Auxiliary supply calculation

Project	Client	Location	Revision	Date
Sample 220/33 kV pooling substation	Sample client	Sample site	0	2 Nov 2026

Document no.	Prepared	Checked	Approved
SSL-C-AUX-001	Sample engineer	Sample engineer	Sample engineer

Rev	Date	Description	By
0	2 Nov 2026	Issued	Sample engineer

220/33 kV pooling substation, 250 MW. Load ratings are the design's values unless marked * (edited or added by you in the load list).

1. 415 V AC load list

Duty factor: continuous 1, intermittent 0.5, standby 0. Demand kW = quantity × kW × duty factor.

Group	Load	Qty	kW per unit	pf	Duty	Demand kW
Transformers	ICT cooler fans (ONAF), 160 MVA	2	8	0.85	continuous	16.0
Transformers	ICT OLTC drive motor	2	1.1	0.80	intermittent	1.1
Transformers	ICT marshalling box heaters and lighting	2	0.5	1.00	continuous	1.0
220 kV switchyard	CB spring-charging motor	4	1.5	0.80	intermittent	3.0
220 kV switchyard	Isolator / earth switch motor	15	0.75	0.80	intermittent	5.6
220 kV switchyard	Bay marshalling kiosk heaters and lighting	6	0.3	1.00	continuous	1.8
Lighting	Switchyard flood lighting (LED, 1 W/m²)	1	19.8	0.95	continuous	19.8
Lighting	Peripheral road lighting (one 100 W pole per 30 m)	19	0.1	0.95	continuous	1.9
Lighting	Building lighting (10 W/m²)	1	6.5	0.95	continuous	6.5
HVAC	Air conditioning: control, relay and battery rooms (0.06 kW/m²)	1	15.1	0.85	continuous	15.1
HVAC	Switchgear hall ventilation (0.02 kW/m²)	1	6.5	0.80	continuous	6.5
DC system	220 V float-cum-boost charger (duty, at boost)	1	11.6	0.80	continuous	11.6
DC system	220 V float-cum-boost charger (standby)	1	11.6	0.80	standby	0.0
DC system	48 V DC telecom / PLCC charger	1	2	0.80	continuous	2.0
Control	SCADA, RTU, SAS servers and network	1	3	0.90	continuous	3.0
Control	Fire detection and alarm panel	1	1	0.90	continuous	1.0
Control	CCTV, access control and boundary security	1	2	0.90	continuous	2.0
SVG and filters	SVG cooling and auxiliaries (0.3 kW/Mvar)	2	9.4	0.85	continuous	18.8
Fire fighting	Electric fire-water pump (main)	1	37	0.85	standby	0.0
Fire fighting	Jockey pump	1	5.5	0.85	intermittent	2.8
Utilities	Raw water / service water pump	1	3.7	0.85	intermittent	1.9
Utilities	Building power sockets	1	5	0.90	intermittent	2.5
Utilities	Transformer oil filtration machine outlet	1	30	0.85	standby	0.0
Utilities	Switchyard welding / maintenance outlets	1	20	0.80	standby	0.0
33 kV switchgear	Panel heaters, lighting and spring-charging motors	23	0.4	0.90	continuous	9.2
	Connected kW (total)		248.4			133.0

Calculation trail

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1 · Maximum demand

Design rule

$P = \sum q_i P_i d_i, \quad Q = \sum P_i \tan(\arccos \mathrm{pf}_i), \quad S = \sqrt{P^2 + Q^2}$

25 loads, connected 248.4 kW → P = 133.0 kW, Q = 74.0 kvar, S = 152.2 kVA

2 · Auxiliary transformer

Design rule

$S_{\mathrm{TR}} = 1.2 S$

required 182.7 kVA → 2 × 250 kVA (one duty, one standby)

3 · DC duty cycle

IEEE 485 §5

$I(t) = I_{\mathrm{cont}} + I_{\mathrm{light}}(t) + I_{\mathrm{trip}}(t) + I_{\mathrm{close}}(t)$

4 periods, 107 cells at 240.8 V float → continuous 10.5 A

4 · Cell sizing sections

IEEE 485 §6.3

$F_S = \sum (A_p - A_{p-1}) K_t$

4 sections → largest section 118.8 Ah

5 · Battery capacity

IEEE 485 §6.4

$C = F_S \, k_{\mathrm{aging}} \, k_{\mathrm{margin}} \, k_{\mathrm{temp}}$

required 163.4 Ah → 2 × 200 Ah C10

6 · Chargers

IEEE 946

$I = L + \frac{1.1 C}{H}$

L 10.5 A, C 200 Ah → 2 × 40 A float-cum-boost, 11.6 kW each

7 · DG set and motor-start dip

ISO 8528-5 (class G3)

