.4 Substations

A1.4.1 General data

Data	Norway	Sweden
Map	Se appendix 2	Se appendix 3
Number of substations	38	See section A1.2.4 and A1.3.2.
Type of substations	Transformers only: 3 Converters feeding contact line: 35 Hydro power station: 1	See references above
Nominal power rating of complete substation [MVA]	min: 2x0.625 typ: 2x5.8 max: 3x15	See references above
Feeding of railway lines	Single side Double side Multiple side (2 T-connections)	Single and double sided feeding.
Distance between substations [km]	min: 12 typ: 80 max: 92	See section A1.5.1.
Distance of single fed line [km]	min: typ: max: 63	See section A1.5.1.
Normal operation of network	Interconnected	Interconnected
Separation of feeding areas (neutral sections)	Seldom sectioned, but depending on operation of utility grid	Normally no separation of feeding areas.

Voltage at railway side	Controlled during operation	16.5 kV controlled during operation, stiff or slightly declining, proportional to the inductive load (slightly increasing at capacitive load
Modifications planned in future	No information available.	More stations will have slightly declining voltage, proportional to the inductive load (slightly increasing at capacitive load

A1.4.2 Autotransformers

Data	Norway	Sweden
Autotransformers exist	No, but planned in future	Yes, but only on single track lines
Voltages [kV]	2x15	2x15
Transformer rating [MVA]	min: typ: 5 max: 2x5	5 Normally two AT's in parallel are used as feeding transformer feeding an AT-line.
Short circuit impedance [%]	min: typ: 0.4 max:	uk = 0,4 %, 57.53° (or 0.184+j0.117 Ω)
Distance between trafos [km]	min: 8 typ: 10 max: 12	min: 8 typ: 10 max: 12
Present on … fed lines	…both single and double side…	…both single and double …
Connection of AT to lines	Negative feeder (-15 kV), rail (0 kV) and positive feeder (+15 kV). Positive feeder interconnected to contact line (sectioned) typical each 5 km.	Normal connection, i.e. negative feeder (-15 kV), rail (0 kV) and contact line as positive feeder (+15 kV).
Combination with other systems	Not planned	At some lines with booster transformers, i.e. some lines may in the future be converted into ATBT-system.
Modifications planned in future	Planned to be used for today's weak lines	More AT-system lines are planned. AT-system may occur on double track lines in the future.

A1.4.3 Passive filters and compensators

Data	Norway	Sweden
Passive filters exist	Yes	No, only at converter stations with static converters, see A1.2.4
Type of filter	Series capacitor and shunt capacitor	N.A.
Schematics etc.	No information available.	N.A.
Resonance frequencies	Series: No significant effects on resonance frequencies. Shunt: No information available.	N.A.
Where in service	Series capacitor between converter stations on weak lines, shunt capacitor in heavy load area (Oslo S)	N.A.
Purpose	Series capacitor for voltage increase and shunt capacitor for reactive power feeding	N.A.
Rating	Series cap -j7.35 [Ohm] Shunt cap 4 [MVAr]	N.A.
Modifications planned in future	Series capacitors will probably be removed when line is reinforced/rebuilt with AT-system	More filters built when new converters are built

A1.4.4 Controlled filters, compensators and balancers

Data	Norway	Sweden
Controlled filters/ comp. exist	No	No
Type of installation	N.A.	N.A.
Schematics	N.A.	N.A.
Where in service	N.A.	N.A.
Purpose	N.A.	N.A.
Modifications planned in future	N.A.	N.A.

A1.4.5 Auxiliaries

Data	Norway	Sweden
Substation and station supply	Yes	Yes
Switch heating	Yes	Yes
Train heating	Yes	Yes

Any other equipment	No	See section 6.9.4 in the report.
Modifications planned in future	No information available.	None

A1.4.6 Other equipment

Data	Norway	Sweden
Other equipment exist	No	No
Description	N.A.	N.A.
Modifications planned in future	No information available.	None

A1.5 Railway lines

A1.5.1 Longitudinal characteristics

Data	Norway	Sweden
Map	See appendix 2	See appendix 3
Max length between feeding points [km]	92	156 (one weak line), normally 60-120 km but shorter in areas with heavy traffic, the longer distance reflects that 132 kV lines are present
Max length between feeding points and open line end [km]	63	63
Modifications planned in future	Introducing AT-systems, the max length between feeding points probably will be increased to 120 km	No specific modifications planned.

A1.5.2 Cross connections on double-track lines

Data	Norway	Sweden
Cross connection is done	Never in normal operation but one shorter line where the two tracks are operated n parallel (connected in the ends)	Exists on some lines (Tranås-Malmö) as normal operation. On other lines only during fault conditions or maintenance.
Cross-connections (if existing) are	Switchable, but just in use in fault situations	Switchable.
Distance between connections (if existing)	min: typ: very variable max:	Normally 7-10 km.

