Base Load Power Hub (BLPH)

LV Electrical Equipment Sizing Calculation Report

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

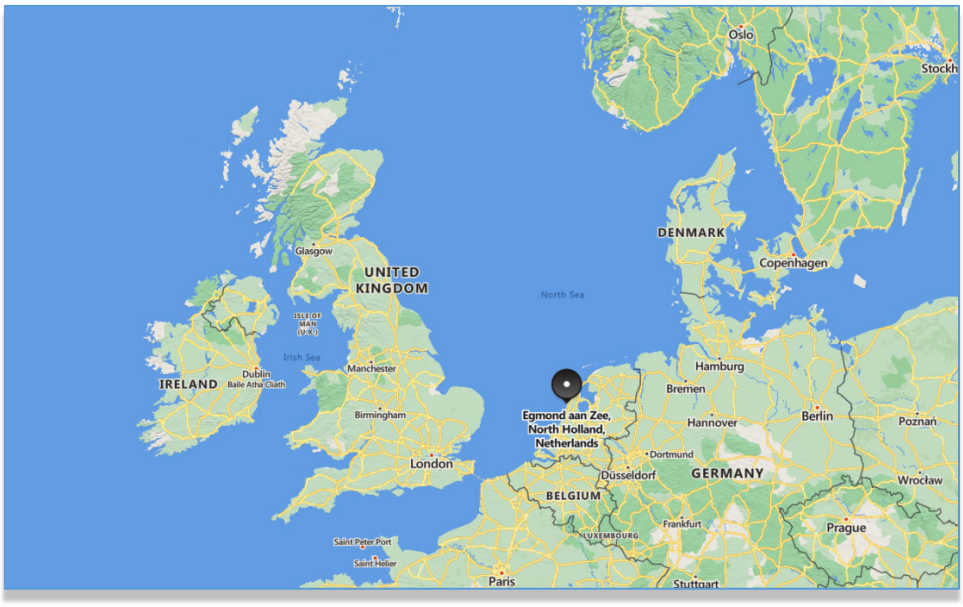


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

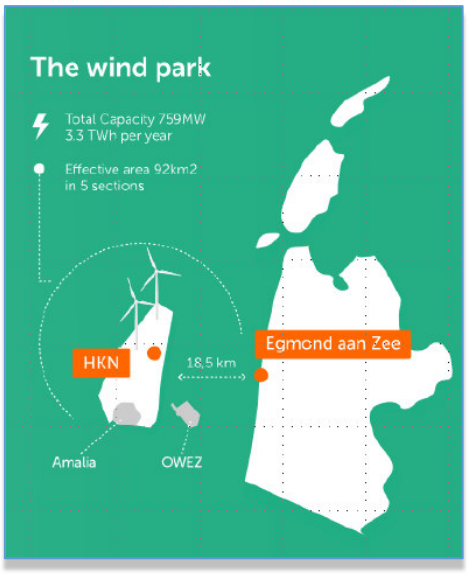


Figure 2 - Wind Park Details

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

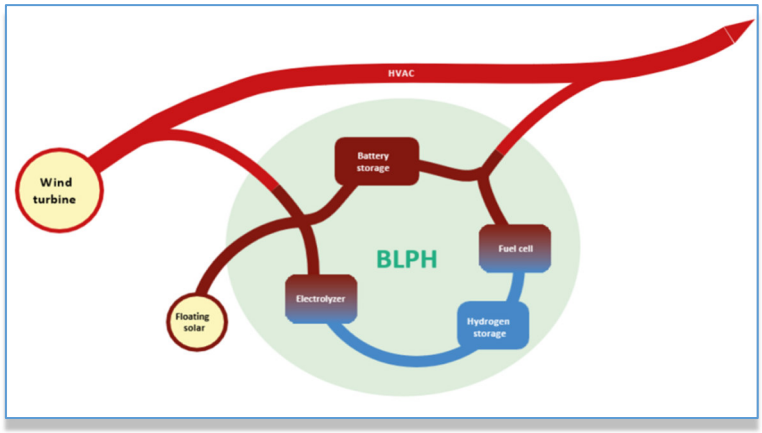


Figure 3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

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2 DOCUMENT SCOPE

This calculation report covers the LV Electrical equipment sizing in terms of Continuous Current Rating, Voltage and Short Circuit Current Ratings.

