

OWNER

Standby Generator and Transfer Switch

Calculation



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TORUS

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

ISSUE SUMMARY AND APPROVAL

This page records each issue of ELE-CAL-002. The preparer, reviewer and approver sign for each revision.

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1. OBJECTIVE

This calculation confirms the rating of standby generator G-101 and automatic transfer switch ATS-101 for the . It checks that the generator carries the whole station through a winter restart after a utility outage, that each block of load it picks up stays within the engine's capability and a tolerable voltage dip, and it states the fuel the generator draws from the station.

2. METHODOLOGY

TORUS took the coincident winter peak demand from ELE-CAL-001, Electrical Load Analysis, removed the engine block heater (its thermostat opens once the engine runs) and added a 10 % margin. Standard natural-gas generator ratings were derated for the 1,150 ft site elevation and the 110 °F design ambient, and the smallest rating that carries the margin load was identified.

A spark-ignition gas engine accepts a smaller block of load than a diesel before its frequency sags, so the restart was modeled as a sequence of load blocks set by restart time-delay relays. Each block was checked against the engine's block-load capability and against a transient voltage dip calculated from the alternator transient reactance. The worst motor-starting event, the shutdown valve pumps restarting together after an emergency shutdown reset, was checked with all other load already connected.

Fuel use follows the generator's heat-rate curve and the higher heating value of the design gas from GEN-DB-001, Basis of Design. The generator breaker, conductors and transfer switch follow NFPA 70 Article 445 and UL 1008.

3. DESIGN INPUTS

Table 3-1 lists the inputs. Generator characteristics are typical values for a 60 kW natural-gas set and will be replaced with the selected vendor's data (HOLD H-15).

Table 3-1: Design Inputs

Input	Value	Source
Winter coincident peak demand, station	37.0 kW	ELE-CAL-001
Engine block heater (off when running)	1.5 kW	ELE-CAL-001
Normal running demand, winter / summer	21.0 kW / 10.4 kW	ELE-CAL-001
Site elevation / maximum ambient	1,150 ft / 110 °F	GEN-DB-001

Input	Value	Source
Derating, altitude / temperature	3.5 % per 1,000 ft above 500 ft / 1 % per 10 °F above 77 °F	Typical, HOLD H-15
Alternator transient reactance X'_d	0.25 per unit	Typical, HOLD H-15
Single block load capability	40 % of rating	ISO 8528-5 class G2, typical
Allowable transient voltage dip	20 %	IEEE 446 guidance
Higher heating value, design gas	1,104 Btu/scf	GEN-DB-001
Heat rate at 25 / 50 / 75 / 100 % load	20,500 / 15,000 / 13,200 / 12,400 Btu/kWh	Typical, HOLD H-15

4. ASSUMPTIONS

1. The alternator transient reactance, block-load capability, derating and heat rate are typical of a 60 kW natural-gas set. *Verification required against the selected vendor's data (HOLD H-15).*
2. Motor starting demand is 9.5 kVA per horsepower at 0.4 power factor (NEMA code letter L). *Verification required against actuator nameplates (HOLD H-15).*
3. The restart time-delay relays in HCP-161 and on UH-101 and AC-102A are furnished and set as stated in Section 6.3.
4. The engine is rated for the design gas. The off-specification rich gas envelope in GEN-DB-001 lowers the methane number. *Verification required (HOLD H-12, H-15).*

5. REFERENCES

1. NFPA 70, National Electrical Code, 2023 Edition: Articles 445 and 702, and 250.30 and 250.35.
2. NFPA 110, Standard for Emergency and Standby Power Systems, 2022 Edition (applied as good practice; the system is optional standby under Article 702).
3. NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, 2022 Edition.
4. ISO 8528-5:2022, Reciprocating internal combustion engine driven alternating current generating sets, Part 5: Generating sets.
5. UL 1008, Transfer Switch Equipment, 8th Edition; UL 2200, Stationary Engine Generator Assemblies.
6. IEEE 446-1995, Recommended Practice for Emergency and Standby Power Systems (Orange Book).