Modifications planned in future	No information available.	More lines using cross connections are under investigations

A1.5.3Cross sections of lines

Data	**Norway**	**Sweden**
Number of tracks on open line (i.e. outside stations/yards)	Mostly single track, but double and multiple track exist	Normally single track but double track between the cities Stockholm, Gothenburg and Malmö and north and west of Stockhom, see Appendix 3, Network map of Sweden. In the Stockholm area 4 track lines exists.
Earth wire	On some lines, both sectioned and interconnected exist	Exits on some lines.
Feeder (electrically parallel to contact line)	Normally not, but exist on some lines	Only on a few lines.
Feeder (connection in switch posts only)	On some lines	Only at a few locations, e.g . in the Stockholm area.
Return conductor	On some lines, normally two 240 mm^2 Al	Yes, normally two 212 mm^2 Al
Auto-/booster wires	No information available.	BT-systems: Booster wire is normally (212 mm^2 Al) used in the north of Sweden and some lines in the south, see Appendix 3, Network map of Sweden. AT-systems: Booster wire is normally used.
Public utility (no direct connection to railway system)	Not at all	None
Auxiliary supply (no direct to railway system)	Not at all	Auxiliary power of 3-phase 22 kV or 11 kV (also 2-phase exists) are normally placed on top of the contact line poles. This auxiliary power is normally fed from converter stations. Loads along the lines can also be fed from the public network. Transformers at loads along

		the line. The voltage is very weak
Open communication lines	On some lines	On most of the lines, placed in the embankment.
Typical cross section(s) layout(s)	No information available.	See appendix 6 for a typical BT-line and appendix 7 and 8 for AT-lines.
Any other important info	Isolation standard (target/planing level) for the contact overhead line system is 170/70 kV.	Isolation standard (target/planning level) for the contact overhead line system is 170/70 kV. There exists lines with isolation levels between 150/55 kV and 225/75 kV.
Modifications planned in future	No information available.	Earth wire are planned to be standard on all future AT-lines, probably also on BT-lines. Exits already on some lines.

A1.5.4Cable sections

Data	**Norway**	**Sweden**
Length of cable connection substation to contact line [km]	typ: 0.1 max: 5	0.1 – 4 km, typical value 300 m.
Length of feeder cable parallel to railway line (e.g. tunnels, urban areas) [km]	typ: max: short	Exist only in the Stockholm area (4 cable feedings). Typical length : 13 km.
Specific impedance [Ohm/km]	min: 0.10+j0.03 typ: 0.12+j0.06 max:	For cables in the Stockholm area: 0.12 + j 0.054 and 0.15 + j 0.036
Specific capacitance [µF/km]	min: typ: 0.26 max:	For cables in the Stockholm area: 0.16 and 0.26 µF/km.
Modifications planned in future	Introducing AT-system may cables for negative and positive feeder in tunnels may be necessary	Under investigation (Citybanan in Stockholm).

A1.5.5Return current arrangement

Data	**Norway**	**Sweden**
Rail types	S49: 2700 km S54: 750 km	Normally UIC 50 and UIC 60 or corresponding.

	UIC60: ca. 200 km	
Rail info	Normally welded, isolated gaps/joints exists	One rail welded (S-rail) and one rail with isolated joints (I-rail) which is used by the DC-track signalling circuit.
Isolated rails	No isolation at all	Yes, see item above.
Return conductor	See section A1.5.3.	See section A1.5.3.
Earth wire	On some lines, both sectioned and interconnected (typical distance between connections to rail is 3 km) exist	See section A1.5.3.
Track transformers	No	No
Other characteristics	No	No
Earth resistivity [Ωm] Wet soil: 20-200 Humus/clay: 50-200 Wet sand: 100-300 Dry sand: 1000-50000 Mountains: 1000-10000	Railway lines are very often build on bedrock ground or rocky ground. A usable value is 2500 Ωm.	Earth resistivity is high. A usable value is 2500 Ωm.
Future modifications plans	No information available.	None

A1.5.6 Booster transformers

Data	**Norway**	**Sweden**
Booster transformers exist	Yes	Yes, on all lines except AT-system lines.
Transformer power rating [kVA]	min: 33 (380 A, 87 V) typ: 55 (680 A, 92 V) max: 95 (800 A, 118 V)	500 A Booster transformer: 158 kVA (500 A, 316 V, 800 A for 1 hour). Older booster transformers of 300 A exists.
Short circuit impedance [%]	min: 2.7 + j 2.5 typ: 8.4 + j 22.3	500 A Booster transformer: typ: 3.86 + j 10.3 typ: 11 (absolute value)
Distance between booster transformers [km]	min: 2 typ: 3 max: 20	typ: 5.6
Specific contact line system impedance [Ohm/km]	typ: 0.013	See section A1.5.9.
Modifications planned in future	No information available.	3-windings boosters may be introduced if ATBT-systems are introduced.