2.1 REFERENCES

Doc. No.	Description
123A90-DDL-EL-LIS-20016	Electrical Load List & Balance (CCS MODE 1 'IMPORT')
123A90-DDL-EL-LIS-20143	Electrical Load List & Balance (CCS MODE 3 'HOT STANDBY')
123A90-DDL-EL-LIS-20144	Electrical Load List & Balance (CCS MODE 2 'EXPORT')
123A90-DDL-EL-LIS-20145	Electrical Load List & Balance (CCS MODE 4 'COLD STANDBY')
123A90-DDL-EL-LIS-20146	Electrical Load List & Balance (CCS MODE 5 'EMERGENCY MODE (Island)'
123A90-DDL-EL-LIS-20147	Electrical Load List & Balance (CCS MODE 6 'POWER OUT (Blackout)'
123A90-DDL-EL-RE-20151	Cable Sizing Calculation Report
123A90-DDL-EL-RE-20181	LV Cable Sizing Calculation Report
123A90-DDL-EL-DG-20015	Electrical Single Line Diagram HV & MV Systems
123A90-DDL-EL-DG-20159	Electrical Single Line Diagram LV Systems
123A90-DDL-EL-RE-20171	Electrical System Study Report – Short Circuit
K559-2254-EL-CAL-001	Electrical Equipment Sizing Calculations
DEP 33.64.10.10	DEP Specification – Electrical Engineering Design

Table 1 - Reference Documents

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2.2 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY):	CROSSWIND
CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
INSPECTION AUTHORITY:	The organization representing the Owner or Vendor /Contractor that verifies that the equipment and facilities have been designed, constructed, inspected and tested in accordance with the requirements of this specification and the Purchase Order/Contract.
INSPECTOR:	A qualified individual representing the Owner, Vendor/Contractor or the assigned Inspection Authority, who verifies that the equipment and facilities have been designed, constructed, inspected and tested in accordance with the requirements of this specification and the Purchase Order/Contract.
VENDOR:	Individual, firm or manufacturer that provide Materials/Equipment to COMPANY in accordance with this specification and terms of the Purchase Order.
a.c. / d.c	Alternating current / Direct current
ACB:	Air Circuit Breaker
kW / HP:	Kilo Watt / Horse Power
LV:	Low Voltage
MCCB:	Moulded Case Circuit Breaker

Table 2 - Definitions and Abbreviations

3 APPLICABLE CODES AND STANDARDS

The following documents list shall constitute an integral part of this specification.

IEC - International Electro technical Committee (latest edition shall be applied).

- IEC 60909 Short-circuit currents in three-phase a.c. systems
- IEC 60034-1 Rotating electrical machines - Part 1: Rating and performance
- IEC 60034-5 Rotating electrical machines - Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP CODE) – Classification
- IEC 60034-8 Rotating electrical machines - Part 8: Terminal markings and direction of rotation
- IEC 60085 Electrical insulation – Thermal evaluation and designation

4 ENVIRONMENTAL AND OPERATING CONDITIONS

The Metrological and Oceanographic Data are as given below (source: HKN2018 data @ 1979-2018)

Description	Value	Unit
Ambient Conditions		
Ambient Temperature (min/nom/max) – hourly @ +10m	-8.4 / 10.5 / 25.0	° C
Atmospheric Pressure (nominal) – hourly @ +10m	1013.7	mbar
Specific Humidity (min/nom/max) – hourly @ +10m	4.2 / 6.5 / 9.5	x 10^{-3}
Wind conditions		
Annual average wind speed (at 100m)	9.56	m/s
Extreme Wind Speed for 1-Year Recurrence Period (at 100 m)	33.1	m/s
Extreme Wind Speed for 50-Year Recurrence Period (at 100 m)	41.0	m/s
Marine conditions		
Sea Water Temperature (min/max)	1.2 / 20.2	° C
Average Sea Water Density	1025	Kg/m^3

Table 3 - Metrological and Oceanographic Data

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5 ELECTRICAL SYSTEM

The A.C. main power supply characteristics (e.g. voltage, frequency, and voltage and frequency variation) shall be defined in the relevant data sheet.

The following voltage levels shall generally be used where technically possible:

Service	Rated AC Voltage (Volts)	Phase / Wire	System Earthing
Normal LV supply	400	3ph+N+PE	Solid (TN-S)
Solar farm in-feed LV supply	800	3ph+PE	Neutral Not Grounded
Emergency LV supply	400	3ph+N+PE	Solid (TN-S)
Low voltage distribution	400/230	3ph+N+PE/ 1ph+N+PE	Solid (TN-S)
125A welding (power) sockets	400	3ph+PE	Solid (TN-S)
Motor loads	400	3ph+PE	Solid (TN-S)
Luminaires	230	1ph+N+PE	Solid (TN-S)
Emergency luminaires	230	1ph+N+PE	Solid (TN-S)
Convenience sockets	230	1ph+N+PE	Solid (TN-S)
AC UPS	400 (In) 400/230 (Out)	3ph+PE 3ph+N+PE/ 1ph+N+PE	Neutral Not Grounded
DC UPS	400 (In) 110 (Out)	3ph+PE 2+PE	Neutral Not Grounded