7. 40 CFR 60 Subpart JJJJ, Standards of Performance for Stationary Spark Ignition Internal Combustion Engines.
8. GEN-DB-001, Basis of Design; ELE-CAL-001, Electrical Load Analysis; ELE-CAL-004, Cable Sizing, Short Circuit and Arc-Flash Assessment.
9. ELE-DWG-001, One-Line Diagram (Appendix A).

6. CALCULATION

6.1. LOAD ON THE GENERATOR

The generator carries every load in the station through ATS-101. On a winter restart the block heater is off, so the load it must carry is:

$$P_{gen} = P_{peak} - P_{BH} = 37.0 - 1.5 = 35.5 \text{ kW (38.9 kVA)}$$

With a 10 % margin the generator must deliver 39.1 kW at site conditions.

6.2. RATING AND SITE DERATING

The standby rating falls with elevation and ambient temperature:

Typical natural-gas genset derating (HOLD H-15)

$$P_{site} = P_{rated} \left[1 - 0.035 \frac{1,150 - 500}{1000} \right] \left[1 - 0.01 \frac{110 - 77}{10} \right] = 60 \times 0.9772 \times 0.9670 = 56.7 \text{ kW}$$

The smallest standard rating that meets 39.1 kW at site is 45 kW. TORUS nevertheless retains the 60 kW rating in the Basis of Design. At 60 kW the winter peak loads the set to 63 % of its site rating, which leaves room for the largest load block without exceeding the engine's block-load capability, and it keeps the motor-starting voltage dip below 10 %. A 45 kW set would carry the peak but would sit close to its block-load limit when E-161 restarts.

G-101 is rated 60 kW / 75 kVA standby, natural gas, 480Y/277 V, three-phase. Its site rating is 56.7 kW, against a winter peak of 35.5 kW.

6.3. STEP LOADING AND VOLTAGE DIP

After the transfer switch closes, load returns in the blocks set out in Table 6-1. Without the restart delays, all of the resistive heating (about 27 kW) would land in one block, close to the 22.7 kW that a gas engine can accept at once. The transient voltage dip for each block is:

IEEE 446, voltage dip on load application

$$\Delta V = \frac{X'_d S_{step}}{S_{gen} + X'_d S_{step}} \times 100 \%$$

The governing event is the restart of the shutdown valve pumps after an emergency shutdown reset, with all other load connected. The four pumps total 3.25 hp and draw 30.9 kVA while starting:

IEEE 446, voltage dip on load application

$$\Delta V = \frac{0.25(30.9)}{75 + 0.25(30.9)} \times 100 = 9.3 \%$$

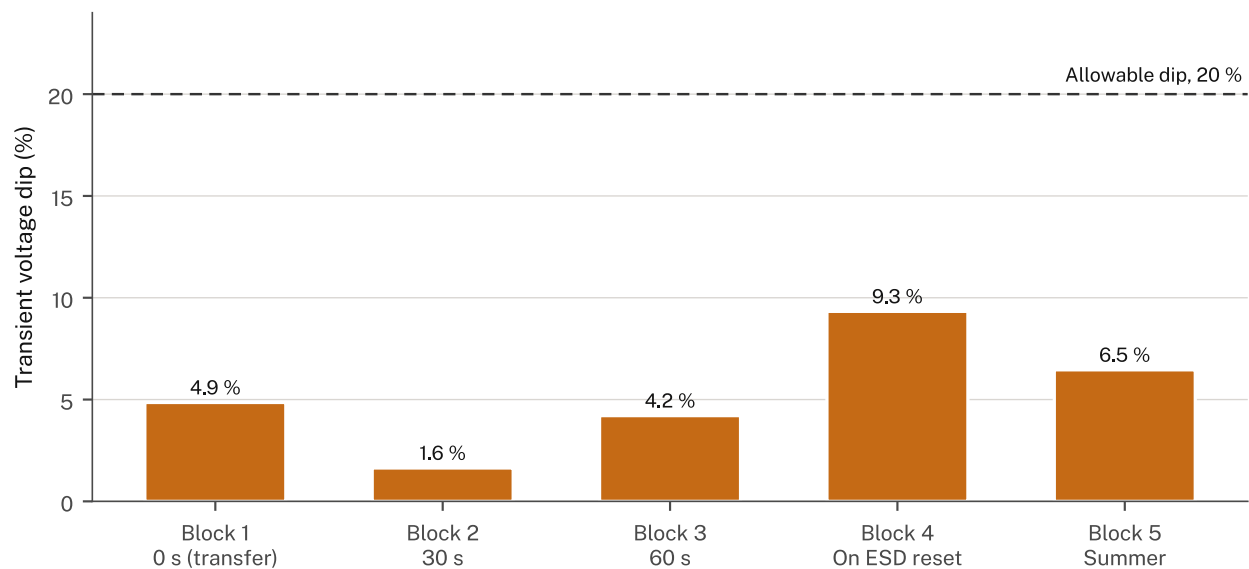
Table 6-1: Restart Load Blocks and Voltage Dip

