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C.C.G.T. Moerdijk

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Cable Sizing Calculation Study

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MAIN DOCUMENT

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1		Information	UPS and DC cables added, new LV cable, MCC feeder cables updated, short circuit currents updated

ATTACHMENTS

ATTACHMENT	DESCRIPTION	REV.	DATE
APPENDIX A	TYPES OF POWER CABLES	0	09-07-10

TEMPLATES

PRELIMINARY OR PENDING INFORMATION

ISSUE	PARAGRAPH	SUBJECT	STATUS
2.2.6	1	LV cable lengths	Preliminary

CONTENTS

Page No.

1. PURPOSE

1.1 MEDIUM VOLTAGE POWER CABLES

This document calculates the minimum section of the medium voltage power cables in the CCGT Moerdijk, taking into account the maximum shortcircuit currents and the power cable ampacity.

The medium voltage power cables shall be sized in accordance with IEC 60502-2.

1.2 LOW VOLTAGE POWER CABLES

This document calculates the section of the low voltage power cables which feed the MCC's, motors and feeders.

The low voltage power cables of power centers shall be sized taking into account the maximum shortcircuit currents, the power cable ampacity and the voltage drop in accordance with NEN 1010. The rest of the low voltage power cables shall be sized according to the power cable ampacity and the voltage drop.

The results of this calculation will include tables in which the maximum length of the cables is shown, depending on the section of the cable, the demand of the consumers and the kind of load (motor, feeder).

1.3 DIRECT CURRENT POWER CABLES

This document calculates the section of the direct current power cables which feed the loads of the 250 VDC, 110 VDC and 24 VDC systems.

The DC power cables shall be sized taking into account the power cable ampacity and the voltage drop in accordance with the document 437-21-F-E-01005 "DC & UPS System Study" and the standard NEN 1010.

2. INPUT DATA

2.1 MEDIUM VOLTAGE POWER CABLES DATA

2.1.1 Ambient temperature

The maximum ambient temperature is 45ºC according to ESS40001e Minimum Requirements for Cables.

2.1.2 Soil temperature

According to contract B0.4.9.1, an earth thermal resistance of 1.5 K.m/W shall be considered.

2.1.3 Earth thermal resistance

According to contract B0.4.9.1, a ground temperature of 25ºC shall be considered.

2.1.4 Laying of the medium voltage power cables

Cables will be laid indoors or outdoors in open – top cable trays, ladder type, without covering excepting from short sections, with a maximum width of 800 mm and a vertical separation between consecutive trays of 300 mm.

In case that the medium voltage cables are laid in ducts at 1 m, a duct diameter of 160 mm has been considered, and a separation between adjacent ducts of 40 mm.

Cable	Laying
10.5 kV Switchgears 21BBA11/12	
Cable to MV/LV transformers (21BFT11, 21BFT12 and 21BMT10)	Indoor ladder tray / duct from electrical building to power transformers
HP/IP boiler feedwater pumps	Indoor ladder tray

Cable	Laying
Condensate pumps	Indoor ladder tray
Circulating water pumps (cables sized and supplied by Essent)	Indoor ladder tray / duct from electrical building to circulating water pumps
Cooling pumps (closed cooling circuit) heaters	Indoor ladder tray
Fire water pump (cables sized and supplied by Essent)	Indoor ladder tray / duct from electrical building to fire water pump
Unit auxiliary transformer 21BBT11	
Cable to 21BBW10	Duct from aux transformer to earthing cabinet 21BBW10
LCI system	
Cable to isolation transformer 21MBJ10	Indoor ladder tray / duct from electrical building to power transformer
Cable from each secondary of the isolation transformer to the static starter source bridge	Ducts / outdoor ladder tray
Cable from static starter to DC link reactor	Outdoor ladder tray
Cable from DC link reactor to static starter	Outdoor ladder tray
Cable from static starter to AC link reactor	Outdoor ladder tray
Cable from AC link reactor to static starter	Outdoor ladder tray
Cable from static starter load bridge to generator circuit breaker	Outdoor ladder tray

2.1.5 Medium Voltage load data

MV motors are connected to the MV switchgear with fused vacuum contactors, excepting the HP/IP boiler feedwater pumps, which are connected to the MV switchgear with a circuit breaker.

Transformers are connected to the MV switchgear with circuit breakers.

Load	P (kW)	S (kVA)	In(A)	cosφ	η
MV/LV transformers 21BFT11, 21BFT12 and 21BMT10	--	2900	--	--	--
HP/IP boiler feedwater pumps 21LAC10AP001 and 21LAC20AP001	3550	--	--	0.92	95
Condensate pumps 21LCB10AP001 and 21LCB20AP001	625	--	--	0.9	95
Cooling pump (closed cooling circuit) heaters 21PGC10AP001 and 21PGC20AP001	250	--	--	0.9	95
Primary isolation transformer 21MBJ10	--	8750	--	--	--
Secondary isolation transformer 21MBJ10	--	4375	--	--	--
DC link reactor 21MBJ30	--	--	2500,1	--	--
AC link reactor 21MBJ40	--	--	1950	--	--
Generator circuit breaker static starter	--	--	1950	--	--

2.1.6 Medium Voltage Short-circuit currents

I”k (kA)	Ip (kA peak)	Ik (kA)
31.43	79.66	30.75

Where:

I”k: Initial symmetrical short-circuit current

Ip: Peak value of the short-circuit current

Ik: Symmetrical short-circuit current in steady-state

MV power cables shall be designed taking into consideration a minimum short-circuit duration of 0.25 seconds according to contract B0.4.9.3.

2.1.7 Characteristics of the Medium Voltage fuses

The time – current characteristics of the MV fuses rated 160 A and 315 A have been taken from manufacturers data.

2.1.8 Characteristics of the medium voltage power cables

MV power cables are made of copper, with XLPE insulation and 8.7/15 kV of rated voltage. Multi – core cables will be used for sections up to 185 mm^2. Sections higher or equal to 240 mm^2 will be single-core.

Resistance and inductance of cables have been taken from manufacturers data.

Ampacity of copper conductors are according to IEC 60502-2 table B.2 and table B.6. A derating factor of 0.9 has been considered for cables with more than two conductors per phase (see 2.1.9.2).

Section (mm^2)	Cables inside ducts (A)	Air installation (A)
3 x 120	264	352
3 x 150	296	397
3 x 185	335	453
3(1 x 240)	453	641
3(1 x 300)	510	735

Section (mm^2)	Cables inside ducts (A)	Air installation (A)
3(1 x 400)	571	845
2x(3 x 120)	475,2	633,6
2x(3 x 150)	532,8	714,6
2x(3 x 185)	603	815,4
2x3(1 x 240)	815,4	1153,8
2x3(1 x 300)	918	1323
2x3(1 x 400)	1027,8	1521
Conductor temperature: Ambient temperature: Soil temperature: Depth of laying: Ground thermal resistance:	90ºC 30ºC 20ºC 0.8 m 1.5 K.m/W	

2.1.9 Derating factors

2.1.9.1 Ambient temperature

According to IEC 60502-2 table B.10, for an ambient temperature of 45ºC, the derating factor is 0.87.

2.1.9.2 Current imbalance in case of two or more conductors per phase

Due to the current imbalance when two or more conductors are installed per phase, a derating factor of 0.9 will be applied.

2.1.9.3 Soil temperature

According to IEC 60502-2 table B.11, for a soil temperature of 25ºC, the derating factor is 0.96.

2.1.9.4 Depth of laying

According to IEC 60502-2 table B.13, for a depth of laying of 1 m, the derating factor is 0.97.

2.1.9.5 Ground thermal resistance

According to IEC 60502-2 table B.14, for a thermal resistance of 1.5 K.m/W, the derating factor is 1.

2.1.9.6 Cable grouping in ladder trays

According to IEC 60502-2 table B.23, for three ladder trays separated 300 mm and three circuits in each tray, the derating factor is 0.9.

2.1.9.7 Cable grouping in ducts

Derating factor for cable grouping in ducts will be taken from table B.21 of IEC 60502-2.

Cable	Number of cable groups	Derating factor
10.5 kV Switchgears 21BBA11/12		
Cable to MV/LV transformers (21BFT11, 21BFT12 and 21BMT10)	1	1
Unit Auxiliary Transformer 21BBT11		
Cable to 21BBW10	1	1
LCI System		
Cable to isolation transformer 21MBJ10	2	0.85
Cable from each secondary of the isolation transformer to the static starter source bridge	12	0.55

2.2 LOW VOLTAGE POWER CABLES DATA

2.2.1 Ambient temperature

The maximum ambient temperature is 45ºC according to ESS40001e Minimum Requirements for Cables.

2.2.2 Soil temperature

According to contract B0.4.9.1, an earth thermal resistance of 1.5 K.m/W shall be considered.

2.2.3 Earth thermal resistance

According to contract B0.4.9.1, a ground temperature of 25ºC shall be considered.

2.2.4 Voltage range of the 400 V system

- Rated voltage: 400 V
- Range of voltage variation in steady state: ± 10%

2.2.5 Characteristics of the LV motors

Rated power (kW)	Steady state		Start-up	
	η	cosφ	cosφ	I start-up
0.37	0.68	0.69	0.66	7 · In
0.55	0.70	0.71	0.66	7 · In
0.75	0.72	0.72	0.65	7 · In
1.1	0.74	0.73	0.64	7 · In
1.5	0.74	0.74	0.63	7 · In
2.2	0.76	0.77	0.62	7 · In
3.7	0.79	0.78	0.61	7 · In
5.5	0.81	0.79	0.57	7 · In
7.5	0.83	0.80	0.53	7 · In
11	0.83	0.80	0.50	7 · In
15	0.85	0.81	0.47	7 · In
18.5	0.85	0.81	0.44	7 · In
22	0.85	0.82	0.42	7 · In
30	0.85	0.84	0.40	7 · In
37	0.85	0.84	0.38	7 · In
45	0.85	0.85	0.35	7 · In
55	0.85	0.85	0.32	7 · In

Rated power (kW)	Steady state		Start-up	
	η	cosφ	cosφ	I start-up
75	0.88	0.86	0.31	7 · In
90	0.87	0.86	0.30	7 · In
110	0.89	0.87	0.28	7 · In
125	0.90	0.87	0.27	7 · In
160	0.90	0.87	0.25	7 · In
200	0.90	0.88	0.25	7 · In
250	0.90	0.89	0.25	7 · In

2.2.6 Estimated cable length and way of laying

Cables will be laid indoors in open – top cable trays, ladder type, without covering excepting from short sections, with a maximum width of 800 mm and a vertical separation between consecutive trays of 300 mm.