A1.5.7 Neutral sections/Phase gaps

Data	Norway	Sweden
Neutral sections exist	Yes	Yes
Neutral part is	See clause 6.2 in the report.	Normally floating
Location	See clause 6.2 in the report.	At substations and switching posts.
May be shunted	See clause 6.2 in the report.	Yes, normally to earth, but to contact line voltage exists.
Length [m]	min: 40 typ: 90 max: 350	min: 2 at stations min: 60 typ: 180 max: 180
Concept for emergency supply (e.g. one substation out of order)	No information available.	Converter stations are design for outage of one converter unit with out influencing the traffic.
Modifications planned in future	Neutral sections of 402 m are planned for future.	None

A1.5.8 Interaction AC/DC railways

Data	Norway	Sweden
Infrastructure segment lies adjacent to DC-railways/tramways	Yes	Yes
Special arrangements (such as DC train supply with current return through rails on AC lines)	No, not as we know	No
Description	Grefsen station (750 V DC parallel and 600 V DC crossing) Bryn station (750 V DC crossing) Trondheim station (600 V DC crossing)	Trams lines (750 V DC) parallel to railway lines in Gothenburg. Underground/subway lines (750 V DC) parallel to railway lines in Stockholm.
Modifications planned in future	Lysaker station – tramway face to face planned	No

A1.5.9 Numerical values BT system

Data	Norway	Sweden
Line impedance , single track lines [Ohm/km] including BT	min: 0.092+j0.106 typ: 0.190+j0.210 max: 0.233+j0.228	min: 0.13+j0.16 typ: 0.21+j0.20 max: 0.30+j0.23
Line impedance , double track lines [Ohm/km] including BT	min: 0.160+j0.180 typ: max: 0.218+j0.188	Not calculated.
Specific capacitance, single track [nF/km] (caternary–earth)	min: 9 typ: max: 17	typical for booster transformer lines: 8.8 – 11.1
Lowest resonance frequency (contact line network) double side feeding [Hz]	typ: 800 Hz global typ: 450 Hz local	typ: 800 Hz global typ: 450 Hz local
Lowest resonance frequency (contact line network) single side feeding [Hz]	typ: 450 Hz local	typ: 450 Hz local
Other interesting values	Earth resistivity is high.	Earth resistivity is high. A usable value is 2500 Ωm.
Modifications planned in future	No information available.	No

A1.5.10 Numerical values AT system

Data	Norway	Sweden
Fixed impedance at feeding or starting points [Ohm]	Not yet decided or calculated.	min: 0.189+j0.343 typ: max: 0.468+j0.755 (see note below the table)
Line impedance on single line track [Ohm/km]	Not yet decided or calculated.	min: 0.0335+j0.031 typ: max: 0.0715+j0.066 (linear approximations including AT's)
Line impedance on double line track [Ohm/km]	Not yet decided or calculated.	Not calculated.
Specific capacitance, single track [nF/km] (caternary–earth)	Not yet decided or calculated.	typ: 11.9 – 13.5
Specific capacitance, double track [nF/km] (caternary–earth)	Not yet decided or calculated.	Not calculated.
Lowest resonance frequency (contact line network) double	typ: 450 Hz global typ: 350 Hz local	typ: 400 Hz global typ: 250 Hz local

side feeding [Hz]		
Lowest resonance frequency (contact line network) single side feeding [Hz]	typ: 200 Hz local	typ: <200 Hz local
Modifications planned in future	Exact system design not decided yet	No

NOTE that the values for AT-systems in Sweden regards single track systems. Furthermore note that the AT-system impedances are linear approximations of the AT-system impedances with the intension to get values which can easily be used in simulation programs and for calculations of settings of relay protections. The fixed impedance corresponds approximately to the level of the zero sequence impedance of the system. This impedance shall be placed as a fixed impedance at both ends of the system in case of a AT-system fed from both ends and at the feeding end in case of a single end fed system. The impedance per km corresponds approximately to the positive sequence impedance.

