

OWNER

UPS and Battery Sizing

Calculation



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[REDACTED] [REDACTED], [REDACTED] County, [REDACTED]

ISSUE SUMMARY AND APPROVAL

This page records each issue of ELE-CAL-003. The preparer, reviewer and approver sign for each revision.

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1. OBJECTIVE

This calculation sizes the 24 VDC station battery and its chargers, and the 120 VAC uninterruptible power supply and its battery, so that the control, safety, measurement, analyzer and communications equipment of the keeps running for at least 8 hours with neither the utility nor the standby generator available.

2. METHODOLOGY

The station has two stored-energy systems. The 24 VDC system (battery BT-101, chargers BC-101A and BC-101B, panel DCP-101) carries the RTU, the safety PLC, the flow computer, the analyzers, the field instrument loops, the shutdown valve solenoids and the telecommunications equipment. The 120 VAC system (UPS-101 with battery cabinet UBC-101, panel UP-101) carries the operator workstation, the video recorder, the demarcation panel supply of the receiving pipeline operator, and the LCV-104 and SDV-106 valve actuators. TORUS kept the two systems separate rather than feeding the AC loads from an inverter on the 24 VDC battery: a fault or overload in the AC equipment then cannot pull down the bus that holds the shutdown valves open.

Each battery was sized by the IEEE 485 method. The loads were converted to currents at the end-of-discharge voltage, where a constant-power load draws the most current, and arranged in a duty cycle: a one-minute starting period with momentary loads, the continuous period, and a final minute that carries the random load of the emergency shutdown beacons and horn. The cell size follows from the capacity rating factors of the discharge curve, corrected for minimum electrolyte temperature, a design margin and end-of-life aging. The chargers follow IEEE 946. Hydrogen evolution was checked against the ventilation of B-102.

3. DESIGN INPUTS

Table 3-1 lists the inputs.

Table 3-1: Design Inputs

Input	Value	Source
Autonomy without utility or generator	8 h	GEN-DB-001
24 VDC battery	12 valve-regulated lead-acid (VRLA) cells	TORUS selection
Float / boost voltage	27.0 V (2.25 V/cell) / 28.2 V (2.35 V/cell)	Typical VRLA, HOLD H-15
End-of-discharge voltage	21.6 V (1.80 V/cell)	Matches the 21.6 V low-low DC bus alarm, INS-LST-003

Input	Value	Source
Minimum electrolyte temperature	60 °F (B-102 heated to 65 °F)	ELE-CAL-001
Temperature correction at 60 °F	1.11	IEEE 485 Table 1
Design margin / aging factor	1.10 / 1.25	IEEE 485
24 VDC instrumentation and telecommunications load	Panel and field load list	INS-DS-014, Control Panels and UPS Interface
UPS battery	24 VRLA cells, 48 VDC; inverter efficiency 0.88 at part load	Typical, HOLD H-15
Equipment power	Typical values, Table 6-1 and Table 6-3	HOLD H-15

4. ASSUMPTIONS

1. The equipment power figures are typical of the specified equipment. *Verification required against vendor data (HOLD H-15).*
2. The discharge characteristic is representative of 2 V VRLA cells. *Verification required: the cell size shall be re-checked with the selected manufacturer's published discharge data.*
3. The IEEE 485 temperature correction factors are derived for vented cells. They are applied to VRLA cells here as a close approximation; the manufacturer's factor governs at detailed design.
4. The 900 MHz radio transmits 10 % of the time on average; its transmit bursts are carried as momentary load in the first minute.
5. The receiving pipeline operator's equipment at the demarcation panel draws 100 W. *Verification required (HOLD H-14).*

5. REFERENCES

1. IEEE 485-2020, Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications.
2. IEEE 1184-2006, Guide for Batteries for Uninterruptible Power Supply Systems.
3. IEEE 946-2020, Recommended Practice for the Design of DC Power Systems for Stationary Applications.
4. IEEE 1187-2013 and IEEE 1188-2005, Installation design and maintenance of VRLA batteries; IEEE 1635-2018 / ASHRAE Guideline 21, Ventilation and Thermal Management of Batteries.
5. NFPA 70, National Electrical Code, 2023 Edition, Article 480.
6. GEN-DB-001, Basis of Design; ELE-CAL-001, Electrical Load Analysis; ELE-CAL-004, Cable Sizing, Short Circuit and Arc-Flash Assessment.
7. INS-LST-001, Instrument Index; INS-LST-003, Alarm and Trip Setpoint Schedule.

