7BOD - Electrical (CSI Div 26)

Created: 2025-10-29
Updated from: Pryor_Bod_EVS_Rev01.md

BASIS OF DESIGN - ELECTRICAL

CSI Division 26

Pryor Data Center - PACHYDERM GLOBAL

Parent Document: Saga Pryor DC/Basis of Design/Erik_BOD_Updated/_BOD - Exec Summary and TOC

OVERVIEW

Electrical systems provide Tier III-compliant power distribution with N+1 IT UPS architecture backed by self-healing 11 kV dual-ring MV distribution, N+1 generators and transformers, supporting 3 MW Phase 1 (expandable to 12 MW Phase 2). Customer-owned 138 kV substation with 11 kV distribution integrates utility, solar, BESS, and generators on common voltage infrastructure.

Design Philosophy:

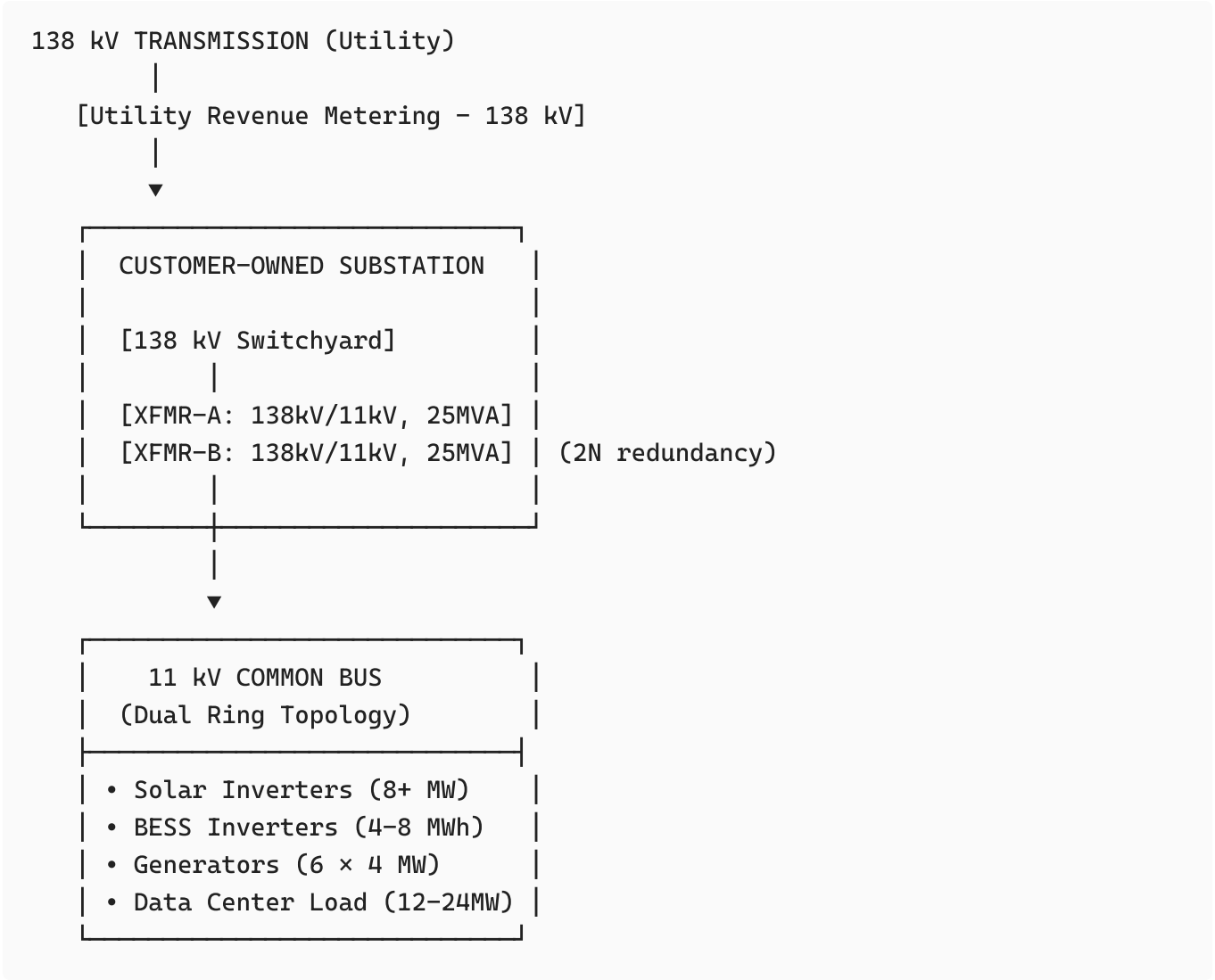
- **Path redundancy:** 11 kV self-healing dual-ring MV distribution with automated SCADA switching
- **Component redundancy:** N+1 (IT UPS, generators, transformers, mechanical UPS)
- **Concurrent maintainability:** Service any component without IT interruption
- **138kV/11kV substation:** Customer-owned, integrates all power sources at 11 kV
- **Prefabricated PDMs:** Factory-tested electrical enclosures accelerate schedule

