Interim Data Center Load Representation in the WECC Composite Load Model

Modeling and Validation Subcommittee

September 2025

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Introduction

Large data centers are rapidly expanding and now represent a significant share of system load.

Their behavior during voltage sags or frequency events can strongly affect stability, yet no dedicated WECC data center model exists.

The WECC Composite Load Model (CMLD) is the primary dynamic load model in present planning studies, but it does not explicitly represent uninterruptable power supply (UPS) battery transfer, staged reconnection, or the very high electronic-load fractions typical of modern server farms.

This white paper presents a practical interim solution: using the existing CMLD with carefully chosen manual load fractions and voltage-dependent electronic-load parameters to emulate key data center characteristics.

The approach lets planners capture UPS support, staged grid return, and power usage effectiveness (PUE)-driven cooling variations. It will remain useful until commercial software includes a dedicated data center model and a more flexible CMLD structure.

Transitional Modeling Method (Direct CMLD Parameterization)

Purpose and Scope

The goal is to emulate data center load behavior within the existing CMLD framework without changing the model structure.

This is done by configuring end-use fractions (Fel, Fma/Fmb/Fmc/Fmd) to represent IT/UPS and cooling components and by setting electronic-load voltage thresholds (Vd1, Vd2, Frcel) to approximate UPS battery transfer and grid reconnection. The CMLD electronic-load recovery is inherently threshold-based and proportional, with no explicit time constant.

Two engineering approximations are proposed. They capture the UPS “delayed/ramped” recovery (Section 2.6).

Mapping PUE to CMLD Fractions

Modern data centers advertise PUE below 1.1; meaning cooling is less than 10% of total power.
This enables a direct mapping of PUE to the CMLD fractions:

High-Efficiency / Modern Sites (PUE ≈ 1.05–1.10, typical PNW fan cooling)

- Recommended fractions (“90/10”):
    - Fel = 0.90 – IT/UPS/rectifier electronic load
    - Fmb = 0.10 – VFD fan load (Three-phase Motor B)
    - Fma = Fmc = Fmd = 0
    - Static load = 0 (ensure fractions sum to 1 to avoid automatic static allocation)

Humid/Hot Season (fan + pump or small chiller)

When pumps or small mechanical chillers are used:

- Fel = 0.80–0.90
- Fmb = 0.05–0.15 (fans)
- Fmc = 0.05–0.10 (pumps)
- Fma = 0–0.05 (compressor motors if present)

Two “Fast-template” Settings

- Dry/Cool Template – Fel = 1.00, others = 0 (treat fans as part of Fel).\
- Hot/Humid Template – Fel = 0.90, Fma = 0.10, others = 0.

Electronic Load (Fel) Parameters — UPS/IT Representation

- PFel = 1.0 (unity power factor)
- Vd1 = 0.85 pu (onset of progressive disconnection / UPS battery transfer)
- Vd2 = 0.50–0.52 pu (complete disconnection threshold)
- Frcel (fraction restored on voltage recovery) controls the magnitude of reconnection:
    - 1.0 — full instantaneous recovery (upper bound)
    - 0.0 — no reconnection, all load remains on battery (lower bound)
    - 0.7–0.85 — recommended sensitivity range for partial or staged return

The CMLD logic uses Vd1, Vd2 and the minimum historical voltage Vmin to compute tripping and reconnection.

Cooling Equipment – Fan/Pump Motors

- Fans: Motor B (Mtypb = 3): torque grows as speed squared, suitable for VFD operation.
- Pumps: Motor C (Mtypc = 3): only if present.
- Compressors: Motor A (Mtypa = 3): optional for sites with small chillers.
  Motor parameters (Rs, Ls, Lp, Lpp, Tpo, Tppo, H, Etrq) may use software defaults; focus on fractions and undervoltage settings to avoid premature tripping.

Engineering Options for UPS “Delayed/Ramped” Recovery

Modern data centers use UPS systems to ride through voltage dips. When the grid voltage recovers after a fault, the IT/UPS load does not necessarily reconnect to the grid all at once. This section provides two engineering options to model a gradual or staged return of grid power (instead of a sudden “all-on” jump).

Multi-Block Parallel CMLD

Divide the total data center load into two to three parallel CMLD blocks with identical fractions but different voltage thresholds and Frcel:

Block	Share	Vd1	Vd2	Frcel
Fast return	40–50%	0.85	0.5	1.0
Medium	30–40%	0.87–0.88	0.50–0.52	0.7–0.85
Slow	20%	0.88–0.90	0.52	0.3–0.5

Different thresholds cause sequential reconnection, producing an effective “time-spread” ramp, even though each block follows the standard CMLD logic.

Single-Block Split Fel

Within one CMLD, conceptually split Fel into “return-to-grid” and “stay-on-battery” portions by setting Frcel < 1 (e.g., 0.6 – 0.85).

Optionally model fans/pumps in a separate CMLD block to decouple their response.

Appendix A — CMLD Input Template

Use direct manual fractions in CMLD. Keep the static component at zero by ensuring fractions sum to 1 (otherwise CMLD normalizes or assigns the remainder to static).

Fractions and Electronic Load (UPS/IT)

Field	Meaning	Recommended starting value	Notes
Fel	Electronic load fraction (UPS/IT/rectifiers)	0.90 (PNW "90/10"); 0.80–0.90 (humid/hot)	PUE=1.05–1.10 cooling <=10%
Fma	Motor A (compressors)	0.00 (PNW) ; 0–0.05 (humid/hot)	Only if small chillers exist
Fmb	Motor B (VFD fans)	0.10 (PNW "90/10"); 0.05–0.15 (humid/hot)	Fan torque grows as speed squared
Fmc	Motor C (pumps)	0.00 (PNW) ; 0.05–0.10 (humid/hot)	Only if pumps are present
Fmd	Motor D (single-phase AC)	0.00	Not used for DCs
(sum)		= 1.00	

Electronic Load Voltage Logic (UPS transfer and return)

Field	Meaning	Recommended value	Rationale
PFel	PF of electronic load	1.0	Unity PF for rectifiers
Vd1	Start of progressive disconnection	0.85 pu	Begin UPS transfer to battery
Vd2	Complete disconnection	0.50–0.52 pu	Fully on battery
frcel	Fraction restored on recovery	0.85 (test 0.7/1.0)	Magnitude of reconnection; no time constant

Motor Assignments (cooling side)

Field	Meaning	Recommended value	Notes
Mtypa	Motor A type	3 if used	3-ϕ induction (compressor)
Mtypb	Motor B type	3	3-ϕ induction (VFD fan)
Mtypc	Motor C type	3 if used	3-ϕ induction (pump)
UV trips	Under-voltage trips	Conservative or disabled	Avoid nuisance tripping on shallow sags

References

- CMLD Specification — composite structure, fraction normalization, electronic-load Vd1/Vd2/frcel and Vmin logic, initialization and outputs.

Disclaimer

This paper provides interim guidance for representing data center loads with the existing WECC CMLD. All parameter values are engineering estimates based on WECC specifications and industry practice, not site-specific measurements. Users must validate and adjust settings for their own systems. This approach is a temporary solution until a dedicated data center model and flexible CMLD structure are implemented in commercial software and the WECC base case.

Approving Committee, Entity, or Person	Approval Date
Modeling and Validation Subcommittee	