Cables between equipments inside the electrical building will be laid in one level of ladder tray without covering, with a maximum width of 800 mm in the false floor.

In case that the low voltage cables are laid in ducts at 0.8 m, a duct diameter of 160 mm has been considered, and a separation between adjacent ducts of 200 mm.

From	To	Estimated length (m)	Laying
21BFA11 Unit Sv. Switchgear 1	21BJA11 MCC-1 GT,ST&G Sv	72	Indoor ladder tray
	21BJA13 MCC-1 Unit Sv.	125	Indoor ladder tray
	21BJA15 MCC-1 General Sv.	22	Indoor ladder tray
	BPM-2 main bearing lube oil pump 2	60	Indoor ladder tray
	88TK-1 turbine shell exhaust frame blower 1	125	Indoor ladder tray
	23FGEH-1 gas fuel heater	100	Indoor ladder tray
	21BJL11 normal lighting switchgear 1	22	Indoor ladder tray

From	To	Estimated length (m)	Laying
	21SCA10AN001 air compressor 1	145	Indoor ladder tray
	MCC-1 Demin Water Plant (Cable sized and supplied by Essent)	200	Indoor ladder tray / Ducts
	21LCA05AP001 LP economizer recirculation pump	115	Indoor ladder tray
21BFA12 Unit Sv. Switchgear 2	21BJA12 MCC-2 GT,ST&G Sv.	80	Indoor ladder tray
	21BJA14 MCC-2 Unit Sv.	135	Indoor ladder tray
	21BJA16 MCC-2 General Sv.	20	Indoor ladder tray
	88TK-2 turbine shell exhaust frame blower 2	140	Indoor ladder tray
	21MAW01AC001 Electric Heater	95	Indoor ladder tray
	21BJL12 normal lighting switchgear 2	25	Indoor ladder tray
	21SCA20AN001 air compressor 2	150	Indoor ladder tray
	21SMA10AE001 turbine building bridge crane (main & aux)	60	Indoor ladder tray
	MCC-2 Demin Water Plant (Cable sized and supplied by Essent)	200	Indoor ladder tray / ducts
	21LCP30AP001 deareator pump	80	Indoor ladder tray
	21LCA06AP001 LP economizer recirculation pump	130	Indoor ladder tray
21BMA10 Essential Sv. Switchgear	21BMB10 MCC Unit Essential Sv.	22	Indoor ladder tray
	BPM-1 main bearing lube oil pump 1	70	Indoor ladder tray
	21XKA10 Incoming from EDG	50	Indoor ladder tray / ducts
	12BFA09 Incoming from MD01 (Cable sized and supplied by Essent)	300	Indoor ladder tray / ducts
	21BMB20 MCC GT&ST&G Essential Sv.	22	Indoor ladder tray

2.2.7 Protective device settings and power demand, taken into account for the cable sizing

Service	Sizing according to		Notes
	Protective device setting (A)	Power demand (kW)	
MCCs 21BJA11, 21BJA12, 21BJA13, 21BJA14, 21BJA15, 21BJA16, 21BMB10 and 21BMB20	800		
BPM main bearing lube oil pump 1/2		223.7	η=0.9 cosφ=0.88
88TK turbine shell exhaust frame blower 1/2		160	η=0.9 cosφ=0.87
23FGEH-1 gas fuel heater		650	
21BJL11/12 normal lighting switchgear 1/2	630		Simultaneity factor f=0.87
21SCA10/20AN001 air compressor 1/2		94.7	η=0.89 cosφ=0.87
21MAW01AC001 electric heater		648	
21SMA10AE001 turbine building bridge crane (main & aux)		81	η=0.85 cosφ=0.87
21LCP30AP001 deareator pump		110	η=0.9 cosφ=0.87
21XKA10 Incoming from EDG		1080 (1350 kVA)	cosφ=0.80
21LCA05/6AP001 LP economizer recirculation pumps		110	η=0.89 cosφ=0.87

2.2.8 Maximum short-circuit currents in the 400 V system

In Power Centers

I"k (kA)	Ip (kA peak)	Ik (kA)
60.81	142.40	55.79

Where:

I"k: Initial symmetrical short-circuit current

Ip: Peak value of the short-circuit current

Ik: Symmetrical short-circuit current in steady-state

2.2.9 Feeders protective device setting

The following protective device settings are available:

- 16 A, 25 A, 40 A, 63 A, 80, 100 A, 125 A, 160 A, 250 A, 320 A, 400 A, 500 A, 630 A, 800 A, 1250 A, 2500 A, 3200 A, 4000 A.

2.2.10 Characteristics of the low voltage power cables

LV power cables are made of copper, with XLPE insulation and 0.6/1 kV of rated voltage. Multi – core cables will be used for sections up to 185 mm^2. Sections higher or equal to 240 mm^2 will be single-core.

Resistance and inductance of cables have been taken from manufacturers data.

Ampacity of copper conductors are according to NEN 1010 tables A.52.-4, A.52-6 and A.52-13. A derating factor of 0.9 has been considered for cables with more than two conductors per phase (see 2.2.11.2).

Section (mm^2)	Ladder tray installation (A)	Ducts installation (A)
2 x 1.5	26	26
2 x 2.5	36	34
2 x 4	49	44
2 x 6	63	56
2 x 10	86	73
2 x 16	115	95
2 x 25	149	121
2 x 35	185	146
2 x 50	225	173
2 x 70	289	213
2 x 95	352	252
2 x 120	410	187
2 x 150	473	324
2 x 185	542	363
2(1 x 240)	641	419
2(1 x 300)	741	474
2x(2 x 70)	520,2	383,4
2x(2 x 95)	633,6	453,6
2x(2 x 120)	738	336,6
2x(2 x 150)	851,4	583,2
2x(2 x 185)	975,6	653,4
2x2(1 x 240)	1153,8	754,2
2x2(1 x 300)	1333,8	853,2
4 x 1.5	23	22
4 x 2.5	32	29
4 x 4	42	37
4 x 6	54	46
4 x 10	75	61
4 x 16	100	79
4 x 25	127	101
4 x 35	158	122
4 x 50	192	144
4 x 70	246	178

Section (mm^2)	Ladder tray installation (A)	Ducts installation (A)
4 x 95	298	211
4 x 120	346	240
4 x 150	399	271
4 x 185	456	304
4(1 x 240)	607	351
4(1 x 300)	703	396
4(1 x 400)	823	444
2x(4 x 120)	622,8	432
2x(4 x 150)	718,2	487,8
2x(4 x 185)	820,8	547,2
2x4(1 x 240)	1092,6	631,8
2x4(1 x 300)	1265,4	712,8
2x4(1 x 400)	1481,4	799,2
3x(4 x 120)	934,2	648
3x(4 x 150)	1077,3	731,7
3x(4 x 185)	1231,2	820,8
3x4(1 x 240)	1638,9	947,7
3x4(1 x 300)	1898,1	1069,2
3x4(1 x 400)	2222,1	1198,8
4x(4 x 120)	1245,6	864
4x(4 x 150)	1436,4	975,6
4x(4 x 185)	1641,6	1094,4
4x4(1 x 240)	2185,2	1263,6
4x4(1 x 300)	2530,8	1425,6
4x4(1 x 400)	2962,8	1598,4
5x4(1 x 400)	3704	1998
Includes earth conductor Conductor temperature: 90ºC Ambient temperature: 30ºC Soil temperature: 20ºC Depth of laying: 0.7 m		

Section (mm^2)	Ladder tray installation (A)	Ducts installation (A)
Ground thermal resistance: 2.5 K.m/W		

2.2.11 Derating factors

2.2.11.1 Ambient temperature

According to NEN 1010 table A.52-15, for an ambient temperature of 45ºC, the derating factor is 0.87.

2.2.11.2 Current imbalance in case of two or more conductors per phase

Due to the current imbalance when two or more conductors are installed per phase, a derating factor of 0.9 will be applied.

2.2.11.3 Soil temperature

According to NEN 1010 table A.52-16, for a soil temperature of 25ºC, the derating factor is 0.96.

2.2.11.4 Depth of laying

According to NEN 1010 table A.52-2, for a depth of laying of 0.7 m, the derating factor is 1.

2.2.11.5 Ground thermal resistance

According to NEN 1010 table A.52-17, for a thermal resistance of 1.5 K.m/W, the derating factor is 1.18.

2.2.11.6 Cable grouping in ladder trays

According to NEN 1010 table A.52-22, for three ladder trays separated 300 mm and twenty circuits in each tray, the derating factor is 0.64.

Inside the electrical building, only one level of ladder trays will be installed in the false floor, therefore according to NEN 1010 table A.52-18 for twenty circuits in the tray, the derating factor is 0.77.

2.2.11.7 Cable grouping in ducts

According to NEN 1010 table A.52-20, with a distance (a) between ducts of 40 mm, the derating factor is as follows:

Number of circuits	40 mm between ducts (*)
2	0,86
3	0,78
4	0,72
5	0,67
6	0,64
7	0,60
8	0,57
9	0,55
10	0,53
11	0,51
12	0,49
13	0,48
14	0,46
15	0,45
16	0,43
17	0,42
18	0,41
19	0,40
20	0,39

(*) These values have been estimated according to NEN 1010 table A.52-20.

2.2.11.8 Harmonics

Due to the harmonics in the UPS system, a derating factor of 0.9 will be applied.

2.3 DIRECT CURRENT POWER CABLES DATA

2.3.1 Ambient temperature

The maximum ambient temperature is 45ºC according to ESS40001e Minimum Requirements for Cables.

2.3.2 Voltage range of the DC systems

250 VDC system

- Maximum voltage: 250 VDC + 10%
- Minimum voltage: 250 VDC – 15%
- 250 V DC motors startup: 204 V DC (85% of 240 V rated voltage)

110 VDC system

- Maximum voltage: 110 VDC + 10%
- Minimum voltage: 110 VDC – 15%

2.3.3 Main DC loads

250 VDC Consumers

Load	Rated current, A	Transient operation current (3,5xIn), A
EBPM Emergency BRG Oil Pump (56 kW)	251	879
ESPM Emergency Seal Oil Pump (37,3 kW)	192	672
Switchgear 21BUB10	443	1551

110 VDC Consumers

Load	Rated current, A	Rated power, kVA
Switchgears 21BUA11/12	726	
Inverters 21BRU11/12		20 (η=0,85)

2.3.4 Estimated cable length and way of laying

Cables will be laid indoors in open – top cable trays, ladder type, without covering excepting from short sections, with a maximum width of 800 mm and a vertical separation between consecutive trays of 300 mm.