---

UTILITY SERVICE & SUBSTATION

Customer-Owned 138 kV Substation

Configuration:



138 kV Primary Service

Utility Interconnection:

- **Voltage:** 138 kV transmission
- **Capacity:** 25-30 MVA (sized for 24 MW master plan + solar/BESS)
- **Metering:** Revenue-grade metering at 138 kV (utility-owned)
- **Protection:** Distance relay, differential, overcurrent per utility standards

138kV/11kV Substation Transformers:

- **Quantity:** 2 transformers (N+1 redundancy - either can carry full load)
- **Rating:** 25 MVA each @ 138kV/11kV
- **Type:** Oil-filled, ONAN cooling
- **Configuration:** Delta-wye with neutral solidly grounded
- **Impedance:** ~7-8%
- **Location:** Outdoor substation yard on data center site

Cost: ~$5-9M for complete customer-owned substation

Benefits:

- **Single 11 kV infrastructure** for utility, solar, BESS, generators, data center
- **Microgrid capability** - island at 11 kV during utility outages
- **Future expansion** - no utility upgrades required for 24 MW build-out
- **Export capability** - sell excess solar to grid (if permitted)
- **Better power quality** - transmission-level connection (stiffer grid)

MEDIUM VOLTAGE DISTRIBUTION (11 kV)

System Configuration

Dual-Ring MV Topology:

```
138kV UTILITY ──[XFMR-A: 25MVA]──[RMU-1]──[RMU-2]──[RMU-3]── RING A
                                     |        |        |
                                  [XFR-1]  [XFR-3]  [XFR-5]

138kV UTILITY ──[XFMR-B: 25MVA]──[RMU-4]──[RMU-5]──[RMU-6]── RING B
                                     |        |        |
                                  [XFR-2]  [XFR-4]  [XFR-6]

Phase 2: Add [XFR-7] and [XFR-8]

GENERATORS (6 × 4.0 MW @ 11 kV) ─► Connect to both rings via paralleling
switchgear
SOLAR INVERTERS (8+ MW) ──────────► Connect to 11 kV common bus
BESS INVERTERS (4-8 MWh) ─────────► Connect to 11 kV common bus
```

Ring Main Units (RMUs)

Equipment: 6 × RMUs (11 kV, 630A rated)

- **Configuration:** 3 RMUs per ring (Ring A and Ring B)
- **Type:** SF6 or vacuum circuit breakers
- **Rating:** 11 kV, 630A continuous, 20 kA short-circuit
- **Controls:** SCADA-controlled remote switching for load transfer
- **Location:** Electrical equipment yard, generator/PDM boundary

- **Function:** Isolate transformers, enable ring reconfiguration, interconnect generators/solar/BESS

Advantages:

- Any transformer can be isolated for maintenance without facility shutdown
- Load automatically transfers to remaining transformers via SCADA
- Generators, solar, and BESS parallel onto either or both rings
- True concurrent maintainability

GENERATOR SYSTEM

Configuration

6 × 4.0 MW @ 11 kV Diesel Generators (N+1 Redundancy)

- **Phase 1:** 3 generators (positions 1-3)
- **Phase 2:** +3 generators (positions 4-6)
- **N+1 Operation:** 5 generators carry full Phase 2 load (18.2 MW), 1 standby

Generator Specifications (Each Unit)