Table 4 – System voltage levels and Earthing arrangements

6 LV ELECTRICAL EQUIPMENT

6.1 EQUIPMENT LIST

The LV equipment sizing calculation is carried out for the following list of LV equipment. Maximum short circuit current is used as input for selection & verification of short circuit current withstand capacity of Circuit breakers, Bus bars and cables in the LV power distribution system. For protection sizing purpose the minimum short circuit current shall be used.

1. LV Switchboard SG-200N1
2. Temporary Generator / Mobile Battery Pack Incomer
3. Solar farm in-feed Power Circuit Breaker panel
4. Feeders, DBs and UPS systems fed from LV Switchboard SG-200N1

6.2 BASIS FOR EQUIPMENT SIZING CALCULATION

The LV equipment sizing calculation is based on the worst BLPH loading condition, defined by the "IMPORT" mode.

The following documents are used in the LV equipment sizing calculation and end of line short circuit current:

i) Electrical Load List & Balance (CCS MODE 1 'IMPORT') Doc. No. 123A90-DDL-EL-LIS-20016

ii) LV Cable sizing calculation report, Doc. No. 123A90-DDL-EL-RE-20181

6.3 EQUATIONS USED FOR EQUIPMENT SIZING CALCULATION

The input data for the equipment sizing calculation are listed as below:

- Voltage : 400 V ± 5% (3 phase), 230 V ± 5% (1 phase)
- Power supply : 3 phase (3P+N), 1 phase (1P+N)
- Frequency : 50 Hz ± 2%
- LV Transformer Rating : 1600 kVA, 6.6/0.4kV, Impedance = 6%, solidly earthed, Dyn11
- Solar farm Inverter Rating : 0.5 MW, 0.8kV
- Solar farm Transformer Rating : 0.5MVA, 6.6/0.8kV, Impedance = 6%, Neutral Not Grounded, Dyn11

The following equations are used for equipment sizing calculation:

LV Switchgear:

Circuit breaker current rating : Transformer rating/ (√3 x secondary voltage)

Bus bar continuous current rating : Transformer rating/ (√3 x secondary voltage)

Short circuit current rating : Transformer rating / (√3 x secondary voltage x impedance)

Solar farm in-feed power circuit breaker:

Circuit breaker current rating : Rated kW x Efficiency / (√3 x Voltage x power factor)

Inverter side short circuit current rating : 1.2 times x Nominal Current rating (assumed)

Temporary Generator circuit breaker:

Circuit breaker current rating : Generator capacity x Efficiency / (√3 x Voltage x Power factor)

Three Phase Loads circuit breaker:

Circuit breaker current rating : Equipment Rating / (√3 x Voltage x Power factor x Efficiency)

Single Phase Loads circuit breaker:

Circuit breaker current rating : Equipment Rating / (Voltage x Power factor x Efficiency)

UPS Loads circuit breaker:

Circuit breaker current rating : Rated kW / (√3 x Voltage x Power factor x Efficiency)

Distribution board circuit breaker:

Circuit breaker current rating : Equipment Rating / (√3 x Voltage x Power factor x Efficiency)

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7 EQUIPMENT SIZING CALCULATION

7.1 LV SWITCHGEAR

The Maximum current rating of the transformer (TR-200DE1) is taken from document 123A90-DDL-EL-RE-20171.

3.4.3 Transformers

ITEM	An [kVA]	V1n/V2n [kV]	I1n/I2n [A]	Zcc [%]	X/R [pu]	Vector Group
TR-100AD1	7000.0	66.0+/-8x1.25%/0.69	61.2/585.7	8.0	16.01	Dyn11
TR-200DE1	1600.0	6.6/0.42	139.9/2199.5	6.0	7.94	Dyn11
TR-200ED1	500.0	6.6/0.8	43.7/360.8	6.0	7.63	Dyn11

Table 5 - Data for Main Transformers

The switchgear bus-bar continuous rating shall be rated to deliver the selected transformer (TR-200DE1) power rating of 1600 kVA. So the bus-bar is selected as 2500A based on the results obtained as 2500A is the next available bus-bar.

To calculate the maximum fault level of the bus-bar from the transformer, the impedance of the transformer is taken from document 123A90-DDL-EL-RE-20171.