6. CALCULATION

6.1. 24 VDC LOADS

Table 6-1 lists the 24 VDC loads. The instrumentation and telecommunications loads, 541 W, are taken from INS-DS-014, Control Panels and UPS Interface, which builds them from the I/O module counts of the RTU and safety PLC (INS-LST-002, I/O List) and the panel contents. That list governs the instrumentation load because it is built from the actual hardware rather than from typical allowances. TORUS added the loads on the same bus that are outside the instrumentation scope: the fuel gas Coriolis transmitter FT-163, the demarcation interface isolators, the sampler pump stroke as a momentary load, and the emergency beacons and horn as a random load.

Table 6-1: 24 VDC Loads

Tag	Description	Location	Continuous, W	Peak, W
CP-102A	CP-102A	B-102	107.4	107.4
CP-102B	CP-102B	B-102	113.4	113.4
CP-102C	CP-102C	B-102	48.9	48.9
TR-102	TR-102	B-102	85.0	85.0
SY-SOL	Dump solenoids SY-101, SY-102, SY-103, SY-165 (8 W each, energized)	Field	32.0	32.0
SY-106R	SDV-106 actuator interposing relay (actuator on the 120 VAC UPS)	Field	2.0	2.0
SY-141	SDV-141 sample shutoff solenoid	Field	4.0	4.0
FT-111/121	Ultrasonic meter electronics FT-111, FT-121	SK-110	20.0	20.0
AT-141	Gas chromatograph AT-141 electronics (oven heaters excluded)	B-101	30.0	30.0
AT-142	Moisture analyzer AT-142	B-101	30.0	30.0
AT-143	H2S analyzer AT-143	B-101	30.0	30.0
AT-144	O2 analyzer AT-144	B-101	10.0	10.0
SMP-146	Composite sampler SMP-146 controller	B-101	5.0	5.0
GD-205/206/207	Gas detectors GD-205, 206, 207	Field	15.0	15.0
BE-213	Flame detector BE-213	Field	5.0	5.0
XS-212	Smoke detector XS-212 and beacons at standby	Field	3.0	3.0
FT-163	Fuel gas Coriolis transmitter FT-163 (4-wire)	FG-101	7.0	7.0
WDP-101	Demarcation interface isolators and relays	B-102	10.0	10.0
SMP-146P	Composite sampler pump stroke (momentary)	B-101	0.0	10.0

Tag	Description	Location	Continuous, W	Peak, W
XY-214	Gas and ESD beacons and horn in alarm (random)	B-101 / B-102	0.0	40.0
Total			557.7	

The continuous load is 558 W. The momentary load in the first minute is 10 W, and the random load of the beacons and horn during an emergency shutdown is 40 W.

6.2. STATION BATTERY BT-101

At the end-of-discharge voltage the continuous current is:

IEEE 485, constant-power load

$$I_c = \frac{P_c}{V_{end}} = \frac{557.7}{21.6} = 25.82 \text{ A}$$

The duty cycle has three periods: 26.28 A for the first minute, 25.82 A to 479 minutes, and 25.82 A for the final minute, with a random load of 1.85 A. For each section S of the duty cycle, IEEE 485 sums the change in current at the start of each period times the capacity rating factor K_t for the time from that point to the end of the section:

IEEE 485-2020, cell sizing worksheet

$$F_S = \sum_{p=1}^S (A_p - A_{p-1}) K_t (T_S - T_{p-1})$$

Table 6-2 gives the worksheet.