Cables between equipments inside the electrical building will be laid in one level of ladder tray without covering, with a maximum width of 800 mm in the false floor.

2.3.5 Characteristics of the DC power cables

DC power cables are made of copper, with XLPE insulation and 0.6/1 kV of rated voltage. Multi – core cables will be used for sections up to 185 mm^2. Sections higher or equal to 240 mm^2 will be single-core.

Resistance and inductance of cables have been taken from manufacturers data.

Ampacity of copper conductors are according to NEN 1010 table A.52-13. A derating factor of 0.9 has been considered for cables with more than two conductors per phase (see 2.3.6.2).

Section (mm^2)	Ladder tray installation (A)
2 x 2.5	36
2 x 4	49
2 x 6	63
2 x 10	86
2 x 16	115
2 x 25	149
2 x 35	185
2 x 50	225
2 x 70	289
2 x 95	352
2 x 120	410
2 x 150	473
2 x 185	542
2(1 x 240)	679
2(1 x 300)	783
2x(2 x 70)	520,2
2x(2 x 95)	633,6
2x(2 x 120)	738
2x(2 x 150)	851,4
2x(2 x 185)	975,6
2x2(1 x 240)	1222,2
2x2(1 x 300)	1409,4
2x2(1 x 400)	1692
3x2(1 x 240)	1833,3
3x2(1 x 300)	2114,1
3x2(1 x 400)	2538
4x2(1 x 240)	2444,4
4x2(1 x 300)	2818,8
4x2(1 x 400)	3384

2.3.6 Derating factors

2.3.6.1 Ambient temperature

According to NEN 1010 table A.52-15, for an ambient temperature of 45ºC, the derating factor is 0.87.

2.3.6.2 Current imbalance in case of two or more conductors per phase

Due to the current imbalance when two or more conductors are installed per phase, a derating factor of 0.9 will be applied.

2.3.6.3 Cable grouping in ladder trays

According to NEN 1010 table A.52-22, for three ladder trays separated 300 mm and twenty circuits in each tray, the derating factor is 0.64.

Inside the electrical building, only one level of ladder trays will be installed in the false floor, therefore according to NEN 1010 table A.52-18 for twenty circuits in the tray, the derating factor is 0.77.

3. HYPOTHESIS

Single cables will be used for sections equal or higher than 240 mm^2.

Related to cables laid in parallel, the same length and section shall be considered. If two or more cables per phase are necessary a derating factor of 0.9 shall applied.

Cables are made of copper, with XLPE insulation. Consequently, the maximum conductor temperature is 90ºC.

The following temperatures and thermal resistivity are considered in the calculations:

- Ambient temperature: 45ºC
- Soil temperature: 25ºC
- Ground thermal resistivity: 1.5 K·m/W

3.1 MEDIUM VOLTAGE CABLE SIZING

MV cable sizing has been performed taking into account the short-circuit currents in the MV system and the cable ampacity for cables of 8.7/15 kV. Voltage drop has not been considered for the sizing of the MV cables, as they have little significance in a MV system.

Cables laid in ladder trays will be installed with a cable spacing equals to a cable diameter. However, to carry out the cable ampacity calculation, the derating factors relative to cables laid together have been used according to IEC 60502-2 table B.23.

Cable laid in ducts will be installed with a duct spacing between centres of 0.20 m. However, to carry out the cable ampacity calculation, the derating factors relative to a ducts spacing of 0.2 m have been used according to IEC 60502-2 table B.21.

The maximum allowable currents are calculated applying the correction factors indicated in IEC60502-2

The cable will be protected against short-circuits by fuse or circuit breaker for the system short-circuit currents calculated in accordance with IEC 60865-1.

LCI system cables will be sized according to GE document 365A5126 “Static Starter KWH Curve, Harmonic. Analysis and Cable Summary.”

Finally, the following table shows the derating factors used to perform the MV cable sizing according to the cable ampacity.

Laying	No circuits	Ambient temperature factor	Soil temperature factor	Ground thermal resistance factor	Depth of laying	Cable grouping	Total derating factor
Ladder tray	--	0.87	--	--	--	0.9	0.78
Ducts	1	--	0.96	1	0.97	1	0.93
	2	--	0.96	1	0.97	0.85	0.79
	12	--	0.96	1	0.97	0.55	0.51

3.2 LOW VOLTAGE CABLE SIZING

Low voltage cables will be sized taking into account the cable ampacity and the voltage drop. In addition, LV cables connected to the power centre busbars will be sized to withstand the short-circuit currents during 400 ms according to NEN 1010 table 41A (TN-S system).

- Cable ampacity:

The ampacity of the LV cables has been determined with the following criteria:

- Ambient temperature: 45ºC

- Cables laid in ladder trays indoors, with a 50% tray fill.

- Maximum cable tray width: 800 mm

- Cable ducts: outer diameter 160 mm, inner diameter 150 mm

- Duct filling: 30%

- Power centre motor cables are sized for the overload protection relay setting, 110% of the motor rated current, and the power centre feeder cable for the 110% of the feeder rated power demand. Consequently the effect of the minimum voltage in the power demand has been considered.

- For the MCC's, due to the protection device rated current (800 A) is much greater than its demand rated current, the cable is sized for the 90% of the protection rated current (800x0.9 = 720 A). Overload protection will be set to this value.

- MCC motor cables are sized for the 110% of the rated motor current. Overload protection will be set to this value.

- MCC feeder cables are sized for the circuit breaker thermal rated current.

- UPS cables are sized for the circuit breaker thermal rated current.

Finally the following tables show the derating factors used to perform de LV cable sizing according to the cable ampacity.

Laying	No circuits	Ambient temperature factor	Soil temperature factor	Ground thermal resistance factor	Depth of laying	Cable grouping	Harmonics	Total derating factor
Ladder tray	--	0.87	--	--	--	0.64	0.9	0.56 / 0.50
Ladder tray false floor	--	0.87	--	--	--	0.77	--	0.67
Ducts	1	--	0.96	1.18	1	1	--	1,13
	2	--	0.96	1.18	1	0.86	--	0.96
	3	--	0.96	1.18	1	0.78	--	0.88
	4	--	0.96	1.18	1	0.72	--	0.82
	5	--	0.96	1.18	1	0.67	--	0.76

3.3 DIRECT CURRENT CABLE SIZING

Direct current power cables will be sized taking into account the cable ampacity and the voltage drop.

- Cable ampacity:

The ampacity of the DC cables has been determined with the following criteria:

- Ambient temperature: 45ºC
- Cables laid in ladder trays indoors, with a 50% tray fill.
- Maximum cable tray width: 800 mm
- DC feeders cables are sized for the circuit breaker thermal rated current

- 250 VDC motors are sized for the transient current because motors are only protected by magnetic circuit breakers.

Finally the following tables show the derating factors used to perform de DC cable sizing according to the cable ampacity.

Laying	No circuits	Ambient temperature factor	Soil temperature factor	Ground thermal resistance factor	Depth of laying	Cable grouping	Total derating factor
Ladder tray	--	0.87	--	--	--	0.64	0.56
Ladder tray false floor	--	0.87	--	--	--	0.77	0.67

- Voltage drop:

250 VDC system:

a) Voltage drop in the cable between the battery terminals (21BTB10) and the switchgear (21BUB10): 3 V

b) Voltage drop due to the cables between the switchgear (21BUB10) and consumer terminals: 5.86 V

110 VDC system:

a) Voltage drop in the cable between the battery terminals (21BTA11/12) and the switchgear (21BUA11/12): 1 V

b) Voltage drop due to the cables between the switchgear (21BUA11/12) and consumer terminals: 3.7 V

24 VDC system:

a) Voltage drop due to the cables between the switchgear (21BUM11/12) and consumer terminals: 3% (0.72 V)

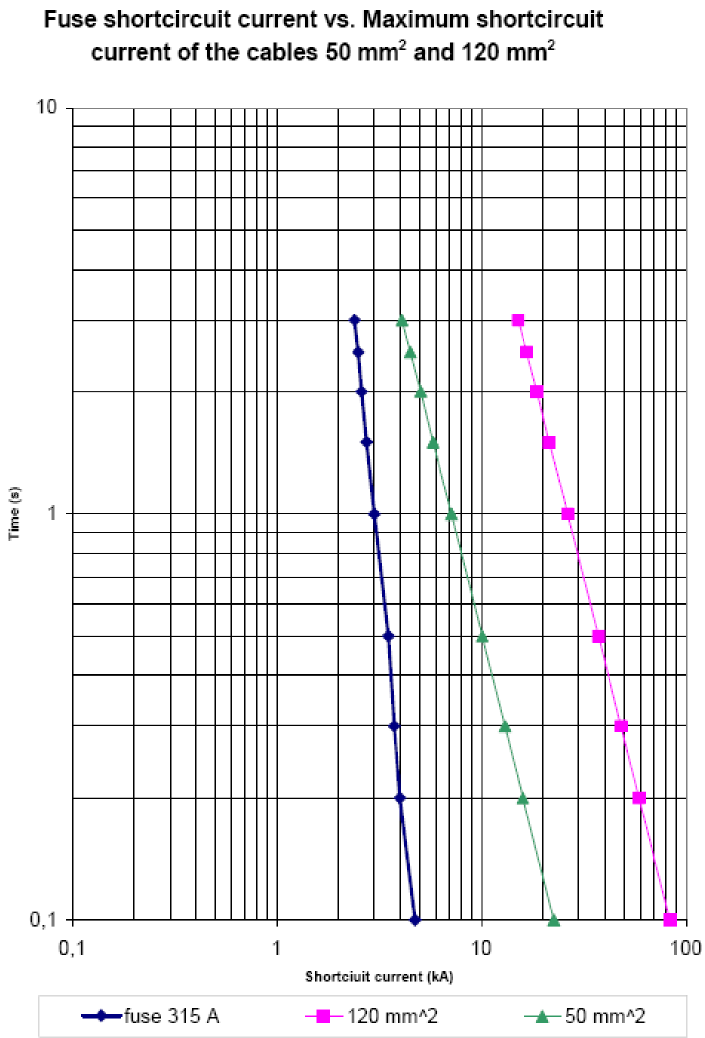
4. CALCULATIONS

4.1 MEDIUM VOLTAGE SYSTEM

4.1.1 Cable sizing according to its short-circuit withstand capacity

The following picture shows that fuses protect effectively against short-circuits the medium voltage cables of those services connected with fused vacuum contactors to the medium voltage busbars.