$S_{\mathrm{DG}} = 1.2 \max(S, P/0.8), \quad \Delta U = \frac{S_{\mathrm{start}}}{S_{\mathrm{start}} + S_{\mathrm{DG}}/x''_d} \le 15\%$

required 199.5 kVA, largest motor Electric fire-water pump (main) 37 kW → 250 kVA, dip 14.8 %

8 · Switchgear ratings

IEC 60947-2, IEC 60269-1, IEC 61439-2

$I = \frac{S}{\sqrt{3}\, U}, \quad I_n \ge I$

18 devices at 415 V and 220 V DC → ACDB 630 A, DCDB 315 A

Device	Type	Full-load current (A)	Rated current
AUX TR-1 incomer	ACB	348	630 A
AUX TR-2 incomer	ACB	348	630 A
DG set incomer	ACB	348	630 A
Bus coupler	ACB	348	630 A
415 V ACDB	bus	348	630 A
Transformers feeder	MCCB	29	100 A
220 kV switchyard feeder	MCCB	17	100 A
Lighting feeder	MCCB	41	100 A
HVAC feeder	MCCB	36	100 A
DC system feeder	MCCB	24	100 A
Control feeder	MCCB	9	100 A
SVG and filters feeder	MCCB	31	100 A
Fire fighting feeder	MCCB	5	100 A
Utilities feeder	MCCB	7	100 A
33 kV switchgear feeder	MCCB	14	100 A
FCBC-1 charger	gG fuse	40	40 A
FCBC-2 charger	gG fuse	40	40 A
BATTERY-1	gG fuse	83	100 A
BATTERY-2	gG fuse	83	100 A
220 V DCDB	bus	140	315 A

2. Auxiliary transformer

Quantity	Formula	Result

SAMPLE

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Quantity	Formula	Result
Active demand	$P = \sum q_i P_i d_i$	133.0 kW
Reactive demand	$Q = \sum P_i \tan(\arccos \mathrm{pf}_i)$	74.0 kvar
Maximum demand	$S = \sqrt{P^2 + Q^2}$	152.2 kVA
With margin	$S_{\mathrm{TR}} = 1.2S$	182.7 kVA
Selected	next standard size	2 × 250 kVA (one duty, one standby)

3. DG set

Quantity	Formula	Result
Full aux load	$S_{\mathrm{DG}} = 1.2\max(S, P/0.8)$	199.5 kVA
Largest motor	DOL start, 6 × FLC	Electric fire-water pump (main) 37 kW
Start dip	$\Delta U = \frac{S_{\mathrm{start}}}{S_{\mathrm{start}} + S_{\mathrm{DG}} x''_d}$	14.8 % (limit 15 %)
Selected	next standard size that meets both	250 kVA, 415 V, AMF

4. 220 V DC battery (IEEE 485)

VRLA lead-acid, 107 cells. Float 240.8 V, end of discharge 187.2 V at 1.75 V/cell (not below 0.85 × 220 V):

$$N = \lfloor 1.1 \times 220 / V_{\mathrm{float}} \rfloor$$

Period	Duration	Load (A)	Load
1	1 min	83.4	continuous + emergency lighting + breaker tripping
2	59 min	17.4	continuous + emergency lighting
3	539 min	10.5	continuous
4	1 min	20.5	continuous + largest breaker closing

Section	Required (Ah, before factors)	Formula
1	54.2	$F_S = \sum (A_p - A_{p-1}) K_t$
2	29.1	$F_S = \sum (A_p - A_{p-1}) K_t$
3	112.2	$F_S = \sum (A_p - A_{p-1}) K_t$
4	118.8	$F_S = \sum (A_p - A_{p-1}) K_t$

Quantity	Formula	Result
Largest section	max FS	118.8 Ah
Factors	$C = F_S \, k_{\mathrm{aging}} \, k_{\mathrm{margin}} \, k_{\mathrm{temp}}$	163.4 Ah
Selected	next standard C10 rating	2 × 200 Ah

5. Chargers (IEEE 946)

Quantity	Formula	Result
Charger current	$I = L + \frac{1.1C}{H}$	10.5 + 1.1 × 200/10 = 32.5 A
Selected	next standard rating	2 × 40 A float-cum-boost
AC input	$P_{\mathrm{AC}} = \frac{N V_{\mathrm{boost}} I}{\eta}$	11.6 kW each

6. Assumptions

1. The capacity rating factor Kt is the design's VRLA curve to 1.75 V per cell. The battery vendor's own curve applies at detail design.

2. DC loads: 150 W per 220 kV bay, 40 W per 33 kV panel, 500 W common. Emergency lighting 1.5 kW for 1 h. Trip 5 A per 220 kV CB, 2 A per 33 kV CB. Closing 10 A.

3. The design assumes an air-conditioned battery room (temperature factor 1.0).

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