A1.6 Signalling equipment

A1.6.1 Track circuits

Data	Norway	Sweden
DC track circuits	Only on non-electrified lines and at one electrified railway station (Filipstad)	DC track signalling circuits exists on nearly the whole network. None existing only on none electrified lines.
High voltage impulse	Do not exist	Do not exist
Low frequency (25-275 Hz)	Exist on most of the electrified lines. 95 and 105 Hz only, uncoded.	Do not exist
Reed frequency (275-1000Hz)	Do not exist	Do not exist
Lower audio frequency (1-4 kHz)	Exist on a small part of the network. Bombardier TI 21 (1.5 - 2.6 kHz), digital processor based and not transmitter signal coded.	Do not exist
Upper audio frequency (4-20 kHz)	Exist on a part (110 km) of network. Siemens FTGS (4.7-16.5 kHz), digital and transmitter signal coded.	Do not exist
Other	Do not exist	Train radio or radio blocking of trains on some none electrified low traffic lines
Modifications planned in future	No information available.	More radio block systems are planned for low traffic

		lines.

A1.6.2 Axle counters

Data	Norway	Sweden
Mechanical	Do not exist	No
Electro-magnetic	Do not exist	Yes, but not used as signalling equipment They are placed together with axle box heating locked braking detectors
Electronic	Do not exist, but are being tested	No
Others	Do not exist	No
Modifications planned in future	Are planned for future use	None

A1.6.3 Automatic train protection (ATP) and automatic train control (ATC)

Data	Norway	Sweden
ETCS/ERTMS level 1	Does not exist	Does not exist.
ETCS/ERTMS level 2	Does not exist	Introduced on the Botniabanan
ETCS/ERTMS level 3	Does not exist	Does not exist.
National system(s)	"ATC" used in nearly the whole network. EBICAB700 manufactured by ATSS and Bombardier	"ATC" used in nearly the whole network, manufactured by ATSS and Bombardier. Radio blocking of trains or manual train blocking used on some none electrified low traffic lines.
Modifications planned in future	Long term strategy is ERTMS level 2	Ongoing project for introducing ERTMS level 2 (the lines Malmö-Stockholm-Sundsvall are planed for 2010-2015)

A1.6.4 Interference monitors

Data	Norway	Sweden
Philosophy of application	Monitors recommended. Monitors needed if safety case can not be fulfilled otherwise	DC-current monitor on new electrical traction vehicles is required.

Purpose	Monitored frequencies: 95 and 105 Hz. Trip level 2 A rms. Filter characteristics ±3 Hz. Response time 1 sec.	To monitor the DC-component, a component which can have an influence on the track signalling circuits.
Type(s) in service	95 and 105 Hz monitor for warning and disconnection of main circuit breaker.	DC-monitors are in operation on some new vehicles.
Modifications planned in future	No information available.	None

A1.6.5 Interference limits

Data	**Norway**	**Sweden**
Frequency band (name)	See section 5.2 and 5.4 in the report.	Limits on DC-components and psophometric currents, see section 5.2 and 5.4 in the report.

A1.6.6 Data transmission and remote control systems

Data	**Norway**	**Sweden**
System(s)	Various communication systems exists, such as PCM (puls code modulation, BF (frequency carrier), etc, on Cu-cable. Also ordinary telephone lines on Cu-cables excists. Opto-communication is the dominating transmission for long distances communication. GSM-R is being introduced in the whole country.	Various communication systems exists, such as PCM (puls code modulation, BF (frequency carrier), ADSL, etc, on Cu-cable. Also ordinary telephone lines on Cu-cables exists. Opto-communication is the dominating transmission for long distances communication. Transmission used for SCADA-systems are ELCOM, X25, RP570 and more. At the moment IEC 870-5-104 (on TCP/IP) is introduced. GSM-R is being introduced in the whole country.

A1.7 Operational conditions

A1.7.1 Line frequency

See section 6.1.2.1 in the report.

A1.7.2 Line voltage RMS value

See section 6.1.1.1 in the report.