Calculations have been performed for the largest fuse (315 A).



Therefore cables of the services protected with fuses shall be of at least 50 mm^2.

The cables of the services connected to the medium voltage busbars with circuit breakers shall be of at least 120 mm^2, to withstand the short-circuit currents in the medium voltage system for at least 250 ms according to IEC 60865:

$$I_{th} = I_k^{"} \cdot \sqrt{m+n}$$

$$n = \frac{I_k^{"}}{I_k} = \frac{31.43}{30.75} = 1.02 \cong 1$$

$$\chi = \frac{I_p}{\sqrt{2} \cdot I_k^{"}} = \frac{79.66}{\sqrt{2} \cdot 31.43} = 1.79$$

$$m = \frac{1}{2 f T_k \ln(\chi - 1)} \left[e^{4 f T_k \ln(\chi-1)} - 1 \right] = \frac{1}{2 \cdot 50 \cdot 0.25 \ln(1.79-1)} \left[e^{4 \cdot 50 \cdot 0.25 \ln(1.79-1)} - 1 \right] = 0.17$$

$$I_{th} = 31.43 \cdot \sqrt{0.17+1} = 34 kA$$

$$S \geq I_{th} \frac{\sqrt{T_k}}{K} = 34000 \frac{\sqrt{0.25}}{143} = 118 mm^2$$

4.1.2 Cable sizing according to cable ampacity

4.1.2.1 MV/LV transformers 21BFT11, 21BFT12 and 21BMT10

The transformers rated current is as follows:

$$I_n = \frac{2900}{\sqrt{3} \cdot 10.5} = 159.5 \text{ A}$$

Cable laying: Indoor ladder tray / duct from electrical building to power transformers, where the most restrictive installation method is inside ducts.

Ampacity for 120 mm^2 copper cable: 264 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.93

$$n = \frac{264 \cdot 0.93}{159.5} = 1.54$$

3 x 120 mm^2 cable is therefore valid.

4.1.2.2 HP/IP boiler feedwater pumps 21LAC10AP001 and 21LAC20AP001

The motor rated current is as follows:

$$I_n = \frac{3550}{\sqrt{3} \cdot 10.5 \cdot 0.92 \cdot 0.95} = 223.3 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 120 mm^2 copper cable: 352 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.78

$$n = \frac{352 \cdot 0.78}{223.3} = 1.2$$

3 x 120 mm^2 cable is therefore valid.

4.1.2.3 Condensate pumps 21LCB10AP001 and 21LCB20AP001

The motor rated current is as follows:

$$I_n = \frac{625}{\sqrt{3} \cdot 10.5 \cdot 0.9 \cdot 0.95} = 40.2 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 50 mm^{2}copper cable: 205 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.78

$$n = \frac{205 \cdot 0.78}{40.2} = 4.0$$

3 x 50 mm^2 cable is therefore valid.

4.1.2.4 Cooling pump (closed cooling circuit) heaters 21PGC10AP001 and 21PGC20AP001

The motor rated current is as follows:

$$I_n = \frac{250}{\sqrt{3} \cdot 10.5 \cdot 0.9} = 15.3 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 50 mm^{2}copper cable: 205 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.78

$$n = \frac{205 \cdot 0.78}{15.3} = 10.5$$

3 x 50 mm^2 cable is therefore valid.

4.1.2.5 Isolation transformer 21MBJ10

Cables to transformer are sized for the 115% of the transformer rated current

$$I_n = \frac{8750}{\sqrt{3} \cdot 10.5} = 481.1 \text{ A}$$

Cable laying: Indoor ladder tray / duct from electrical building to power transformer, where the most restrictive installation method is inside ducts.

Ampacity for 2x240 mm^2 copper cable: 815 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.79

$$n = \frac{815 \cdot 0.79}{481.1 \cdot 1.15} = 1.2$$

2x3(1 x 240) mm^2 cable is therefore valid.

4.1.2.6 Cables from each secondary of the isolation transformer to the static starter bridge

Cables to transformer are sized for the 115% of the secondary transformer rated current

$$I_n = \frac{4375}{\sqrt{3} \cdot 2.08} = 1214.4 \text{ A}$$

Cable laying: Indoor ladder tray / duct from the isolation transformer to the LCI, where the most restrictive installation method is inside 12 ducts.

Ampacity for 6x400 mm^2 copper cable: 3083 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.51

$$n = \frac{3083 \cdot 0.51}{1214.4 \cdot 1.15} = 1.13$$

6x3(1 x 400) mm^2 cable is therefore valid.

4.1.2.7 Cables from the static starter to the DC link reactor and vice versa

Cables are sized for the 115% rated current

$I_n = 2500.1$ A

Cable laying: Indoor ladder tray.

Ampacity for 5x400 mm^2 copper cable: 3802 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.78

$$n = \frac{3802 \cdot 0.78}{2500.1 \cdot 1.15} = 1.03$$

5(1 x 400) mm^2 cable is therefore valid.

4.1.2.8 Cables from the static starter to the AC link reactor and vice versa

Cables are sized for the 115% rated current

$I_n = 1950$ A

Cable laying: Indoor ladder tray.

Ampacity for 4x400 mm^2 copper cable: 3042 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.78

$$n = \frac{3042 \cdot 0.78}{1950 \cdot 1.15} = 1.06$$

4x3(1 x 400) mm^2 cable is therefore valid.

4.1.2.9 Cables from the static starter to the generator circuit breaker

Cables are sized for the 115% rated current

$I_n = 1950$ A

Cable laying: Indoor ladder tray.

Ampacity for 4x400 mm^2 copper cable: 3042 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.78

$$n = \frac{3042 \cdot 0.78}{1950 \cdot 1.15} = 1.06$$

4x3(1 x 400) mm^2 cable is therefore valid.

4.1.2.10 Cable from the auxiliary transformer to the earthing cabinet 21BBW10

The earth fault is limited to 5 A through the earthing cabinet.

Cable laying: Outdoor ladder tray / duct from the transformer, where the most restrictive installation method is inside ducts.

Ampacity for 240 mm^2 copper cable: 151 A.

Therefore, taking into account the total derating factor table of the paragraph 3.1: 0.93

$$n = \frac{151 \cdot 0.93}{5} = 28$$

1 x 240 mm^2 cable is therefore valid.

4.2 LOW VOLTAGE SYSTEM

4.2.1 Cable sizing according to its short-circuit withstand capacity

The cables of the services connected to the power center busbars with circuit breakers shall be of at least 300 mm^2, to withstand the short-circuit currents in the low voltage system for at least 400 ms according to NEN 1010 table 41A (TN-S system):

$$I_{th} = I_k^{"} \cdot \sqrt{m+n}$$

$$n = \frac{I_k^{"}}{I_k} = \frac{60.81}{55.79} = 1.08 \cong 1$$

$$\chi = \frac{I_p}{\sqrt{2} \cdot I_k^{"}} = \frac{142.40}{\sqrt{2} \cdot 60.81} = 1.66$$

$$m = \frac{1}{2 f T_k \ln(\chi - 1)}\left[e^{4 f T_k \ln(\chi-1)} - 1\right] = \frac{1}{2 \cdot 50 \cdot 0.4 \ln(1.66-1)}\left[e^{4 \cdot 50 \cdot 0.4 \ln(1.66-1)} - 1\right] = 0.06$$

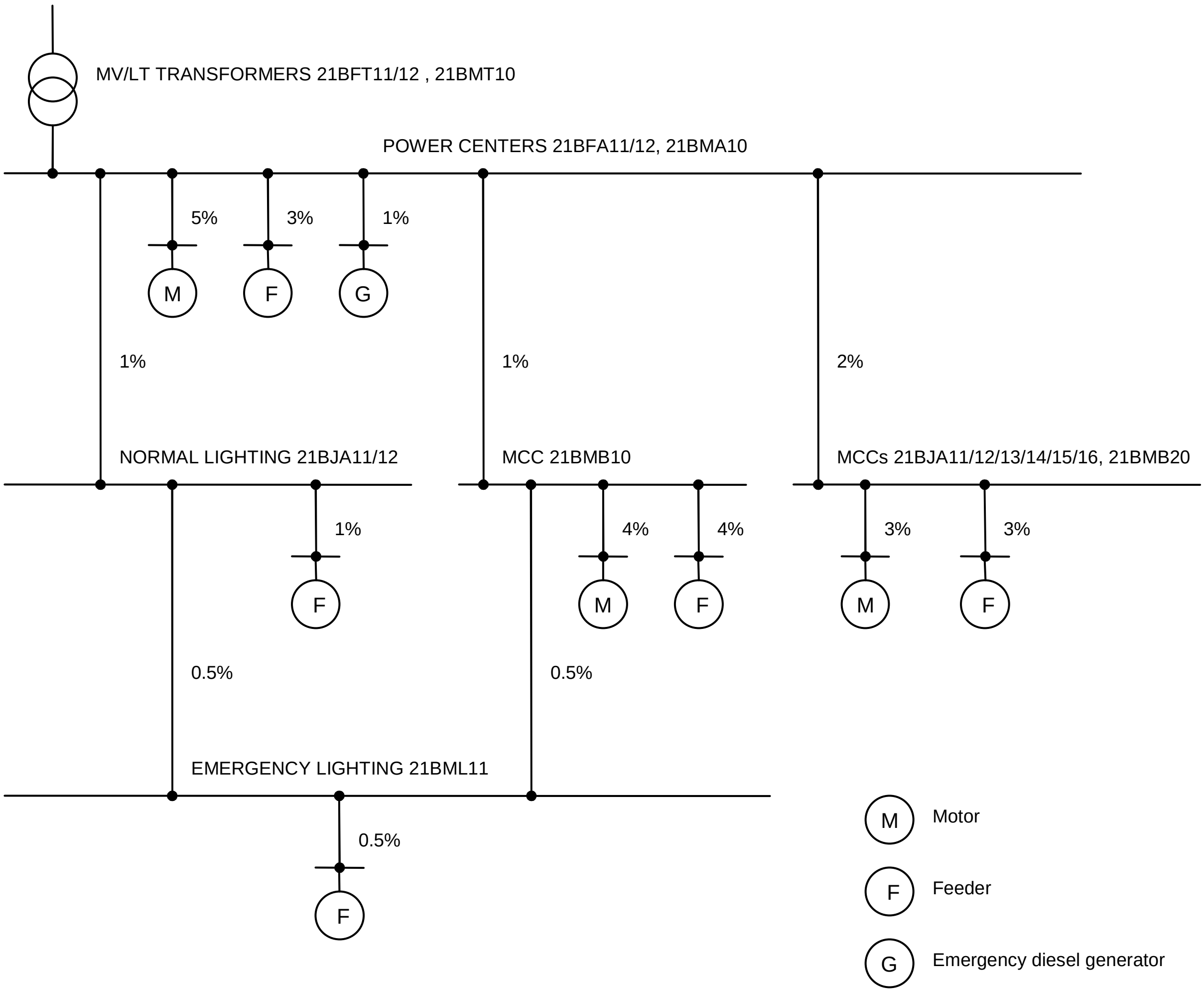
$$I_{th} = 60.81 \cdot \sqrt{0.06+1} = 62.61 kA$$