Parameter	Specification
Rating	4,000 kW continuous @ 11 kV, 3-phase, 60 Hz
Standby Rating	4,400 kW
Power Factor	0.8 lagging
Voltage	11,000V ±5%
Fuel	Diesel (EPA Tier 4 Final emissions)
Fuel Consumption	~85 gal/hr at full load (verify with vendor)
Fuel Capacity	~2,000 gal belly tank per unit (connected to central bulk fuel tank farm via common manifold)
Endurance	~24 hours at full load (central bulk fuel storage + redundant supply contracts)
Paralleling Controls	Woodward easYgen 3500 series (or equivalent)
Synchronizing	Automatic paralleling with load sharing

Parameter	Specification
Enclosure	Sound-attenuated (-65 dBA @ 7m)
Seismic	IBC 2018 certified for SDC B
Emissions	NOx < 0.67 g/bhp-hr (Tier 4 Final)

Why 11 kV Generators (Not 480V)

Technical Advantages:

- **Cable sizing:** 11 kV reduces current by 23× vs. 480V
  - 4 MW @ 480V = 8,333 A → requires 6 × 500 kcmil per phase
  - 4 MW @ 11 kV = 364 A → requires 1 × 2/0 per phase
- **I²R losses:** Lower current = dramatically reduced cable losses
- **Paralleling:** Easier to parallel MV generators than massive LV generators
- **Standard products:** 3-5 MW @ 11 kV is off-the-shelf for data centers
- **Common voltage:** Matches utility substation, solar inverters, BESS inverters

Generator Yard Layout

- **Location:** Outdoor electrical equipment yard (south side)
- **Arrangement:** Horizontal layout with 8-10 ft clearances
- **Fuel:** ~2,000 gal belly tanks per generator connected via common fuel manifold to centralized bulk fuel storage tank farm (24 hours runtime) with redundant supply contracts
- **Testing:** Closed-transition load bank, monthly run tests, annual full-load tests
- **Maintenance Access:** Crane pad for major overhauls

TRANSFORMER SYSTEM (11 kV/480V)

Configuration

8 × 3,500 kVA (11 kV/480V) Oil-Filled Transformers

- **Phase 1:** 3 transformers (N+1 for 5.8 MW load)
- **Phase 2:** +5 transformers (8 total for 18.2 MW load)

Transformer Specifications (Each Unit)

Parameter	Specification
Rating	3,500 kVA
Voltage	11,000V delta / 480Y/277V
Impedance	5.75%
Efficiency	98.5% at full load
Cooling	ONAN (oil natural, air natural)
Insulation	65°C rise, 150°C hot spot
BIL	95 kV (primary), 30 kV (secondary)
Sound	60 dBA @ 10 feet
Liquid	Mineral oil or high fire-point vegetable oil
Containment	Secondary containment per EPA 40 CFR 112

Why 8 Transformers

Phase 1: 3 × 3,500 kVA = 10,500 kVA = 9,660 kW @ 0.92 PF

- Design load: 5,800 kW
- N+1 operation: 2 transformers = 6,440 kW for 5.8 kW load (11% margin) ✓

Phase 2: 8 × 3,500 kVA = 28,000 kVA = 25,760 kW @ 0.92 PF

- Design load: 18,200 kW
- Running: 7 transformers = 22,540 kW (24% margin) ✓
- N+1: 6 transformers = 19,320 kW (6% margin) ✓

8th transformer provides:

- Better load distribution (lower per-unit utilization = longer life)
- Future expansion headroom
- True concurrent maintainability with margin

SOLAR & BESS INTEGRATION

Solar Array Interconnection

Configuration:

- **Capacity:** 8+ MW DC solar array (adjacent to data center)
- **Inverters:** String or central inverters outputting 11 kV AC
- **Connection:** Direct to 11 kV common bus via dedicated circuit breaker
- **Metering:** Bi-directional revenue metering (production + export)

BESS Interconnection

Configuration:

- **Capacity:** 4-8 MWh battery energy storage system
- **Inverters:** Bi-directional inverters (charge/discharge) outputting 11 kV AC
- **Connection:** Direct to 11 kV common bus via dedicated circuit breaker
- **Function:** Peak shaving, demand response, solar smoothing, backup power

Microgrid Operation

Normal Mode (Grid-Connected):

- Utility + Solar + BESS → Data Center Load
- Export excess solar to grid (if permitted)