Block	Time	Loads	Block kW	Starting kVA	Dip, %	Result
1	0 s (transfer)	Chargers and UPS recharging, lighting, analyzer and tracing heaters, BMS, receptacles, EF-101A restart	9.2	15.3	4.9	Acceptable
2	30 s	E-161 fuel gas preheater (restart delay in HCP-161)	5.0	5.0	1.6	Acceptable
3	60 s	UH-101 shelter heater and AC-102A electric heat (restart delay relays)	12.9	13.2	4.2	Acceptable
4	On ESD reset	SDV-101, SDV-102, SDV-103 and SDV-165 pumps start together (3.25 hp)	3.1	30.9	9.3	Acceptable
5	Summer	AC-102A compressor start (locked-rotor current 26 A)	2.4	20.7	6.5	Acceptable

Note 1: Block load limit 22.7 kW (40 % of the site rating); voltage dip limit 20 %.

Figure 6-1 compares the dip for each block with the limit. Every block is within both limits; the worst dip is 9.3 %.

Figure 6-1. Transient Voltage Dip by Load Block



All load blocks are within the engine's block-load capability, and the worst transient dip is 9.3 % against a 20 % limit. Restart time-delay relays shall be provided: 30 s on E-161 (in HCP-161) and 60 s on UH-101 and on the AC-102A electric heat stage.

6.4. FUEL CONSUMPTION

Fuel demand at each operating point follows from the heat rate and the design gas heating value, as listed in Table 6-2:

Vendor heat-rate curve (HOLD H-15)

$$Q_{fuel} = \frac{HR \times P}{HHV} = \frac{12,400 \times 60}{1,104} = 674 \text{ scf/h}$$

Table 6-2: Generator Fuel Demand

Case	Load, kW	Load, % of rating	Heat rate, Btu/kWh	Fuel, MMBtu/h	Fuel, scf/h
Normal running, winter	19.8	33	18,722	0.37	337
Normal running, summer	10.4	17	20,500	0.21	194
Winter peak	35.5	59	14,335	0.51	462
Rated output	60.0	100	12,400	0.74	674

The fuel supply line 1"-F-1052 from second-cut regulator PCV-162 on skid FG-101 must deliver 674 scf/h at the engine regulator inlet pressure the vendor requires, typically 7 to 11 in WC. The process design of the fuel gas system (PRO-CAL-010, Fuel Gas System) confirms this capacity together with the line heater demand. Because the generator burns station gas, its runtime is not limited while the station is pressurized. An emergency shutdown closes fuel shutoff SDV-165 and therefore stops the generator; the critical loads then run on the 8 h batteries in ELE-CAL-003, UPS and Battery Sizing.

6.5. GENERATOR BREAKER, CONDUCTORS AND TRANSFER SWITCH

The generator's rated current and the limit on its overcurrent device are:

NFPA 70-2023, 445.12(A) and 445.13(A)

$$I_{gen} = \frac{75 \text{ kVA} \times 1000}{\sqrt{3} \times 480} = 90.2 \text{ A}, \quad I_{OCPD} \leq 1.15 I_{gen} = 103.7 \text{ A}$$

A 110 A breaker is the next standard rating, which 445.12(A) permits. The generator conductors, 4-1/C 1/0 AWG copper rated 150 A at 75 °C, exceed the 115 % ampacity requirement of 445.13. The breaker shall have an electronic trip with its instantaneous element set at 2 x In (220 A). On generator the bolted fault at DP-101 is only 596 A, so a thermal-magnetic breaker would clear an arcing fault slowly;

the low instantaneous setting keeps the clearing time within the limits of the NFPA 70E arc-flash table method used in ELE-CAL-004. Selectivity with the 15 A and 20 A branch breakers is partial on generator, which NFPA 70 Article 702 permits for optional standby systems.