$$S \geq I_{th} \frac{\sqrt{T_k}}{K} = 62610 \frac{\sqrt{0.4}}{143} = 277 mm^2$$

4.2.2 Cable sizing according to the voltage drop

The maximum allowable voltage drop is 2% for lighting installations and 5% for power installations. In addition, during the starting of motors, 10% of voltage drop will be considered

A diagram with the different voltage drops considered is shown as follows:



4.2.3 Cable sizing according to cable ampacity

4.2.3.1 21BJA11 MCC-1 GT,ST&G Sv

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$I_n = 800 \cdot 0.9 = 720$ A

Cable laying: Indoor ladder tray.

Ampacity for 2x400 mm^2 copper cable: 1481 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{1481 \cdot 0.56}{720} = 1.2$$

2x4(1 x 400) + 1 x 400 mm^2 cable is therefore valid.

4.2.3.2 21BJA12 MCC-2 GT,ST&G Sv

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$I_n = 800 \cdot 0.9 = 720$ A

Cable laying: Indoor ladder tray.

Ampacity for 2x400 mm^2 copper cable: 1481 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{1481 \cdot 0.56}{720} = 1.2$$

2x4(1 x 400) + 1 x 400 mm^2 cable is therefore valid.

4.2.3.3 21BJA13 MCC-1 Unit Sv.

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$$I_n = 800 \cdot 0.9 = 720 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 2x400 mm^2 copper cable: 1481 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{1481 \cdot 0.56}{720} = 1.2$$

2x4(1 x 400) + 1 x 400 mm^2 cable is therefore valid.

4.2.3.4 21BJA14 MCC-2 Unit Sv.

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$$I_n = 800 \cdot 0.9 = 720 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 2x400 mm^2 copper cable: 1481 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{1481 \cdot 0.56}{720} = 1.2$$

2x4(1 x 400) + 1 x 400 mm^2 cable is therefore valid.

4.2.3.5 21BJA15 MCC-1 General Sv.

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$$I_n = 800 \cdot 0.9 = 720 \text{ A}$$

Cable laying: Indoor ladder tray in false floor.

Ampacity for 2x300 mm^2 copper cable: 1265 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.67

$$n = \frac{1265 \cdot 0.67}{720} = 1.18$$

2x4(1 x 300) + 1 x 300 mm^2 cable is therefore valid.

4.2.3.6 21BJA16 MCC-2 General Sv.

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$$I_n = 800 \cdot 0.9 = 720 \text{ A}$$

Cable laying: Indoor ladder tray in false floor.

Ampacity for 2x300 mm^2 copper cable: 1265 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.67

$$n = \frac{1265 \cdot 0.67}{720} = 1.18$$

2x4(1 x 300) + 1 x 300 mm^2 cable is therefore valid.

4.2.3.7 21BMB10 MCC Unit Essential Sv.

Cables to these MCC’s are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$$I_n = 800 \cdot 0.9 = 720 \text{ A}$$

Cable laying: Indoor ladder tray in false floor.

Ampacity for 2x300 mm^2 copper cable: 1265 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.67

$$n = \frac{1265 \cdot 0.67}{720} = 1.18$$

2x4(1 x 300) + 1 x 300 mm^2 cable is therefore valid.

4.2.3.8 21BMB20 MCC GT&ST&G Essential Sv.

Cables to these MCC's are sized for the 90% of the protection device current, in this case 800 A. Overload protection relay will be set to this value.

$$I_n = 800 \cdot 0.9 = 720 \text{ A}$$

Cable laying: Indoor ladder tray in false floor.

Ampacity for 2x300 mm^2 copper cable: 1265 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.67

$$n = \frac{1265 \cdot 0.67}{720} = 1.18$$

2x4(1 x 300) + 1 x 300 mm^2 cable is therefore valid.

4.2.3.9 BPM main bearing lube oil pump 1/2

Cables to motors are sized for the 110% of the motor rated current:

$$I_n = \frac{223.7}{\sqrt{3} \cdot 0.4 \cdot 0.9 \cdot 0.88} = 407.7 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 400 mm^2 copper cable: 823 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{823 \cdot 0.56}{407.7 \cdot 1.1} = 1.03$$

3(1 x 400) + 1 x 240 mm^2 cable is therefore valid.

4.2.3.10 Turbine shell exhaust frame blower 1/2

Cables to motors are sized for the 110% of the motor rated current:

$$I_n = \frac{160}{\sqrt{3} \cdot 0.4 \cdot 0.9 \cdot 0.87} = 294.9 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 400 mm^2 copper cable: 823 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{823 \cdot 0.56}{294.9 \cdot 1.1} = 1.4$$

3(1 x 400) + 1 x 240 mm^2 cable is therefore valid.

4.2.3.11 23FGEH-1 gas fuel heater

Cables to feeders are sized for the 110% of the rated current.

$$I_n = \frac{650}{\sqrt{3} \cdot 0.4} = 938.2 \text{ A}$$

Gas fuel heater, is a pure resistive load.

Cable laying: Indoor ladder tray.

Ampacity for 4x300 mm^2 copper cable: 1898 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{1898 \cdot 0.56}{938.2 \cdot 1.1} = 1.03$$

3x4(1 x 300) + 2(1 x 240) mm^2 cable is therefore valid.

4.2.3.12 21BJL11/12 normal lighting switchgear

$I_n = 630$ A with a simultaneity factor of 0.87

Cable laying: Indoor ladder tray in false floor

Ampacity for 400 mm^2 copper cable: 823 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.67

$$n = \frac{823 \cdot 0.67}{630 \cdot 0.87} = 1.01$$

4(1 x 400) + 1 x 240 mm^2 cable is therefore valid.

4.2.3.13 21SCA10/20AN001 air compressor

Cables to feeders are sized for the 110% of the rated current.

$$I_n = \frac{94.7}{\sqrt{3} \cdot 0.4 \cdot 0.89 \cdot 0.87} = 176.5 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 300 mm^2 copper cable: 703 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{703 \cdot 0.56}{176.5 \cdot 1.1} = 2.0$$

4(1 x 300) + 1 x 150 mm^2 cable is therefore valid.

4.2.3.14 21MAW01AC001 electric heater

Cables to feeders are sized for the 110% of the rated current.

$$I_n = \frac{648}{\sqrt{3} \cdot 0.4} = 935.3 \text{ A}$$

Electric heater is a pure resistive load.

Cable laying: Indoor ladder tray.

Ampacity for 3x300 mm^2 copper cable: 1898 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{1898 \cdot 0.56}{935.3 \cdot 1.1} = 1.03$$

3x4(1 x 300) + 2x(1 x 240) mm^2 cable is therefore valid.

4.2.3.15 21SMA10AE001 turbine building bridge crane (main & aux)

Cables to feeders are sized for the 110% of the rated current.

$$I_n = \frac{81}{\sqrt{3} \cdot 0.4 \cdot 0.87 \cdot 0.85} = 158.1 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 300 mm^2 copper cable: 703 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{703 \cdot 0.56}{158.1 \cdot 1.1} = 2.26$$

4(1 x 300) + 1 x 150 mm^2 cable is therefore valid.

4.2.3.16 21LCP30AP001 deareator pump

Cables to motors are sized for the 110% of the motor rated current:

$$I_n = \frac{110}{\sqrt{3} \cdot 0.4 \cdot 0.9 \cdot 0.87} = 202.8 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 300 mm^2 copper cable: 703 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{703 \cdot 0.56}{202.8 \cdot 1.1} = 1.76$$

3(1 x 300) + 1 x 150 mm^2 cable is therefore valid.

4.2.3.17 21XKA10 emergency diesel generator

Cables to feeders are sized for the rated current.

$$I_n = \frac{1080}{\sqrt{3} \cdot 0.4 \cdot 0.8} = 1948.6 \text{ A}$$

Cable laying: Indoor ladder tray / duct. The duct derating factor can be neglected due to the short distance of the duct (5 meters), compared to the total length of the laying (50 meters).

Ampacity for 5x400 mm^2 copper cable: 3704 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{3704 \cdot 0.56}{1948.6} = 1.06$$

5x4(1 x 400) + 3(1 x 400) mm^2 cable is therefore valid.

4.2.3.18 21LCA05/6AP001 LP economizer recirculation pumps

Cables to motors are sized for the 110% of the motor rated current:

$$I_n = \frac{110}{\sqrt{3} \cdot 0.4 \cdot 0.89 \cdot 0.87} = 205.1 \text{ A}$$

Cable laying: Indoor ladder tray.

Ampacity for 300 mm^2 copper cable: 703 A.

Therefore, taking into account the total derating factor table of the paragraph 3.2: 0.56

$$n = \frac{703 \cdot 0.56}{205.1 \cdot 1.1} = 1.7$$

3(1 x 300) + 1 x 150 mm^2 cable is therefore valid.

4.3 DIRECT CURRENT SYSTEM

4.3.1 Cable sizing according to cable ampacity and voltage drop

4.3.1.1 EBPM Emergency BRG Oil Pump

$I_n = 251$ A

$I_{tr} = 879$ A

Maximum voltage drop: 5.86 V

Cable laying: Indoor ladder tray. Total derating factor in table of paragraph 3.3: 0.56

Ampacity for 2x400 mm^2 copper cable: 1694 A.