Bus ID	Voltage kV	MAXIMUM SHORT CIRCUIT CURRENTS											
		LLL			LG			LL			LLG		
		Ik'' [kA]	Ip [kA]	Ik [kA]	Ik'' [kA]	Ip [kA]	Ik [kA]	Ik'' [kA]	Ip [kA]	Ik [kA]	Ik'' [kA]	Ip [kA]	Ik [kA]
HKN57	66.00	15.55	38.38	15.54	7.11	17.55	7.11	13.46	33.24	13.46	13.66	33.72	13.66
HNA6-AFA70	66.00	14.76	35.03	14.75	6.71	15.93	6.71	12.78	30.34	12.78	12.98	30.81	12.98
SG-100D1	6.60	8.11	20.74	8.05	0.40	1.02	0.40	7.03	17.96	7.03	7.13	18.22	7.13
SG-200N1	0.40	31.35	74.08	30.37	33.52	79.23	33.52	27.15	64.16	27.15	32.66	77.19	32.66

Table 11: Results of CASE 2: SCCMAX – Unbalance – IEC 60909

From the above table the contribution was found to be 31.35kA. Therefore, 31.35kA is considered as the short circuit contribution from the 1600kVA Transformer.

The selected size and fault level of the bus-bar is 2500A, 50kA, 1sec. 3ph+N+PE

The selected size and fault level of the breaker is 2500A, 50kA, 1sec. ACB, 3ph+N

7.2 SOLAR FARM IN-FEED POWER CIRCUIT BREAKER

The Solar farm in-feed power circuit breaker (SG-200D2) is sized for the solar farm inverter output power of 0.5 MW, 0.8kV. The power circuit breaker (SG-200D2) is connected to Transformer (TR-200ED1) which has a power rating of 0.5 MVA and the operating voltage is 0.8kV.

The equation for calculating the current is as follows:

I = (Rated kW x Efficiency) / (Voltage kV * sqrt (3) * Power factor)

Inserting all the known variables, the current is calculated as follows:

kW	Efficiency	Voltage(kV)	Power Factor	I(A)
500	1	0.8	1	360.84

The maximum current rating of the solar farm breaker is 360.84A

The circuit breaker is selected as 630A based on the results obtained as 630A is the next available breaker size.

Inverter side short circuit current rating as follows:

The inverter side short circuit current rating is assumed to be 1.2 times the normal current rating of the inverter.
Maximum fault level of the inverter side is 0.433kA

The equation for calculating Transformer side short circuit current rating as follows:

Isc = (Transformer kVA * 100) / (Sqrt (3) * Secondary kV * %Z transformer)

Inserting all of the known variables, the available fault current is calculated as follows:

Transformer rated KVA	Secondary Voltage(kV)	Impedance (%Z)	I_{sc} (kA)
500	0.8	6	6.014

Maximum fault level of the transformer side is 6.014kA

The selected size and fault level of the breaker is 630A, 16kA, 1sec. ACB, 3ph.

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7.3 TEMPORARY GENERATOR / MOBILE BATTERY PACK CIRCUIT BREAKER

The temporary generator incomer circuit breaker is sized for the power capacity of the temporary generator / battery pack. The capacity of generator / battery pack is 138.5 kW, 0.4kV. The generator power factor is assumed to be 0.95 and efficiency 95%. Sub transient reactance of the generator assumed as 12%

The equation for calculating the current is as follows:

I = (Rated kW * Efficiency) / (Voltage * sqrt (3) * Power factor)

Inserting all the known variables, the current is calculated as follows:

kW	Voltage(kV)	Efficiency	Power Factor	I(A)
138.5	0.4	0.95	0.95	199.91

The maximum current rating of the generator / battery pack is 199.91A

The switchgear continuous rating shall be rated to deliver the selected temporary generator / battery pack power rating of 138.5 kW. So the circuit breaker is selected as 250A based on the results obtained.

The equation for calculating generator short circuit current rating as follows:

Isc = (Rated kW * Efficiency) / (Sqrt (3) * Voltage kV * Power factor * Sub transient reactance)

Inserting all of the known variables, the available fault current is calculated as follows:

kW	Voltage(kV)	Power factor	Efficiency	Sub transient reactance (%)	I_{sc} (kA)
138.5	0.4	0.95	0.95	12%	1.665

Maximum fault level of the temporary generator side is 1.665kA

The selected size and fault level of the breaker is 250A, 16kA, 1sec. MCCB, 3ph+N

7.4 MOTOR FEEDERS CIRCUIT BREAKER

The 3phase motors are started by Direct-On-Line (DOL) starters from the LV Switchboard. The starting current of motors as per Vendor data sheet is 7.6 times the full load current for DOL starting.

