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# 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 TRANSMISSION (Utility)  
 │  
 [Utility Revenue Metering - 138 kV]  
 │  
 ▼  
 ┌─────────────────────────────┐  
 │ CUSTOMER-OWNED SUBSTATION │  
 │ │  
 │ [138 kV Switchyard] │  
 │ │ │  
 │ [XFMR-A: 138kV/11kV, 25MVA] │  
 │ [XFMR-B: 138kV/11kV, 25MVA] │ (2N redundancy)  
 │ │ │  
 └────────┼─────────────────────┘  
 │  
 ▼  
 ┌─────────────────────────────┐  
 │ 11 kV COMMON BUS │  
 │ (Dual Ring Topology) │  
 ├─────────────────────────────┤  
 │ • Solar Inverters (8+ MW) │  
 │ • BESS Inverters (4-8 MWh) │  
 │ • Generators (6 × 4 MW) │  
 │ • Data Center Load (12-24MW) │  
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### 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 |
| **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**

11 kV DUAL RING (Ring A + Ring B)  
 │ │  
 [XFMR-A] [XFMR-B]  
 │ │  
 480V 480V  
 │ │  
 [SWBD-A]──────[SWBD-B]  
 │ │  
 ┌───────┴───────────┴───────┐  
 │ │  
 │ UPS MODULES (N+1) │  
 │ │  
 │ UPS-1 UPS-2 UPS-3 ... │  
 │ (1,250)(1,250)(1,250)... │  
 │ │  
 │ (N running, +1 standby) │  
 └───────────┬───────────────┘  
 │  
 ▼  
 IT Distribution Panels  
 │  
 ┌─────────┴─────────┐  
 │ │  
 Panel-A Panel-B  
 (fed from (fed from  
 different different  
 SWBD/Ring) SWBD/Ring)  
 │ │  
 └──► Cabinet PDUs ◄──┘  
 (Dual PDUs per cabinet)

### 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) |
| **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)

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