Ampacity for 1x400 mm^2 copper cable: 940 A.

During start-up of the motor, the voltage drop is:

Between 21BUB10 and EBOP, with length 50 m and using a 2x2x(1x400) mm^2 cable:

$U = 2 \cdot R \cdot L \cdot I_{tr} = 2.79$ V

Between EBOP and EBPM, with length 15 m and using a 2x(1x400) mm^2 cable:

$U = 2 \cdot R \cdot L \cdot I_{tr} = 1.67$ V

Total voltage drop during start-up 4.46 V.

Cables are also sized for the 150 % of the motor rated current.

$$n = \frac{1694 \cdot 0.56}{251 \cdot 1.5} = 2.52$$

$$n = \frac{940 \cdot 0.56}{251 \cdot 1.5} = 1.4$$

Therefore the cable 2x2x(1 x 400) mm^2 cable is valid between the 21BUB10 and the EBOP, and the cable 2x(1 x 400) mm2 is valid between the EBOP and EBPM.

4.3.1.2 ESPM Emergency Seal Oil Pump

$I_n = 192$ A

$I_{tr} = 672$ A

Maximum voltage drop: 5.86 V

Cable laying: Indoor ladder tray. Total derating factor in table of paragraph 3.3: 0.56

Ampacity for 2x300 mm^2 copper cable: 1409 A.

Ampacity for 1x300 mm^2 copper cable: 783 A.

During start-up of the motor, the voltage drop is:

Between 21BUB10 and ESOP, with length 50 m and using a 2x2x(1x300) mm^2 cable:

$U = 2 \cdot R \cdot L \cdot I_{tr} = 2.70$ V

Between ESOP and ESPM, with length 15 m and using a 2x(1x300) mm^2 cable:

$U = 2 \cdot R \cdot L \cdot I_{tr} = 1.62$ V

Total voltage drop during start-up 4.32 V.

Cables are also sized for the 150 % of the motor rated current.

$$n = \frac{1409 \cdot 0.56}{192 \cdot 1.5} = 2.74$$

$$n = \frac{783 \cdot 0.56}{192 \cdot 1.5} = 1.52$$

Therefore the cable 2x2x(1 x 300) mm^2 cable is valid between the 21BUB10 and the ESOP, and the cable 2x(1 x 300) mm2 is valid between the ESOP and ESPM.

4.3.1.3 Cable from battery 21BTB10 to switchgear 21BUB10

$I_{tr} = 1561$ A

Maximum voltage drop: 3 V

Cable laying: Indoor ladder tray.

Ampacity for 4x300 mm^2 copper cable: 2818 A.

Therefore, taking into account the total derating factor table of the paragraph 3.3: 0.56

$$n = \frac{2818 \cdot 0.56}{1561} = 1.01$$

Maximum cable length: 48 m

4x2(1 x 300) mm^2 cable is therefore valid.

4.3.1.4 Cable from batteries 21BTA11/12 to switchgears 21BUA11/12

$I_n = 726$ A

Maximum voltage drop: 1 V

Cable laying: Indoor ladder tray.

Ampacity for 3x300 mm^2 copper cable: 2114 A.

Therefore, taking into account the total derating factor table of the paragraph 3.3: 0.56

$$n = \frac{2114 \cdot 0.56}{726} = 1.63$$

Maximum cable length: 26 m

3x2(1 x 300) mm^2 cable is therefore valid.

4.3.1.5 Cable from switchgears 21BUA11/12 to inverters 21BRU11/12

$I_n = \frac{40}{0.11} = 364$ A

Maximum voltage drop: 3.7 V

Cable laying: Indoor ladder tray in false floor.

Ampacity for 1x240 mm^2 copper cable: 679 A.

Therefore, taking into account the total derating factor table of the paragraph 3.3: 0.67

$$n = \frac{679 \cdot 0.67}{364} = 1.25$$

Maximum cable length: 47 m

2 x (1 x 240) mm^2 cable is therefore valid.

5. RESULTS

5.1 MEDIUM VOLTAGE POWER CABLES

In accordance with the calculations shown is paragraph 4, the following medium voltage power cable sections have been obtained.

Cable	Section
10.5 kV Switchgear 21BBA11	
Cable to MV/LV transformers (21BFT11, 21BFT12 and 21BMT10)	3 x 120 mm^2
HP/IP boiler feedwater pumps	3 x 120 mm^2
Condensate pumps	3 x 50 mm^2
Cooling pumps (closed cooling circuit) heaters	3 x 50 mm^2
Unit Auxiliary Transformer 21BBT11	
Cable to 21BBW10	1 x 240 mm^2
LCI System	
Cable to isolation transformer 21MBJ10	2x3(1 x 240) mm^2
Cable from each secondary of the isolation transformer to the static starter source bridge	6x3(1 x 400) mm^2
Cable from static starter to DC link reactor	5(1 x 400) mm^2
Cable from DC link reactor to static starter	5(1 x 400) mm^2
Cable from static starter to AC link reactor	4x3(1 x 400) mm^2
Cable from AC link reactor to static starter	4x3(1 x 400) mm^2
Cable from static starter load bridge to generator circuit breaker	4x3(1 x 400) mm^2

5.2 LOW VOLTAGE POWER CABLES

5.2.1 Cable sizing according to its short-circuit withstand capacity

The cables of the services connected directly to the power centre busbars shall be of at least 300 mm^2, to withstand the short-circuit currents in the power centre busbars for 400 ms.

5.2.2 Cable sizing according to cable ampacity and voltage drop

In the tables below it is shown, for the different consumers of the plant, motors and feeders, and the different cable sections, the following information:

- Minimum cable section due to cable ampacity: in the tables it has been indicated the sections that are not valid due to cable ampacity, for the different cable installation conditions. In case that cables are installed in ducts, the sections that are not valid due to cable ampacity are in grey.

- The maximum cable length stated in the tables corresponds to the worst case (shortest cable length), taking into account the voltage drop.

- For the motor cables, voltage drop calculations have been performed in steady-state and during motor start-up, and the worst case (shortest cable length) has been also considered.

- For feeders, the worst case between power factor 0.8 and 1 (shortest cable length), has been considered also.

- The sections in the upper right part of the tables marked with “--“ indicate that cable lengths are of such length that there are no consumers to feed at that length.

5.2.2.1 Cables to power center motors

- BPM main bearing lube oil pump 1/2 (223,7 kW)

- Section: 3(1 x 400) + 1 x 240 mm^2
- Maximum cable length: 98 m

- Turbine shell exhaust frame blower 1/2 (160 kW)
  - Section: 3(1 x 400) + 1 x 240 mm^2
  - Maximum cable length: 145 m

- Deareator pump (110 kW)
  - Section: 3(1 x 300) + 1 x 150 mm^2
  - Maximum cable length: 151 m

- LP economizer recirculation pumps (110 kW)
  - Section: 3(1 x 300) + 1 x 150 mm^2
  - Maximum cable length: 180 m

The following table shows the maximum length of the cables, in meters (m), and it is calculated for a voltage drop in the conductor of 5% in steady state and 10% during motor starting.

Cables to Power Center Motors				
Motor Power (kW)	Maximum cable length, in m, for different sections in mm^2			
	3(1 x 300) + 1 x 150	3(1 x 400) + 1 x 240	2x3(1 x 300) + 1 x 300	2x3(1 x 400) + 1 x 400
90	215	242	430	484
110	180	202	359	403
132	151	170	302	339
160	129	145	258	289
200	Sections not valid due to cable ampacity	109	195	218
250			158	177

5.2.2.2 Cables to MCC's

- MCCs 21BJA11/12/13/14

  - Section: 2x4(1 x 400) + 1 x 400 mm^2

  - Maximum cable length: 139 m

- MCCs 21BJA15/16 and 21BMB20

  - Section: 2x4(1 x 300) + 1 x 300 mm^2

  - Maximum cable length: 117 m

- MCC 21BMB10

  - Section: 2x4(1 x 300) + 1 x 300 mm^2

  - Maximum cable length: 58 m

5.2.2.3 Cables to emergency diesel generator

- Emergency diesel generator 21XKA10

  - Section: 5x4(1 x 400) + 3(1 x 400) mm^2
  - Maximum cable length: 64 m

5.2.2.4 Cables to normal lighting switchgear 21BJL11/12

- Normal lighting switchgear 21BJL11/12

  - Section: 4(1 x 400) + 1 x 240 mm^2
  - Maximum cable length: 46 m

5.2.2.5 Cables to power center feeders

- 23FGEH-1 gas fuel heater

  - Section: 3x4(1 x 300) + 2(1 x 240) mm^2
  - Maximum cable length: 184 m

- 21SCA10/20AN001 air compressor

  - Section: 4(1 x 300) + 1 x 150 mm^2
  - Maximum cable length: 280 m

- 21MAW01AC001 electric heater

  - Section: 3x4(1 x 300) + 2x(1 x 240) mm2

- Maximum cable length: 184 m

- 21SMA10AE001 turbine building bridge crane (main & aux)

  - Section: 4(1 x 300) + 1 x 150 mm2

  - Maximum cable length: 294 m

The following table shows the maximum length of the cables, in meters (m), and it is calculated for a voltage drop in the conductor of 3% in steady state, and for the most unfavourable power factor between 0.8 and 1.

Cables to Power Center Feeders									
In (A)	Maximum cable length, in m, for different sections in mm^2								
	4(1 x 300) + 1 x 150	4(1 x 400) + 1 x 240	2x4(1 x 300) + 1 x 300	2x4(1 x 400) + 1 x 400	3x4(1 x 300) + 2(1 x 240)	3x4(1 x 400) + 2(1 x 300)	4x4(1 x 300) + 2(1 x 300)	4x4(1 x 400) + 2(1 x 400)	5x4(1 x 300) + 2(1 x 400)
200	287	341	574	682	861	1023	1148	1364	1435
250	230	273	459	545	689	818	919	1091	1148
320	179	213	359	426	538	639	718	852	897
400	Sections not valid due to cable ampacity	170	287	341	431	511	574	682	718
500			230	273	344	409	459	545	574
630			182	216	273	325	365	433	456
800					215	256	287	341	359
938					184	218	245	291	306
1104						185	208	247	260

5.2.2.6 Cables to feeders of MCC's 21BJA11/12/13/14/15/16 and 21BMB20

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 3% in steady state, and for the most unfavourable power factor between 0.8 and 1.