Table 6-3 sets out the transfer switch requirements.

Table 6-3: ATS-101 Requirements

Parameter	Requirement
Rating	150 A continuous, 480 V, three-pole with solid neutral, open transition, UL 1008, NEMA 1
Withstand and closing rating	22 kA with the specified upstream breaker (calculated 4.8 kA at ATS-101)
Neutral	Solid neutral; G-101 is not a separately derived system, so the neutral is bonded to ground only at MCB-101
Engine start and transfer	Two-wire start after 3 s; transfer when the generator reaches 90 % voltage and 95 % frequency
Retransfer	5 min after utility returns, with in-phase monitor; 5 min engine cool-down
Exercise	Weekly 30 min; monthly under load
Status to RTU	Utility available and on-generator contacts
Load control	Contacts for the HCP-161, UH-101 and AC-102A restart delays

7. RESULTS AND CONCLUSIONS

Table 7-1 summarizes the results.

Table 7-1: Generator and Transfer Switch Summary

Item	Result
G-101 rating	60 kW / 75 kVA standby, natural gas, 480Y/277 V; site rating 56.7 kW
Winter peak on generator	35.5 kW (63 % of site rating)
Normal running	19.8 kW winter, 10.4 kW summer
Worst transient voltage dip	9.3 % (limit 20 %)
Fuel at rated output	674 scf/h (0.74 MMBtu/h)
Generator breaker	110 A three-pole, electronic trip, instantaneous 2 x In
Transfer switch ATS-101	150 A, three-pole, open transition, 22 kA

TORUS draws the following conclusions:

1. The 60 kW natural-gas standby generator in the Basis of Design is confirmed. It carries the 35.5 kW winter peak with margin for load growth and for the largest load block.