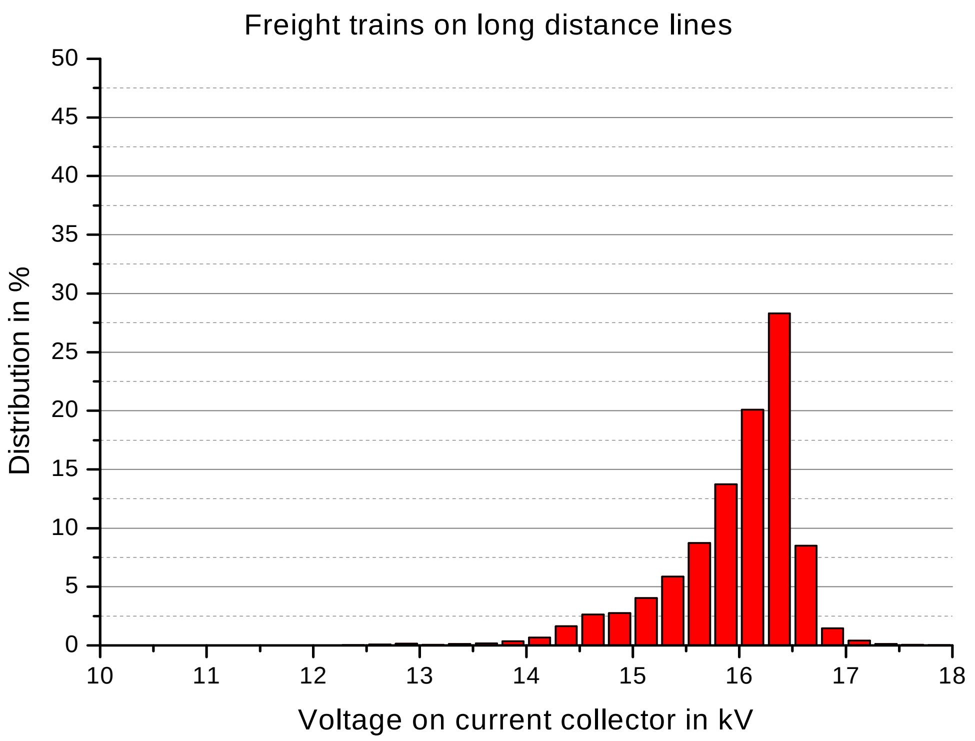
Based on simulation in SIMPOW® TRACFEED® the figures below show a typical statistical distribution of the fundamental voltage at the pantograph of a vehicle in Norway. The values can be used as a fairly good approximation also for Sweden.

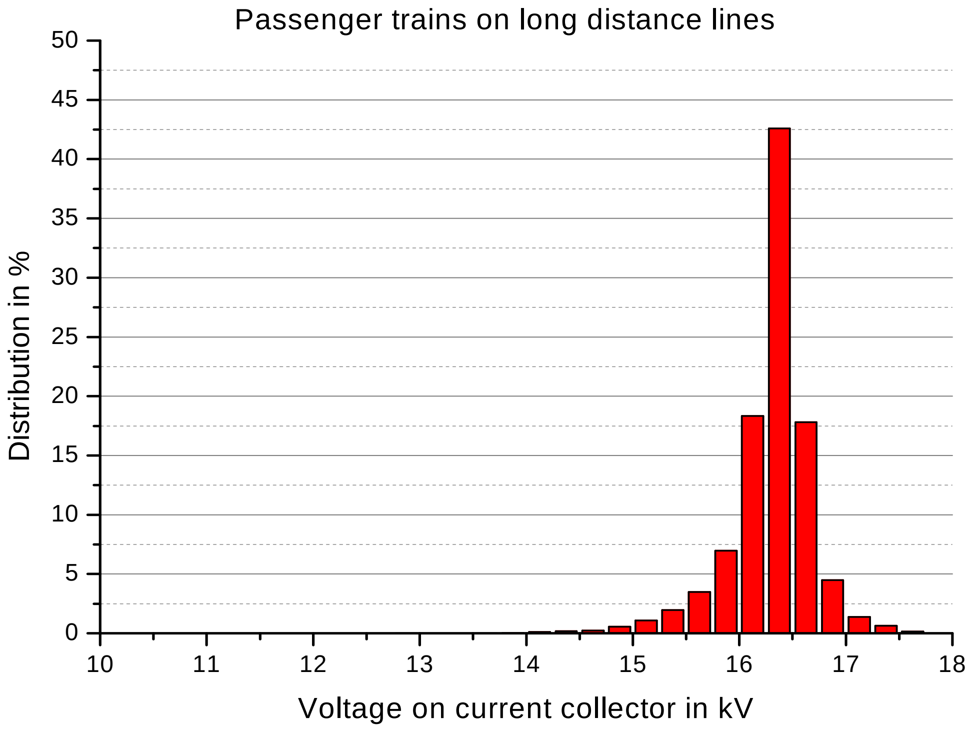
The information is based on 1-second values (mean values during one second) for a 35 different trains considered as representative of the operation to day. Vehicle and line vary and the trains are divided and aggregated into the following groups:

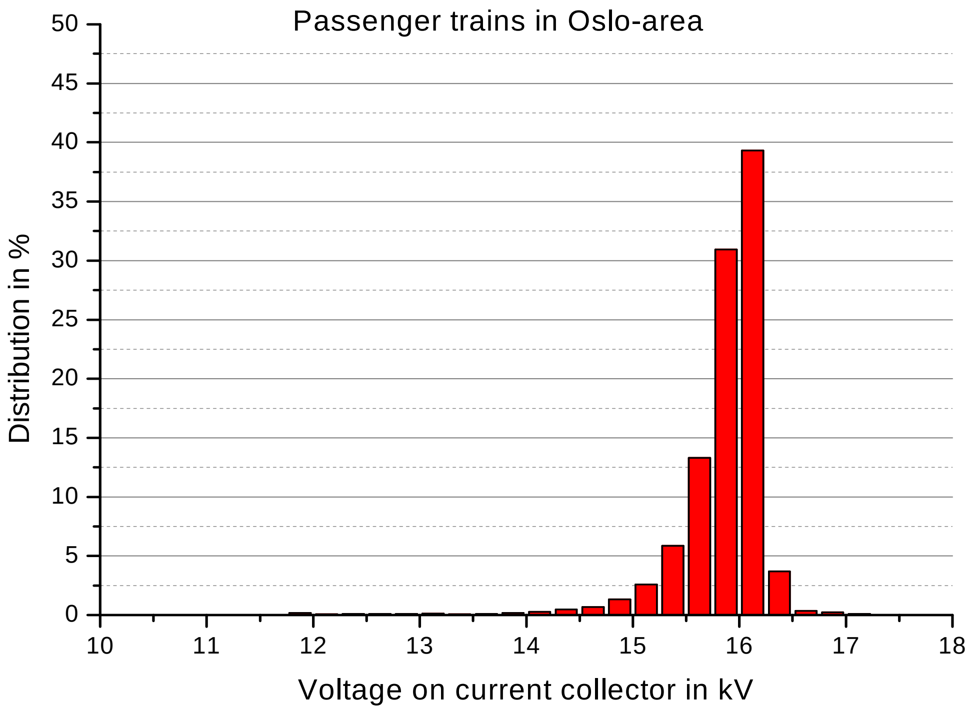
- Freight trains on long distance lines, normally considered as weak lines (Bergen line, Dovre line, Sørland line and Ofoten line).
- Passenger trains on long distance lines, normally considered as weak lines (Bergen line, Dovre line, Sørland line and Ofoten line).
- Passenger trains in Oslo area, also including the Gjøvik line, Østfold line and the Vestfold line. The Olso area is normally considered as relatively stiff compared to long distance lines.

The voltages shown below are simulated for traction, coasting and braking mode, and includes stops at stations between start and stop.

Note that this figures show an overall distribution. For shorter time intervals the voltage distribution for a single train deviates from the figures shown due to sections of lines with lower voltage quality.


Freight trains on long distance lines
Distribution in %
0
5
10
15
20
25
30
35
40
45
50
10
11
12
13
14
15
16
17
18
Voltage on current collector in kV


Passenger trains on long distance lines
Distribution in %
0
5
10
15
20
25
30
35
40
45
50
10
11
12
13
14
15
16
17
18
Voltage on current collector in kV