Cables to motorized valves will have 3 phases and the earth conductor, but the table below is also valid.

Cables to Feeders of MCC's 21BJA11/12/13/14/15/16 and 21BMB20

In (A)	Circuit breaker: thermal rated current (A)	Maximum cable length, in m, for different sections in mm^2														
		5x2.5	5x4	5x6	5x10	5x16	4x25+16	4x35+16	4x50+25	4x70+35	4x95+50	4x120+70	4x150+95	4x185 +95	4(1x240) +1x120	4(1x300) +1x150
2,5	16	366	583	859	1455	2254	--	--	--	--	--	--	--	--	--	--
4	16	229	365	537	909	1408	2174	--	--	--	--	--	--	--	--	--
6	16	153	243	358	606	939	1449	1980	--	--	--	--	--	--	--	--
10	16	92	146	215	364	563	870	1188	1558	2143	--	--	--	--	--	--
12,8	16	72	114	168	284	440	679	928	1218	1674	2232	--	--	--	--	--
16	25	Sections not valid due to cable ampacity		134	227	352	543	743	974	1339	1786	2143	2500	--	--	--
20	25			107	182	282	435	594	779	1071	1429	1714	2000	2308	--	--
25	40				145	225	348	475	623	857	1143	1371	1600	1846	2182	--
32	40				114	176	272	371	487	670	893	1071	1250	1442	1705	1974
40	63						217	297	390	536	714	857	1000	1154	1364	1579
50,4	63						173	236	309	425	567	680	794	916	1082	1253
63	80							189	247	340	454	544	635	733	866	1003
80	100								195	268	357	429	500	577	682	789
100	125									214	286	343	400	462	545	632
125	160										229	274	320	369	436	505
160	250													288	341	395
200	250													231	273	316

5.2.2.7 Cables to motors of MCC’s 21BJA11/12/13/14/15/16 and 21BMB20

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 3% in steady state and 10% during motor starting.

Cables to Motors of MCC's 21BJA11/12/13/14/15/16 and 21BMB20														
Motor Power (kW)	Maximum cable length, in m, for different sections in mm^2													
	4x2.5	4x4	4x6	4x10	4x16	3x25+16	3x35+16	3x50+25	3x70+35	3x95+50	3x120+70	3x150+95	3x185+95	4(1x240) +1x120
0,37	511	812	1193	2021										
0,55	399	634	931	1577	2415									
0,75	297	471	692	1174	1796									
1,1	221	352	516	875	1338	2038								
1,5	167	265	389	660	1007	1533	2079							
2,2	124	197	290	491	749	1140	1545	1983						
3,7	66	104	153	259	395	600	813	1043	1399	1819	2126	2433		
5,5	57	91	133	226	343	519	702	895	1194	1544	1793	2045	2242	
7,5	46	72	106	180	271	409	551	699	927	1192	1376	1562	1698	1914
11	Sections not valid due to cable ampacity	53	78	132	199	299	403	508	671	858	986	1116	1205	1352
15			62 (*)	105	157	235	315	396	520	662	757	854	915	1021
18,5				89	133	198	265	331	432	547	622	699	744	826
22				79 (*)	118	175	234	291	378	477	541	607	643	711
30					94 (*)	139	186	230	298	374	423	473	498	549
37						114 (*)	153	188	243	304	342	381	400	439
45							136 (*)	166	213	265	297	330	343	375
55								146	185	229	254	281	290	315
75										168	186	206	212	230

(*) In this case, cables can not be laid in ladder trays

5.2.2.8 Cables to feeders of MCC 21BMB10

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 4% in steady state, and for the most unfavourable power factor between 0.8 and 1.

Cables to motorized valves will have 3 phases and the earth conductor, but the table below is also valid.

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Energía

Cables to Feeders of MCC 21BMB10													
In (A)	**Circuit breaker: thermal rated current (A)**	**Maximum cable length, in m, for different sections in mm²**											
		5x2.5	**5x6**	**5x10**	**5x16**	**4x25+16**	**4x35+16**	**4x50+25**	**4x70+35**	**4x95+50**	**4x120+70**	**4x150+90**	**4(1x300) +1x150**
2,5	16	489	1145	1939	--	--	--	--	--	--	--	--	--
4	16	305	716	1212	1878	--	--	--	--	--	--	--	--
6	16	204	477	808	1252	1932	--	--	--	--	--	--	--
10	16	122	286	485	751	1159	1584	2078	--	--	--	--	--
12,8	16	95	224	379	587	906	1238	1623	2232	--	--	--	--
16	25	Sections not valid due to cable ampacity	179	303	469	725	990	1299	1786	2381	--	--	--
20	25		143	242	376	580	792	1039	1429	1905	2286	--	--
25	40			194	300	464	634	831	1143	1524	1829	2133	--
32	40			152	235	362	495	649	893	1190	1429	1667	--
40	63				188	290	396	519	714	952	1143	1333	2105
50,4	63					230	314	412	567	756	907	1058	1671
63	80							330	454	605	726	847	1337
80	100							260	357	476	571	667	1053
100	125								286	381	457	533	842
125	160									305	366	427	674
160	250												526
200	250												421

5.2.2.9 Cables to motors of MCC 21BMB10

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 4% in steady state and 10% during motor starting.

Cables to Motors of MCC 21BMB10

Motor Power (kW)	Maximum cable length, in m, for different sections in mm²													
	4x2.5	4x4	4x6	4x10	4x16	3x25+16	3x35+16	3x50+25	3x70+35	3x95+50	3x120+70	3x150+95	3x185+95	4(1x240) +1x120
0,37	511	812	1193	2021	--	--	--	--	--	--	--	--	--	--
0,55	399	634	931	1577	2415	--	--	--	--	--	--	--	--	--
0,75	297	471	692	1174	1796	--	--	--	--	--	--	--	--	--
1,1	221	352	516	875	1338	2038	--	--	--	--	--	--	--	--
1,5	167	265	389	660	1007	1533	2079	--	--	--	--	--	--	--
2,2	124	197	290	491	749	1140	1545	1983	--	--	--	--	--	--
3,7	66	104	153	259	395	600	812	1041	1397	1817	2123	2431	--	--
5,5	57	91	133	226	343	519	702	895	1194	1544	1793	2045	2242	--
7,5	46	72	106	180	271	409	551	699	927	1192	1376	1562	1698	1914
11	Sections not valid due to cable ampacity	53	78	132	199	299	403	508	671	858	986	1116	1205	1352
15			62 (*)	105	157	235	315	396	520	662	757	854	915	1021
18,5				89	133	198	265	331	432	547	622	699	744	826
22				79 (*)	118	175	234	291	378	477	541	607	643	711
30					94 (*)	139	186	230	298	374	423	473	498	549
37						114 (*)	153	188	243	304	342	381	400	439
45							136 (*)	166	213	265	297	330	343	375
55								146	185	229	254	281	290	315
75										168	186	206	212	230

(*) In this case, cables can not be laid in ladder trays

5.2.2.10 Cables to Feeders of the normal lighting switchgears 21BJL11/12

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 1% in steady state, and for the most unfavourable power factor between 0.8 and 1.

Cables from normal lighting switchgear feeders 21BJL11/12										
In (A)	Circuit breaker: thermal rated current (A)	Maximum cable length, in m, for different sections in mm^2								
		5 x 2.5	5 x 6	5 x 10	5 x 16	5 x 25	5 x 50	5 x 95	5 x 150	4(1 x 300) + 1 x 150
2,5	16	122	286	485	751	1159	2078			
4	16	76	179	303	469	725	1299	2381		
6	16	51	119	202	313	483	866	1587	2222	
10	16	31	72	121	188	290	519	952	1333	2105
12,8	16	24	56	95	147	226	406	744	1042	1645
16	25	Sections not valid due to cable ampacity	45	76	117	181	325	595	833	1316
20	25		36	61	94	145	260	476	667	1053
25	40			48	75	116	208	381	533	842
32	40			38	59	91	162	298	417	658
40	63					72	130	238	333	526
50,4	63					58	103	189	265	418
63	125							151	212	334
80	125							119	167	263
100	125							95	133	211

5.2.2.11 Cables to the emergency lighting switchgear 21BML11 from the normal lighting switchgear 21BJL11 and 21BMB10.

Cables to the emergency lighting cabinet 21BML11 have been sized for the 110% of the rated current of the load switch (250 A), and calculated for a voltage drop in the conductor of 0.5% in steady state, for the most unfavourable power factor between 0.8 and 1.

- Cable from 21BJL11 to 21BML11
  - Section: 4(1 x 300) + 1 x 150 mm^2
  - Maximum cable length: 38 m
- Cable from 21BMB10 to 21BML11
  - Section: 4(1 x 300) + 1 x 150 mm^2
  - Maximum cable length: 38 m

5.2.2.12 Cables to Feeders of the emergency lighting switchgear 21BML11

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 0.5% in steady state, and for the most unfavourable power factor between 0.8 and 1.

Cables from emergency lighting switchgear feeders 21BML11										
In (A)	Circuit breaker: thermal rated current (A)	Maximum cable length, in m, for different sections in mm^2								
		5 x 2.5	5 x 6	5 x 10	5 x 16	5 x 25	5 x 50	5 x 95	5 x 150	4(1 x 300) + 1 x 150
2,5	16	61	143	242	376	580	1039	1905		
4	16	38	89	152	235	362	649	1190	1667	
6	16	25	60	101	156	242	433	794	1111	1754
10	16	15	36	61	94	145	260	476	667	1053
12,8	25	Sections not valid due to cable ampacity	28	47	73	113	203	372	521	822
16	25		22	38	59	91	162	298	417	658
20	25		18	30	47	72	130	238	333	526
25	40			24	38	58	104	190	267	421
32	40			19	29	45	81	149	208	329
40	63				23	36	65	119	167	263
50,4	63					29	52	94	132	209
63	125							76	106	167
80	125							60	83	132
100	125							48	67	105

5.2.2.13 Cables to panelboard feeders in the medium voltage switchgears, power centers and MCC's

In the following table is represented the minimum section of the conductors according to the protective device setting. Consequently, depending on the protective device setting, the conductor section shall be equal to or higher than the one shown in the table.