For Sea Water intake pump-A operating at 3phase, 400V, rated power 6.1kW, power factor of 0.74 and efficiency 0.89, the circuit breaker is selected as,

I = Rated kW / (Voltage kV * sqrt (3) * Efficiency * Power factor)

Inserting all the known variables, the current is calculated as follows:

kW	Voltage(kV)	Efficiency	Power Factor	I(A)
6.1	0.4	0.89	0.74	13.37

The maximum current rating of the Sea Water intake pump-A is 13.37A

The switchgear continuous rating shall be rated to deliver the selected Sea Water intake pump-A feeder power rating of 6.1kW. So, the circuit breaker is selected as 20A based on the results obtained.

Maximum fault level of the breaker from the Sea Water intake pump-A feeder is 1.358kA (Refer 123A90-DDL-EL-RE-20181 LV Cable sizing calculation report).

The selected size and fault level of the breaker is 20A, 6kA, 1sec. MCCB, 3ph

7.5 THREE PHASE LOADS CIRCUIT BREAKER

Three phase loads are feed from LV Switchgear SG-200N1

For BESS PCS cabinet, operating at 3phase, 400V, rated power 11.09kW, power factor of 0.92 and efficiency 0.95, the circuit breaker is selected as,

I = Rated kW / (Voltage kV * sqrt (3) * Efficiency * Power factor)

Inserting all the known variables, the current is calculated as follows:

kW	Voltage(kV)	Efficiency	Power Factor	I(A)
11.09	0.4	0.95	0.92	18.31

The maximum current rating of the BESS PCS cabinet load is 18.31 A

The switchgear continuous rating shall be rated to deliver the selected BESS PCS cabinet load power rating of 11.09kW. So, the circuit breaker is selected as 40A based on the results obtained.

Maximum fault level of the breaker from the BESS PCS cabinet feeder is 3.677kA (Refer 123A90-DDL-EL-RE-20181 LV Cable sizing calculation report).

The selected size fault level of the breaker is 40A, 6kA, 1sec. MCCB, 3ph+N

7.6 UPS

AC & DC ups loads are feed from LV Switchgear SG-200N1.

For AC UPS - PAS operating at 3phase, 400V, rated power 36kW. The circuit breaker is selected as,

I = Rated kW / (Voltage kV * sqrt (3) * Power factor * Efficiency)

Inserting all the known variables, the current is calculated as follows:

kW	Voltage(kV)	Power Factor	Efficiency	I(A)
36	0.4	0.80	0.93	70.14

The maximum current rating of the AC UPS - PAS load is 70.14A

The switchgear continuous rating shall be rated to deliver the selected AC UPS - PAS load power rating of 36kW. So the circuit breaker is selected as 100A based on the results obtained.

Maximum fault level of the breaker from the AC ups feeder is 14.092kA (Refer 123A90-DDL-EL-RE-20181 LV Cable sizing calculation report).

The selected size and fault level of the breaker is 100A, 16kA, 1sec. MCCB, 3ph

7.7 LIGHTING & SMALL POWER DISTRIBUTION BOARD

Lighting & Small power BoP distribution board DP-200N1 is feed from LV Switchgear SG-200N1.

For DP-200N1, operating at 3phase+N, 400V, rated power 13.95 kW, power factor of 0.93 and efficiency 1. The circuit breaker is selected as,

I = Rated kW / (Voltage kV * sqrt (3) * Efficiency * Power factor)

Inserting all the known variables, the current is calculated as follows:

kW	Voltage(kV)	Efficiency	Power Factor	I(A)
13.95	0.4	1	0.93	21.65

The maximum current rating of the DB - Lighting & Small Power DP-200N1 load is 21.65A

The switchgear continuous rating shall be rated to deliver the selected DP-200N1 - Lighting & Small Power rating of 13.95kW. So, the circuit breaker is selected as 63A based on the results obtained.

Maximum fault level of the breaker from the DP-200N1 DB - Lighting & Small Power BoP is 19.826kA (Refer 123A90-DDL-EL-RE-20181 LV Cable sizing calculation report).

The selected size and fault level of the breaker is 63A, 25kA, 1sec. MCCB, 3ph+N.

The selected size of the bus-bar is 63A, 25kA, 1 sec, 3ph+N+PE.

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8 EQUIPMENT SIZING VERIFICATION

Verification of equipment sizing is done to ensure that the selected Circuit breaker rating is higher than the full load current of the equipment. 3 phase maximum short circuit current of the each equipment is obtained from ETAP software based short circuit study, each equipment full load current, breaker size & short circuit current tabulated in LV Cable sizing calculation report (123A90-DDL-EL-RE-20181).

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