Table 6-2: IEEE 485 Worksheet, BT-101

Section	Period	Current, A	Change, A	Time to end, min	K_t , h	Capacity, Ah
1	1	26.28	26.28	1	0.604	15.87
1	Section total					15.87
2	1	26.28	26.28	479	8.686	228.28
2	2	25.82	-0.46	478	8.676	-4.02
2	Section total					224.27
3	1	26.28	26.28	480	8.696	228.54
3	2	25.82	-0.46	479	8.686	-4.02
3	3	25.82	0.00	1	0.604	0.00
3	Section total					224.52

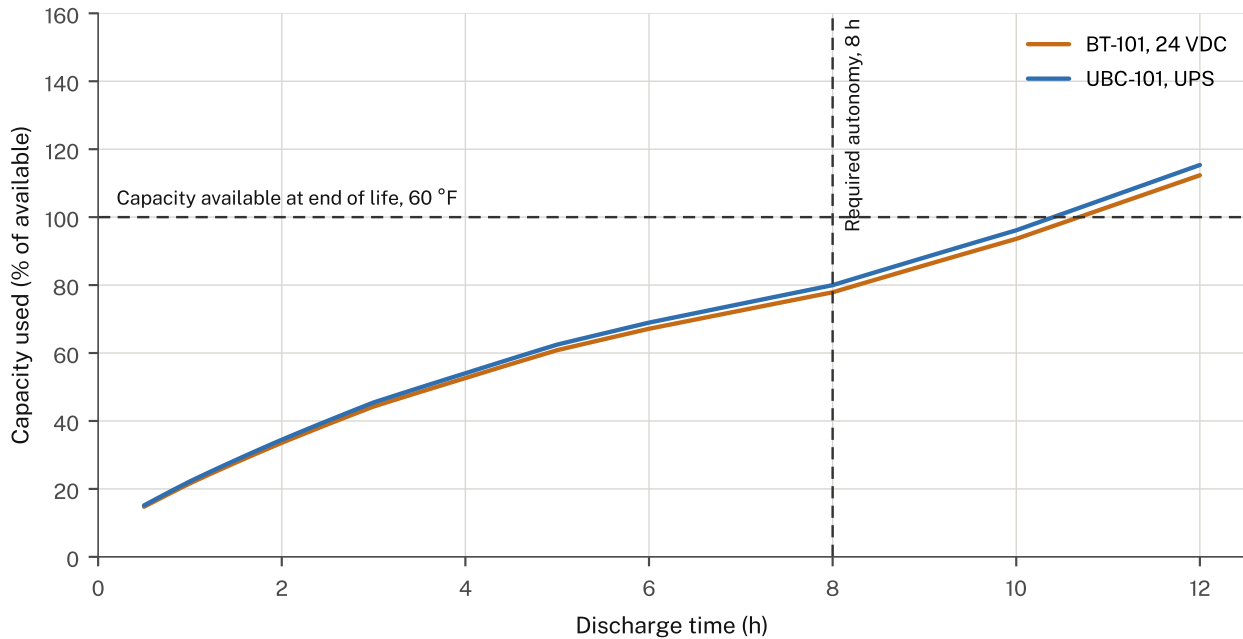
Adding the random load and applying the corrections gives the required 8-hour capacity:

IEEE 485-2020, cell size

$$C = (F_{max} + A_R K_{t, 1 min}) T_c M A = (224.52 + 1.12)(1.11)(1.10)(1.25) = 344.4 \text{ Ah}$$

The next standard cell is 400 Ah. With the battery at the end of its life and at 60 °F, it carries the continuous load for 10.7 h. Figure 6-1 shows the capacity each battery uses over time against what it has available at end of life; both cross the 8-hour requirement with margin.

Figure 6-1. Battery Capacity Used over the Discharge, End of Life at 60 °F



INS-DS-014 checked the battery with a single 8-hour period and found 332 Ah for its 541 W. This calculation carries the full bus load (558 W), the first-minute momentary load and the random beacon load in the IEEE 485 duty cycle, and requires 344 Ah. It therefore governs the cell selection.

BT-101 is 12 VRLA cells of 400 Ah (8-hour rate). It supports the 24 VDC load for 10.7 h at end of life.

6.3. CHARGERS BC-101A AND BC-101B

Each charger must carry the continuous load while recharging the battery:

IEEE 946-2020, charger sizing

$$A = \frac{1.1 C_{rem}}{H} + L_c = \frac{1.1(206.6)}{12} + 20.66 = 39.6 \text{ A}$$

Recharging the full rated capacity within 24 h needs 39.0 A. With 10 % margin on the larger value, a 50 A charger is selected. Two chargers are provided, each able to carry the load and recharge the battery alone, so that a charger can be taken out of service without leaving the safety system on battery.