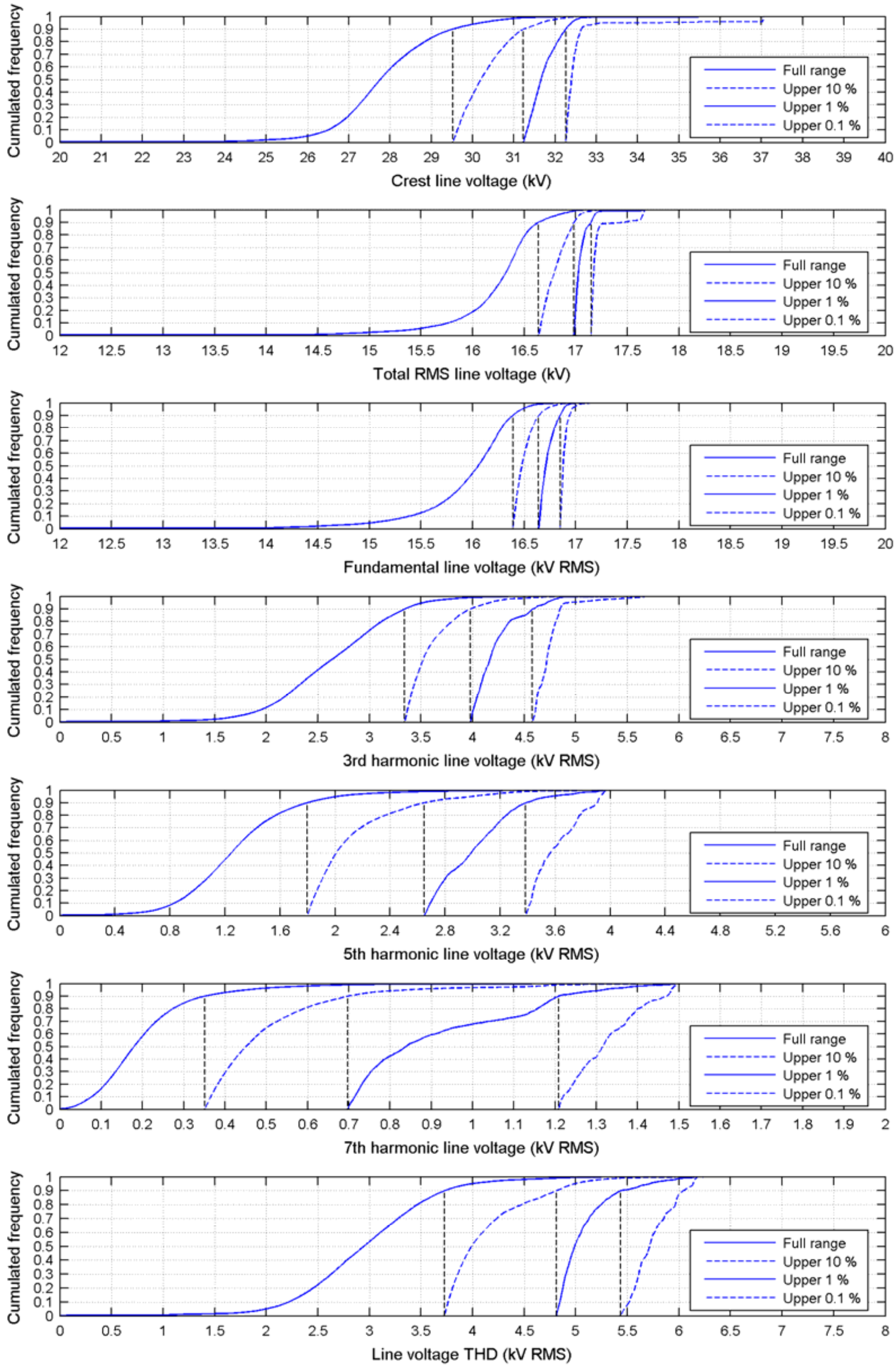
A1.7.3Line voltage spectrum

Data	Norway	Sweden
Sub-harmonics or regular frequency variations occur	Yes, see clause 6.5.1 in the report.	Yes, see clause 6.5.1 in the report.
Line voltage content with harmonics up to 1000 Hz	Significant to very large, higher harmonic orders do occur but are not significant, see section 6.1.3.1 in the report.	Significant to very large, higher harmonic orders do occur but are not significant, see section 6.1.3.1 in the report.
Line voltage content with harmonics 1000-3000 Hz	Very low, no influence on vehicle known from earlier tests	Very low, no influence on vehicle known from earlier tests, so far.
Typical spectra	See section 6.1.3.1 in the report.	See section 6.1.3.1 in the report.

The figure below can be regarded as a typical statistical distribution of the line voltage harmonics for Norway and Sweden. (The values of the figure below are based on recordings made during tests with a locomotive on the Borlänge-Ludvika/Krylbo-Frövi-Eskilstuna line sections in Central Sweden, October 2005. Recordings and analysis by L. Buhrkall.)

Typical distribution of line voltage interference components, measured in Central Sweden.

PLEASE NOTICE: The curves showing the distribution of the fundamental 16 2/3 Hz voltage components are not typical for low voltages at weak supply.



A1.7.4 Regenerative brake

See clause 6.8 in the report.

A1.7.5 Power factor

See clause 6.3 in the report.

A1.7.6 Earthing

Data	Norway	Sweden
Earthing principles	The midpoint of the 2x27.5 kV high transmission line is directly earthed.	The 132 kV system has directly earthed midpoints in the 2-phase system (2x66 kV). AT-systems (2x15 kV) have directly earthed midpoints.

A1.7.7 Traffic information/characterisation

Data	Norway	Sweden
City area	Train density equal to line capacity	Train density equal to line capacity
Suburban area	Train density equal to line capacity	Train density equal to line capacity
Long distance lines	0-6 trains per feeding distance depending on traffic. In high load periods up to or even higher than line capacity.	Some lines (south from Storvik and south from Hallsberg to Mjölby has train density equal to line capacity. Otherwise 0-6 trains per feeding distance.

See respective Network Statement.