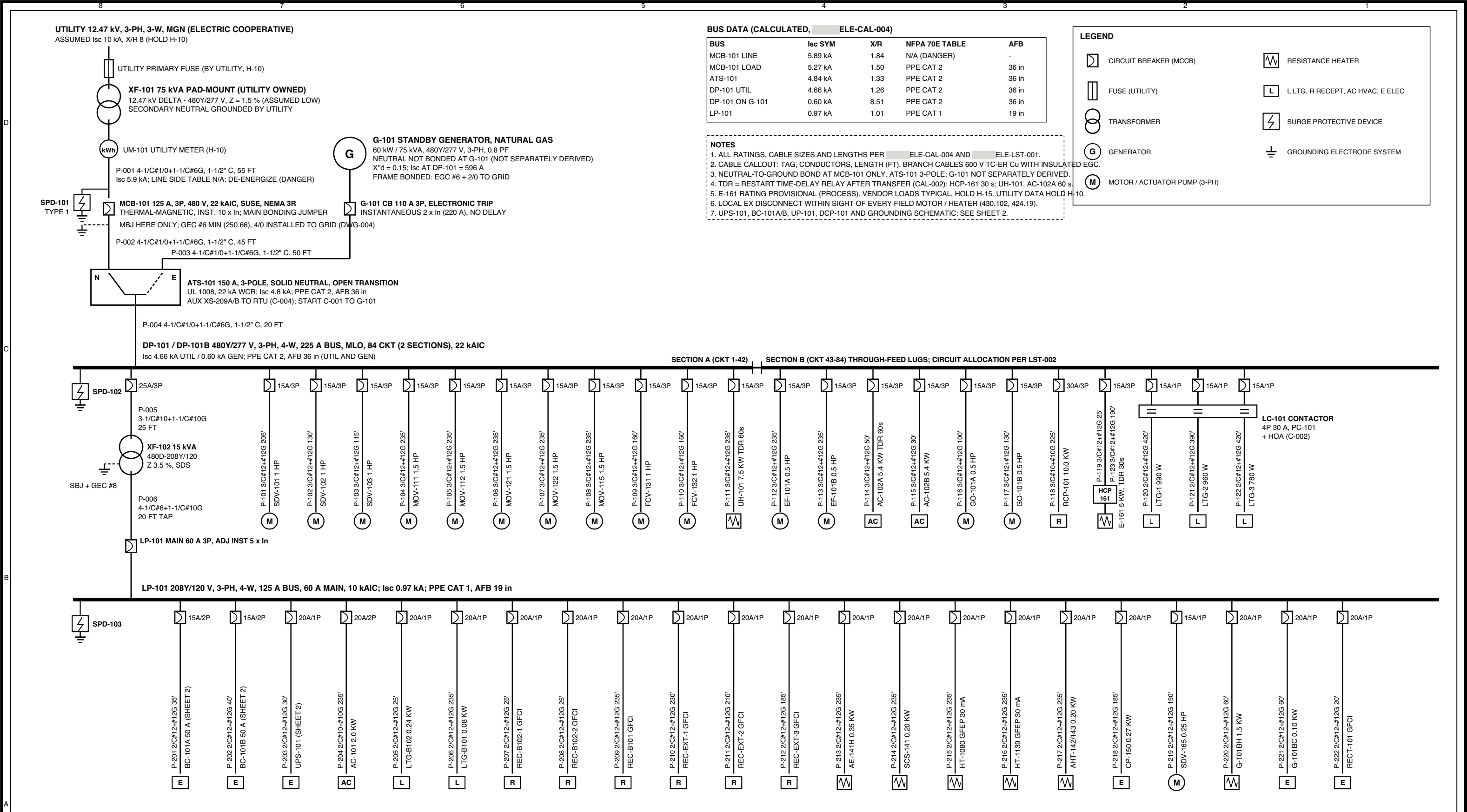
2. Should the E-161 preheater rating grow beyond about 21 kW, the generator shall be increased to the next standard rating of 80 kW.
3. Restart time-delay relays shall be provided on E-161, UH-101 and the AC-102A heat stage, as set out in Section 6.3.
4. The generator breaker shall have an electronic trip with its instantaneous element at 2 x In.
5. G-101 is an outdoor, weatherproof, sound-attenuated set with block heater, battery charger and alarms to the RTU. It lies outside all classified areas (ELE-RPT-001, Hazardous Area Classification). The engine shall be certified to 40 CFR 60 Subpart JJJJ.

The following items remain open: generator and actuator vendor data (HOLD H-15) and the engine rating for the rich-gas envelope (HOLD H-12).



APPENDIX A. ONE-LINE DIAGRAM





NOTES / REFERENCES

- LOADS PER ELE-CAL-001; CABLES AND PROTECTION PER ELE-CAL-004.
- SHORT CIRCUIT AND ARC FLASH SCREENING PER ELE-CAL-004 (FINAL STUDY)
- IEEE 1584-2018 AFTER HOLD H-10 CLOSES).
- LOAD DATA TYPICAL, CONFIRM WITH VENDOR DATA (HOLD H-15).

REF: ELE-CAL-001/002/004
REF: ELE-LST-001/002
REF: ELE-DWG-004

REVISIONS

REV	DATE	DESCRIPTION	BY	CHK	APP
A	2026-09-29	ISSUED FOR REVIEW (IFR)			

PRELIMINARY - ISSUED FOR REVIEW - NOT FOR CONSTRUCTION

ENGINEER OF RECORD SEAL

NOT SEALED
PRELIMINARY

PE NO. _____

PROJECT

120 MMSCFD RECEIPT INTO _____

COUNTY, _____

DISCIPLINE: ELECTRICAL
SCALE: NTS

ONE-LINE DIAGRAM

480 V AND 208Y/120 V DISTRIBUTION

DRAWN: _____ CHECKED: _____ APPROVED: _____

DWG NO. _____
ELE-DWG-001

SHEET 1 OF 2 REV A