	One phase cables to panelboard feeders					
Circuit breaker: thermal rated current (A)	16	20	25	32	40	63
Section (mm^2)	2 x 2.5	2 x 4	2 x 4	2 x 6	2 x 10	2 x 25

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 3 % in steady state, and for the most unfavourable power factor between 0.8 and 1.

The table is made for three cores cable (phase+neutral+earth). Nevertheless, there are loads that shall be fed with two cores cable (phase+neutral). In both situations, the table below is valid.

Cables of 230 Vac panelboard feeders								
Power (W)	Maximum cable length, in m, for different sections in mm^2							
	3 x 2.5	3 x 4	3 x 6	3 x 10	3 x 16	2 x 25 + 16	2 x 35 +16	2 x 50 + 25
40	1915	--	--	--	--	--	--	--
50	1532	2440	--	--	--	--	--	--
65	1178	1877	--	--	--	--	--	--
100	766	1220	1798	--	--	--	--	--
130	589	939	1383	2312	--	--	--	--
200	383	610	899	1503	2355	--	--	--
250	306	488	719	1202	1884	--	--	--
350	219	349	514	859	1346	2074	--	--
500	153	244	360	601	942	1452	1990	--
800	96	153	225	376	589	907	1244	1639
1200	64	102	150	250	393	605	829	1093
1800	43	68	100	167	262	403	553	729
2200	35	55	82	137	214	330	452	596
2500	31	49	72	120	188	290	398	525

5.2.2.14 Cables of the UPS 21BRA11/12

The following table shows the maximum length of the cables, in m, and it is calculated for a voltage drop in the conductor of 3% in steady state, and for the most unfavourable power factor between 0.8 and 1. A total derating factor of 0.50 has been considered.

Cables to UPS loads - 21BRA11/12 switchgear									
In (A)	**Circuit breaker: thermal rated current (A)**	**Maximum cable length, in m, for different sections in mm^2**							
		3 x 2.5	**3 x 6**	**3 x 10**	**3 x 16**	**2 x 25 + 16**	**2 x 50 + 25**	**2 x 95 + 50**	**2(1 x 300) + 1 x 150**
2,5	10	183	430	719	1127	1736	--	--	--
5	10	92	215	359	563	868	1568	--	--
8	10	57	134	225	352	542	980	1778	--
10	16	46	107	180	282	434	784	1423	--
12,8	16	36	84	140	220	339	613	1112	2457
16	25	Sections not valid due to cable ampacity	67	112	176	271	490	889	1966
20	25		54	90	141	217	392	711	1573
25	40			72	113	174	314	569	1258
32	40			56	88	136	245	445	983
40	63					108	196	356	786
50	63					87	157	285	629
63	80						124	226	499
80	125							178	393
100	125							142	315
125	160							114	252

5.3 DIRECT CURRENT POWER CABLES

5.3.1 Cable sizing according to cable ampacity and voltage drop

In the tables below it is shown, for the different consumers of the plant, motors and feeders, and the different cable sections, the following information:

- Minimum cable section due to cable ampacity: in the tables it has been indicated the sections that are not valid due to cable ampacity for ladder tray installation.

- The maximum cable length stated in the tables corresponds to the worst case (shortest cable length), taking into account the voltage drop.

- For the motor cables, voltage drop calculations have been performed in steady-state and during motor start-up, and the worst case (shortest cable length) has been considered also.

- The sections in the upper right part of the tables marked with "--" indicate that cable lengths are of such length that there are no consumers to feed at that length.

5.3.1.1 250 VDC cables

- Cable from battery 21BTB10 to switchgear 21BUB10

  - Section: 4x2(1 x 300) mm^2

  - Maximum cable length: 48 m

- ESPM Emergency Seal Oil Pump

  - Section: 2x2(1 x 300) mm^2

- Maximum cable length: 108 m

- EBPM Emergency BRG Oil Pump

  - Section: 2x2(1 x 400) mm^2

  - Maximum cable length: 105 m

5.3.1.2 110 VDC cables

- Cable from batteries 21BTA11/12 to switchgears 21BUA11/12

  - Section: 3x2(1 x 300) mm^2

  - Maximum cable length: 26 m

- Cable from switchgears 21BUA11/12 to inverters 21BRU11/12

  - Section: 2 x (1 x 240) mm^2

  - Maximum cable length: 70 m

The following table shows the maximum length of the cables, in meters (m), and it is calculated for a voltage drop in the conductor of 3.7 V in steady state.

Cables to 110 VDC loads – 21BUA11/12 switchgears													
In (A)	Circuit breaker: thermal rated current (A)	Maximum cable length, in m, for different sections in mm^2											
		2 x 2.5	2 x 6	2 x 10	2 x 16	2 x 25	2 x 50	2 x 95	2(1 x 300)	2(1 x 400)	2x(2 x 95)	2x2(1 x 300)	2x2(1 x 400)
2,5	10	79	187	317	503	796	1495	--	--	--	--	--	--
5	10	40	94	158	252	398	747	1490	--	--	--	--	--
8	10	25	59	99	157	249	467	931	--	--	1863	--	--
10	16	20	47	79	126	199	374	745	2289	--	1490	--	--
12,8	16	15	37	62	98	155	292	582	1788	2276	1164	--	--
16	25	12	29	50	79	124	234	466	1430	1821	931	--	--
20	25	10	23	40	63	99	187	373	1144	1456	745	2289	--
25	40	Sections not valid due to cable ampacity		32	50	80	149	298	916	1165	596	1831	2330
32	40			25	39	62	117	233	715	910	466	1430	1821
40	63				31	50	93	186	572	728	373	1144	1456
50	63				25	40	75	149	458	583	298	916	1165
63	80					32	59	118	363	462	237	727	925
80	125						47	93	286	364	186	572	728
100	125						37	75	229	291	149	458	583
125	160							60	183	233	119	366	466
150	250								153	194	99	305	388
180	250								127	162	83	254	324
200	250								114	146	75	229	291
240	250								95	121	62	191	243
300	400								76	97	50	153	194

5.3.1.3 24 VDC cables

The following table shows the maximum length of the cables, in meters (m), and it is calculated for a voltage drop in the conductor of 3% in steady state.

Cables to 24 VDC loads - 21BUM11/12 switchgears												
In (A)	Circuit breaker: thermal rated current (A)	Maximum cable length, in m, for different sections in mm^2										
		3 x 2.5	3 x 6	3 x 10	3 x 16	2x25+16	2x50+25	3x95+50	2(1x300)+ 1x150	2(1x400)+ 1x240	2x(2x95+50)	2x2(1x300)+ 1x300
2,5	10	15	36	62	98	155	291	580	1782	2267	1160	--
5	10	8	18	31	49	77	145	290	891	1134	580	1782
8	10	5	11	19	31	48	91	181	557	709	363	1113
10	16	4	9	15	24	39	73	145	445	567	290	891
12,8	16	3	7	12	19	30	57	113	348	443	227	696
16	25	Sections not valid due to cable ampacity	6	10	15	24	45	91	278	354	181	557
20	25		5	8	12	19	36	73	223	283	145	445
25	40			6	10	15	29	58	178	227	116	356
32	40			5	8	12	23	45	139	177	91	278
40	63				6	10	18	36	111	142	73	223
50	63				5	8	15	29	89	113	58	178
63	80					6	12	23	71	90	46	141
80	125						9	18	56	71	36	111
100	125						7	15	45	57	29	89
125	160							12	36	45	23	71

6. REFERENCE DOCUMENTS

- NEN 1010

- IEC 60502-2, Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)

- IEC 60865-1, Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods

- GE 365A5126, Static Starter KWH Curve, Harmonic. Analysis and Cable Summary.

- 437-21-F-E-01002, MV System Study Report

- 437-21-F-E-01003, Low Voltage Technical Report

- 437-21-F-E-01005, DC & UPS System Study

APPENDIX A

TYPES OF POWER CABLES

Ref	Composition (mm^2)	Description
M124	1 x 240	Medium voltage power cable 8.7/15 kV. Single core
M140	1 x 400	Medium voltage power cable 8.7/15 kV. Single core
M312	3 x 120	Medium voltage power cable 8.7/15 kV. Three core (3P)
M350	3 x 50	Medium voltage power cable 8.7/15 kV. Three core (3P)
B130	1 x 300	Low voltage power cable 0.6/1 kV. Single core
B140	1 x 400	Low voltage power cable 0.6/1 kV. Single core
B202	2 x 2.5	Low voltage power cable 0.6/1 kV. Two core (1P+N)
B206	2 x 6	Low voltage power cable 0.6/1 kV. Two core (1P+N)
B210	2 x 10	Low voltage power cable 0.6/1 kV. Two core (1P+N)
B216	2 x 16	Low voltage power cable 0.6/1 kV. Two core (1P+N)
B225	2 x 25	Low voltage power cable 0.6/1 kV. Two core (1P+N)
B250	2 x 50	Low voltage power cable 0.6/1 kV. Two core (1P+N)
B295	2 x 95	Low voltage power cable 0.6/1 kV. Two core (1P+N)
G115	1 x 150	Low voltage power cable 0.6/1 kV. Single core
G124	1 x 240	Low voltage power cable 0.6/1 kV. Single core
G130	1 x 300	Low voltage power cable 0.6/1 kV. Single core
G140	1 x 400	Low voltage power cable 0.6/1 kV. Single core
G202	3 x 2.5	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G206	3 x 6	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G210	3 x 10	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G216	3 x 16	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G225	2 x 25 + 16	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G250	2 x 50 + 25	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G295	2 x 95 + 50	Low voltage power cable 0.6/1 kV. Three core (1P+N+PE)
G302	4 x 2.5	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G306	4 x 6	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G310	4 x 10	Low voltage power cable 0.6/1 kV. Four core (3P+PE)

Ref	Composition (mm^2)	Description
G316	4 x 16	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G325	3 x 25 + 16	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G350	3 x 50 + 25	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G395	3 x 95 + 50	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G315	3 x 150 + 95	Low voltage power cable 0.6/1 kV. Four core (3P+PE)
G402	5 x 2.5	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G406	5 x 6	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G410	5 x 10	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G416	5 x 16	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G425	4 x 25 + 16	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G450	4 x 50 + 25	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G495	4 x 95 + 50	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)
G415	4 x 150 + 95	Low voltage power cable 0.6/1 kV. Five core (3P+N+PE)