A1.7.8 Network operation

Data	Norway	Sweden
Case	The network is normally interconnected with adapted feeding capacity. Sectioning of contact line due to maintenance or failure often occur. Maintenance of converter stations may result in reduced feeding capacity. Sectioning and reduced feeding capacity results in lower resonance frequencies	Single feeding of lines during maintenance or fault conditions may occur resulting in very high impedances at the far end from feeding point and lower resonance frequencies. Other cases not applicable for vehicle compatibility

A1.7.9 Infrastructure classes

Expressions used in table below correspond to the definitions in EN50 163 and EN 50388. For more details see corresponding chapters in the report. Classification of infrastructure is to be given in respective Network Statement, but classes written in *italic* are most used.

Data	**Norway**	**Sweden**
Line voltage levels	*V1: according to EN 50163:2004* V2: U_{min2}=10000 V and U_{min1}=11000 V	*V1: U_{max2} = 17500 V*
Maximum current limitation	C1: I_{max} = 900 A C2: I_{max} = 700 A C3: I_{max} = 450 A	Max current per train is 900 A in tractive mode. Higher values in braking mode can be accepted.
Regenerative braking	B1: I_{max} B2: 10 MW / 600 A B3: 8 MW / 500 A *B4: 5 MW / 300 A*	No classes defined.
Low frequency power oscillations	Under investigation.	Under investigation.

A1.8 Existing electrical vehicles

Passive filters refers to HV-filters or filters on a separate winding of the transformer, not filters on the DC-link in case of an inverter vehicle.

Active behaviour refers to if the control system compensate for harmonics in the traction current in order to draw a sinusoidal current

A1.8.1 Electrical locomotives in Norway and Sweden

Operator	Vehicle (no of vehicles in op. in brackets.)	Type	Passive filter	Active behaviour
Hector Rail AB (pre-liminary accepted)	BR 441 (2) (DB BR 189)	Inverter	Yes	up to 83 1/3 Hz
Hector Rail AB	BR141 (3) (ÖBB Class 1012)	Inverter	No	up to 250 Hz
Hector Rail AB	BR142 (6) (ÖBB Class 1142)	Tap changer	No	No
CargoNet AS, Hector Rail AB, GreenCargoAB	CE119/BR241/BR 185.2 (20-30) (DB BR185.2)	Inverter	Yes	up to 83 1/3 Hz
MTAB	Dm 3 (19)	Tap changer	No	No
MTAB, TKAB	Da (5)	Tap changer	No	No
Raillion AS	EG 3100 (13)	Inverter	Yes	Yes, up to unknown freq.
NSB AS, Ofotbanen AS	El 13 (5)	Tap changer	No	No
CargoNet AS	El 14 (31)	Tap changer	No	No
Hector Rail AB	El 15 / BR 161 (6)	Tap changer, diode rectifier	No	No
CargoNet AS, TKAB, TGOJ	El 16 (17)	Phase angle control	Yes	No
NSB AS	El 17 (10)	Inverter	Yes	Unknown
NSB AS	El 18 (22)	Inverter	No	up to 83 1/3 Hz
MTAB	IORE (2x9=18)	Inverter	Yes	up to 83 1/3 Hz
TGOJ	MA (32)	Tap changer	No	No
SJ AB, Green Cargo AB, TÅGAB, TGOJ	Rc 1 to Rc 7 (356)	Phase angle control	Yes	No
Green Cargo AB	Rm (6)	Phase angle control	Yes	No

A1.8.2 Electrical multiple units in Norway and Sweden

Ofotbanen AS	Class 68 (3)	Tap changer	No	No
NSB AS	Class 69 a-g (77)	Phase angle control	a-c: yes d-g: no	No
NSB AS	Class 70 (16) ("IC 70")	Inverter	No	up to about 300 Hz
Flytoget AS	Class 71 (16) ("FPT")	Inverter	No	up to about 850 Hz
NSB AS	Class 72 (36)	Inverter	No	Unknown
NSB AS	Class 73 (22) Identical to class 71	Inverter	No	up to about 850 Hz
SL	X1 (94)	Phase angle control	Yes	No
SJ	X2 (43) ("X 2000")	Inverter	Yes	up to 216 2/3 Hz
Arlanda Banan AB	X3 (7) ("Arlanda Express")	Inverter	No	unknown
SJ and SL and other regional operators	X10 to X14 (137)	Phase angle control	yes	No
SJ, TKAB	X20 to X23 (3)	Tap changer, diode rectifier	unknown	No
SJ / DSB	X31-32 (3x53) ("Öresund train")	Inverter	yes	unknown
SJ	X40 (2x16 and 3x27 ordered)	Inverter	no	up to 150 Hz
SJ and regional operators	X50-54 (50) ("Regina")	Inverter	yes	up to 83 1/3 Hz
SL	X60 (71 ordered)	Inverter	no	up to 150 Hz

(for a good general overview of vehicles in NO and SE see also www.jarnvag.net)