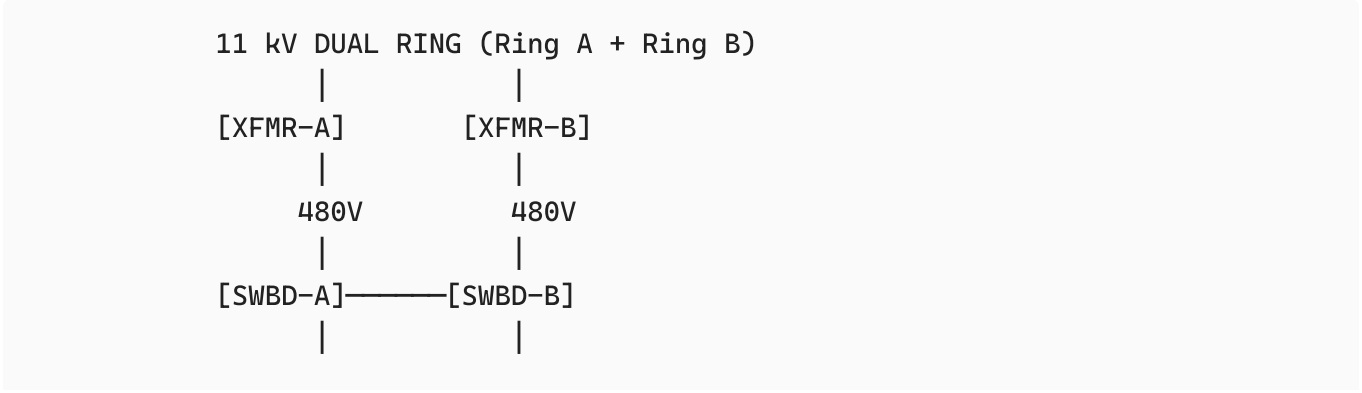
Island Mode (Utility Outage):

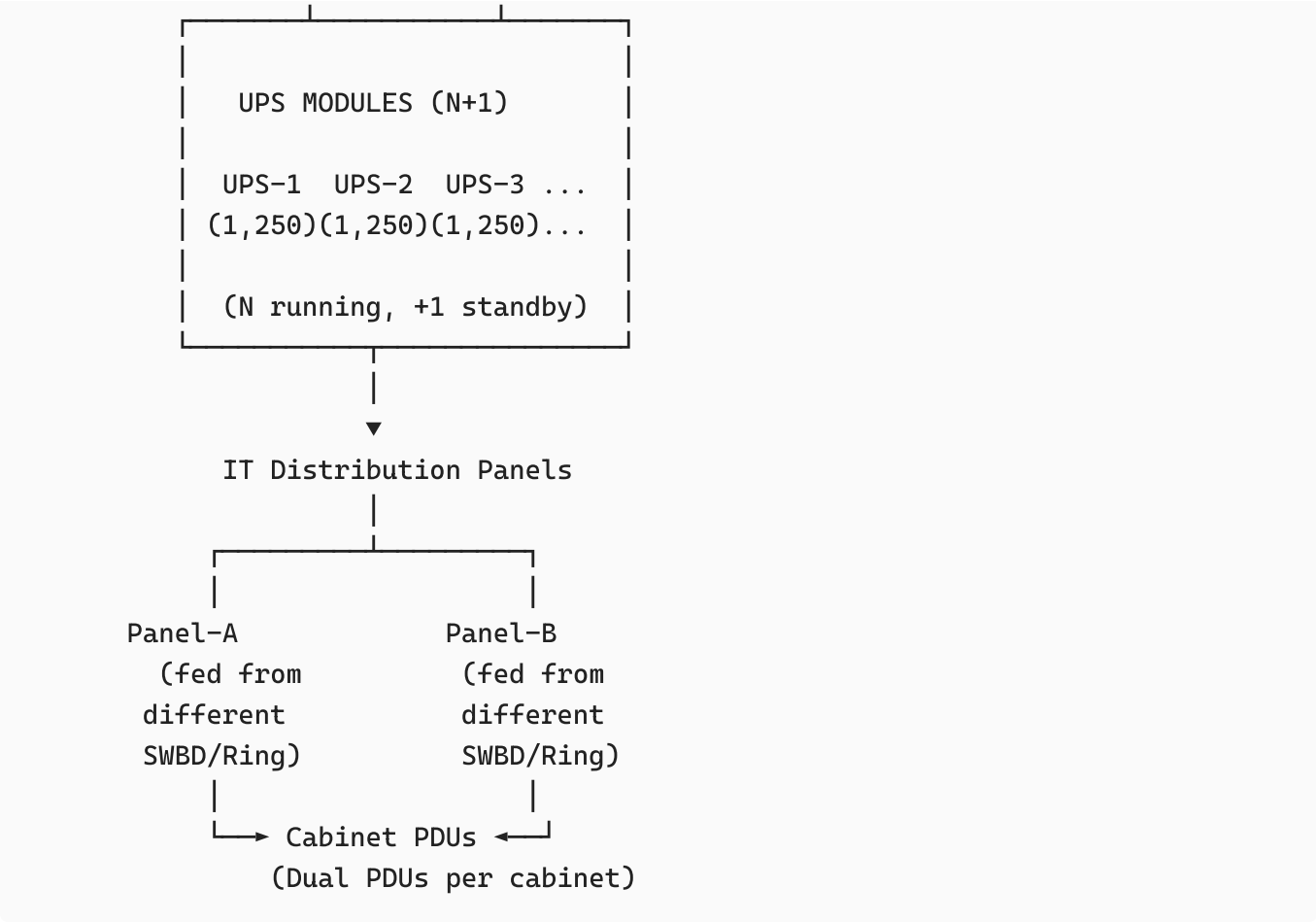
- Solar + BESS + Generators → Data Center Load
- 11 kV bus disconnects from utility, operates as microgrid
- Black start capability via BESS or generators