BC-101A and BC-101B are 50 A, 24 VDC, temperature-compensated chargers with 208 V single-phase input, operating in parallel.

6.4. UPS-101 AND ITS BATTERY

Table 6-3 lists the 120 VAC critical loads.

Table 6-3: 120 VAC Critical Loads

Tag	Description	Running, W	Peak, W
HMI-101	Operator / engineering workstation and monitor	170	170
NVR-101	Network video recorder and 4 PoE cameras	110	110
JB-W01	demarcation panel 120 VAC supply (HOLD H-14)	100	100
LCV-104	V-101 dump valve electric actuator (running 60 W, standby 10 W)	15	60
SDV-106	V-101 liquid outlet SDV, electric spring-return fail-closed actuator (holding 20 W, stroke 100 W)	20	100
ANT-201	Mast base enclosure: surge-protected 120 VAC outlet for mast-mounted telecom equipment (typical, HOLD H-15)	30	50
Spare	20 % of connected peak	59	118

The design load is 708 W, or 0.77 kVA. With 25 % growth and a factor of 1.5 for the inrush of the valve actuators, the UPS must be at least 1.44 kVA; a 1.5 kVA on-line double-conversion UPS is selected. Its battery current at end of discharge is:

IEEE 1184, UPS battery

$$I = \frac{P}{\eta V_{end}} = \frac{504}{0.88 \times 43.2} = 13.26 \text{ A}$$

By the same worksheet, with 18.62 A for the first minute, the required capacity is 176.0 Ah and a 200 Ah cell is selected. The UPS charger must deliver at least 4.86 A to recharge the battery in 24 h.

UPS-101 is 1.5 kVA on-line double conversion with static bypass and an external maintenance bypass switch. UBC-101 is 24 VRLA cells of 200 Ah (48 VDC).

6.5. BATTERY ROOM VENTILATION

A VRLA cell recombines almost all the gas it produces on float, but a failed charger can overcharge it. Hydrogen generation follows Faraday's law, 0.0147 ft³ per ampere-hour per cell:

IEEE 1635, hydrogen evolution

$$Q_{H_2} = I_{oc} n (0.0147) = 4.0 \times 12 \times 0.0147 = 0.708 \text{ ft}^3/\text{h}$$

Holding hydrogen below 1 % by volume, a quarter of its lower flammable limit, needs 1.18 cfm, or 0.025 air changes per hour in the 2,880 ft³ building. The 100 cfm of outdoor air supplied by the B-102 air conditioners exceeds this by two orders of magnitude, so no dedicated battery exhaust fan is needed.

7. RESULTS AND CONCLUSIONS

Table 7-1 summarizes the selections.

Table 7-1: Stored Energy Summary

Item	Selection	Basis
BT-101	12 x 2 V VRLA, 400 Ah, two-tier seismic rack	Required 344 Ah
BC-101A and BC-101B	2 x 50 A, 24 VDC, 208 V single-phase input	Required 39.6 A
UPS-101	1.5 kVA on-line, 120 V	Load 0.77 kVA
UBC-101	24 x 2 V VRLA, 200 Ah (48 VDC)	Required 176 Ah
24 VDC autonomy	10.7 h at end of life, 60 °F	8 h minimum

TORUS draws the following conclusions:

1. BT-101 shall be 12 VRLA cells of 400 Ah with two 50 A chargers in parallel.
2. UPS-101 shall be 1.5 kVA on-line with a 200 Ah, 48 VDC battery for 8 h.
3. The GC oven, analyzer heaters, heat tracing and HVAC are not on stored energy; the standby generator backs them.
4. B-102 cooling is part of the battery design: at a sustained 95 °F, VRLA service life is roughly halved.
5. The UPS and DC bus alarms are wired to the RTU as listed in INS-LST-002, I/O List.

The following items remain open: equipment power and battery discharge data (HOLD H-15) and the receiving pipeline operator's demarcation load (HOLD H-14).