IT UPS SYSTEM (N+1 ARCHITECTURE)

System Configuration

N+1 Modular Topology with MV Dual-Ring Path Redundancy





Phase 1: 5-6 × 1,250 kVA IT UPS Modules

Modular Configuration:

- 5-6 × 1,250 kVA / 1,000 kW modules in parallel
- 4-5 modules running, 1 standby (N+1)
- Running capacity: 4,000-5,000 kW for 3,000 kW IT load ✓
- Feeds: Multiple IT distribution panels fed from different 480V switchboards

Path Redundancy:

- **MV dual-ring:** Switchboards A and B fed from different segments of 11 kV dual-ring
- **Automated switching:** SCADA-controlled ring switching provides path redundancy
- **Cabinet dual PDUs:** Fed from different 480V distribution panels (connected to SWBD-A and SWBD-B)

Component Redundancy:

- **N+1 UPS:** One UPS module fails → remaining N modules continue
- **Modular hot-swap:** Individual module replacement without downtime

Battery: 5-minute runtime maximum (allows for MV generator sync to bus, even two attempts) (Lithium-ion preferred)

Phase 2: 13-15 × 1,250 kVA IT UPS Modules (add 8-9)

Modular Configuration:

- 13-15 × 1,250 kVA = 16,250-18,750 kVA total
- 12-13 modules running, 1-2 standby (N+1 or N+2)
- Running capacity: 12,000-13,000 kW for 12,000 kW load ✓

Redundancy Philosophy

Two Layers of Redundancy:

1. **Path redundancy:** 11 kV dual-ring with self-healing automated switching (feeds SWBD-A and SWBD-B from different ring segments)
2. **Component redundancy:** N+1 UPS modular architecture (any single UPS module failure tolerated)

Cabinet Dual PDUs:

- Each cabinet has two PDUs fed from different 480V distribution panels
- Distribution panels connected to different switchboards (SWBD-A vs SWBD-B)
- SWBD-A and SWBD-B fed from different 11 kV ring segments
- Result: Full path diversity from 11 kV through cabinet PDU

Advantages over Traditional 2N UPS:

- **Lower capital cost:** ~40-50% fewer/smaller UPS modules
- **Higher efficiency:** Single UPS path = one fewer conversion stage
- **Simplified maintenance:** Fewer UPS systems to maintain
- **Equivalent reliability:** MV dual-ring provides path redundancy; N+1 UPS provides component redundancy

UPS Technical Specifications

Parameter	Specification
Rating	1,250 kVA / 1,000 kW per module
Efficiency	96% (ECO mode), 94% (double-conversion)
Topology	Online double-conversion (VFI per IEC 62040-3)

Parameter	Specification
Input	480V, 3-phase
Output	480V, 3-phase
Battery	External Lithium-ion cabinets, 5-minute runtime (max for MV gen sync)
Bypass	Automatic static bypass + manual maintenance bypass
Monitoring	SNMP, Modbus TCP, BACnet integration
Hot-Swap	Individual module replacement without downtime

Recommended UPS Vendors:

- Schneider Electric Galaxy VX/VL
- Eaton 93PM/93PR
- Vertiv Liebert EXL S1

MECHANICAL UPS SYSTEM

Purpose

Protect critical mechanical loads (pumps, fans, CDUs) from brief utility interruptions during generator startup and sync to bus (~30-60 seconds).

NOT for IT loads - IT equipment protected by dedicated IT UPS system.

Configuration

Phase 1: 8 × 250 kW Static UPS Modules (N+1)

- Protected load: 1,631 kW (chillers, pumps, fans)
- 7 running = 1,750 kW capacity ✓

Phase 2: 20 × 250 kW Static UPS Modules (add 12)

- Protected load: 4,576 kW (all loops, chillers, pumps, CDUs, fans)
- 19 running = 4,750 kW capacity ✓

LOW VOLTAGE DISTRIBUTION (480V)

Main Switchboards (Dual Switchboards Fed from Different MV Ring Segments)

SWBD-A and SWBD-B

- **Rating:** 4,000A copper busbar, 480V, 3-phase, 4-wire
- **SWBD-A fed from:** Transformers on Ring A (MV dual-ring segment A)
- **SWBD-B fed from:** Transformers on Ring B (MV dual-ring segment B)
- **Short-circuit rating:** 65 kA SCCR
- **Path diversity:** Each switchboard receives power from different 11 kV ring segment

Distribution Panels (All Dual-Fed)

	Panel	Rating	Loads
	-------	--------	-------
	IT Distribution A/B	800A	Cabinet PDUs
	Mech Dist 1A/1B	800A	Loops 1+2 chillers, pumps
	Mech Dist 2A/2B (Phase 2)	1,200A	Loop 3 chillers, CDUs
	UPS Distribution A/B	400A	IT UPS output
	Building/House Power	400A	Separate system - see Non-Critical Building Power

---

CABINET POWER DISTRIBUTION

Phase 1: 30 Cabinets @ 100 kW IT Load

- 30 cabinets × 2 PDUs = 60 PDUs
- Each PDU: 50 kW capacity
- Cabinet power: 2 × 50 kW = 100 kW (2N for 100 kW IT load) ✓

Phase 2: 30 Cabinets @ 400 kW IT Load

- Upgrade PDUs to 200 kW capacity each
- Cabinet power: 2 × 200 kW = 400 kW (2N for 400 kW IT load) ✓
- Cost: ~$450K for 60 upgraded PDUs

NON-CRITICAL BUILDING POWER (HOUSE POWER)

Philosophy

Separate from Critical Systems: Non-critical building services operate on independent electrical infrastructure from data hall and MMR critical systems.

Purpose: Avoid impact to critical infrastructure from non-critical loads; enable independent maintenance and testing.

Non-Critical Areas Served

- **Office spaces** (conference rooms, hoteling offices, call pods, seating areas)
- **Bathrooms** (restrooms, showers)
- **Hallways and corridors**
- **Security Control Room (SCR)** - main entrance
- **Security Control Booth (SCB)** - loading dock
- **Loading dock** (lighting, doors, HVAC)
- **Staging and storage areas**
- **Break room, lounge, gaming area**
- **NOC** (Network Operations Center) - non-IT systems
- **Gym/fitness center**
- **Storm shelter/safe room** (lighting, ventilation)
- **Building HVAC** (office RTUs, exhaust fans)
- **General lighting** (non-emergency)
- **Elevator** (non-critical use)

Utility Service

Primary Power:

- **Source:** Single 11kV/480V transformer fed from Solar/BESS system (via 11 kV common bus)
- **Voltage:** 480V, 3-phase, 4-wire
- **Capacity:** ~400 kVA (300-350 kW sustained load)
- **Single Point of Failure:** Acceptable (redundant natural gas house generators provide backup)
- **No PDMs Required:** House power uses standard distribution, not prefabricated modules

Backup Power - Natural Gas House Generators

Configuration: Redundant natural gas generators provide backup power to non-critical areas during utility failure

Specifications:

- **Quantity:** 2 generators (N+1 redundancy)
- **Rating:** 250-350 kW each @ 480V, 3-phase, 60 Hz
- **Fuel:** Natural gas (piped from utility or on-site propane if NG not available)
- **Fuel supply:** Utility natural gas service with redundant supply contract
- **Endurance:** Unlimited runtime (continuous fuel supply)
- **Automatic Transfer Switch (ATS):** Two ATSs (one per generator) with priority load shedding
- **Start time:** <10 seconds to rated voltage
- **Paralleling:** Capable of paralleling for load sharing
- **Enclosure:** Sound-attenuated outdoor enclosure
- **Emissions:** EPA-compliant natural gas emissions

Rationale for Natural Gas:

- **Unlimited runtime:** No fuel storage/delivery logistics
- **Lower maintenance:** Cleaner burning than diesel
- **Cost-effective:** Lower fuel and maintenance costs for house power
- **Independent from critical diesel supply:** Preserves diesel fuel for critical IT loads
- **Compliance:** Meets emission standards for continuous backup power

Portable UPS for IT Systems in Non-Critical Areas

Purpose: Provide ride-through battery power for IT equipment in non-critical spaces during transfer to house generators (~10-15 seconds)

Applications:

- **NOC workstations** and display systems
- **SCR/SCB security workstations** and surveillance equipment
- **Office IT equipment** (workstations, network switches, VoIP phones)
- **BMS/DCIM servers** (if not on critical UPS)

Configuration:

- **Type:** Portable rack-mount or tower UPS units
- **Capacity:** Sized per load (typical: 1-3 kVA per workstation/equipment cluster)
- **Runtime:** 10-15 minutes (sufficient for natural gas house generator startup <10 sec + graceful shutdown if needed)
- **Topology:** Line-interactive or online double-conversion
- **Quantity:** ~20-30 units distributed throughout facility

Cost: ~$50-100K for house generators + ATS; ~$30-50K for portable UPS units

---

PREFABRICATED POWER DELIVERY MODULES (PDMs)

2 × Outdoor PDMs (Phase 1)

- Contents: LV Switchboards, IT UPS modules, Battery cabinets, Distribution panels
- Benefits: Factory testing, 8-12 week schedule acceleration, quality control
- Cost premium: 5-10% justified by schedule and quality benefits

---

ELECTRICAL LOAD SUMMARY

Phase 1

Load	Power (kW)
IT (through IT UPS)	3,125
Mechanical (through Mech UPS)	1,700
Building/Lighting	399
Design Load	**5,800**

Generator Capacity (N+1): 3 × 4.0 MW = 12 MW (2 running = 8 MW, 38% margin) ✓

Phase 2

Load	Power (kW)
IT (through IT UPS)	12,500
Mechanical (through Mech UPS)	4,576
Building/Lighting	399
Design Load	**18,200**

Generator Capacity (N+1): 6 × 4.0 MW = 24 MW (5 running = 20 MW, 10% margin) ✓

CODES AND STANDARDS

- **NEC 2023** (National Electrical Code), Oklahoma amendments
- **IEEE 141** (Red Book - Electric Power Distribution)
- **IEEE 142** (Green Book - Grounding)
- **IEEE 242** (Buff Book - Protection and Coordination)
- **NFPA 110** (Emergency and Standby Power Systems)
- **IEC 62040-3** (UPS Classification - VFI topology)

Tags: #pryor-dc #electrical #138kv-substation #11kv-distribution #microgrid #tier-iii

Next Steps:

1. Utility interconnection study for 138 kV transmission connection
2. Substation engineering design (138kV/11kV transformers, switchyard)
3. Solar and BESS inverter specifications (11 kV output)
4. Generator paralleling and microgrid control strategy
5. Protection coordination study (138 kV through 480V)

Document Control:

- **Source:** Pryor_Bod_EVS_Rev01.md
- **Date Updated:** October 29, 2025
- **Prepared by:** EVS / PGCIS Team
- **Key Updates:** 138 kV substation, removed all N-1 references