Operational Resilience Assessment of Power Systems Under Extreme Disruptions through Rolling Horizon Optimization*

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Supplemetary Information

Nomenclature

Binary Variables

y_{zt}^{charge} 1 if battery charging at time t and zone z, 0 otherwise

Continuous Variables

Act_{pzt} Aggregate start-up generation p capacity in zone z at time t, MW

Cap_{pzt} Aggregate active generation p capacity in zone z at time t, MW

$Curt_{rzt}$ Curtailed amount for resource r in zone z at time t, MWh

$Deact_{pzt}$ Aggregate shut-down generation p capacity in zone z at time t, MW

Em_{zt} Emission in zone z at time t, gCOeq

$Exp_{r,z'-z,t}$ Export of resource r from zone z' to z at time t, MWh

$Imp_{r,z-z',t}$ Import of resource r from zone z to z' at time t, MWh

Inv_{rzt} Stored amount for resource r in zone z at time t, MWh

$Missed_{zt}$ Power supplied to unmet demand in zone z at time t, MWh

P_{pzt} Power output of generation p capacity in zone z at time t, MWh

$Power_{zt}$ Power supplied to meet demand in zone z at time t, MWh

Sets

Δ Set of disrupted time periods

$\mathcal{P}$ Set of processes

$\mathcal{P}^D$ Set of dispatchable processes

$\mathcal{P}^M$ Set of must-run processes

$\mathcal{P}^R$ Set of renewable processes

$\mathcal{P}_r$ Set of processes producing resource r

$\mathcal{P}'_r$ Set of processes consuming resource r

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$\mathcal{R}$ Set of resources

$\mathcal{R}^D$ Set of dispatchable resources

$\mathcal{R}^M$ Set of must-run resources

$\mathcal{R}^R$ Set of renewable resources

$\mathcal{R}^S$ Set of stored resources

$\mathcal{T}$ Set of time periods

$\mathcal{Z}$ Set of zones

Indices

p Process

r Resource

t Time Period

z Zone

Parameters

δ_t 1 if undisrupted system, 0 otherwise

ℓ_p^{Act} Startup lead time, hour

ℓ_p^{Deact} Shutdown lead time, hour

C_{pz}^{max} Maximum generation p capacity in zone z, MW

C_{rz}^{max} Maximum storage capacity for r in zone z, MWh

Cap_{pz}^0 Initial aggregate active generation p capacity in zone z at time t, MW

cf_{pz} Capacity factor for generator p on zone z at time t, MW

d_{end} End of disruption, hour

d_{length} Length of disruption, hour

d_{start} Start of disruption, hour

em_p Emission factor, gCO_2eq/MWh

$FopEx_p$ Fixed O&M for generator p, USD/MW/y

Inv_{rz}^0 Initial inventory for resource r in zone z at time t, MWh

$ShutDownEx_p$ Shutdown cost for generator p, USD/MW

$StartEx_p$ Startup cost for generator p, USD/MW/y

$VopEx_p$ Variable O&M for generator p, USD/MWh

Scalar Data

$CurtEx$ Curtailment Cost, USD/MWh 0

$PenaltyEx$ Unmet Demand Cost, USD/MWh 1e6

T_{total} Time horizon considered, h 2000

$TraEx$ Transmission Cost, USD/MWh 0

Rolling Horizon Elements

$\bar{H}$ Prediction and control horizon, h 200

θ Model parameters, -

$Arrivals^{Act}_{pzt}$ Input arrivals of aggregate of process p to shut-down in zone z, -

$Arrivals^{Act}_{pzt}$ Input arrivals of aggregate of process p to start in zone z, -

H Prediction and control horizon, h 200

$QAct_{pz}$ Queue of aggregate capacity of process p to start in zone z, -

$QDeact_{pz}$ Queue of aggregate of process p to shutdown in zone z, -

t^{due} Due time for each item in $QAct_{pz}$ and $QDeact_{pz}$, h

t_{fail} First failure, h

$t_{recover}$ Last failure, h

T_{step} Time step/sampling time, h 24

TTR Time to recover, h

Case Study Data

The following section presents the data used to develop the Texas-based case study.

Superstructure

Set	Elements
$\mathcal{R}$	solar, wind, gas, prepower, chemical, power_available, power_supply, gas_well, gas_stored, coal, uranium
$\mathcal{P}$	solar_generation, wind_generation, power_transfer, charge, discharge, turbine, meet_demand, pump_gas, use_gastor, burn_coal, fission
$\mathcal{P}^R$	solar_generation, wind_generation
$\mathcal{P}^D$	turbine, burn_coal
$\mathcal{P}^M$	fission
$\mathcal{R}^R$	solar, wind
$\mathcal{R}^D$	gas, coal
$\mathcal{R}^M$	uranium
$\mathcal{R}^S$	chemical_energy, gas_well, gas_stored, coal, uranium
$\mathcal{T}$	$0, 1, 2...T_{total}$
$\mathcal{Z}$	SOUTH, COAST, FWEST, WEST, NORTH, NCENT, SCENT, EAST

Figure 1 presents the load by weather-zone ($\mathcal{Z}$) reported in 2025 [5]. This is used as a representative dataset for the demand side and its hourly variation. In this work, the first $T_{total} = 2000$ hours are used.

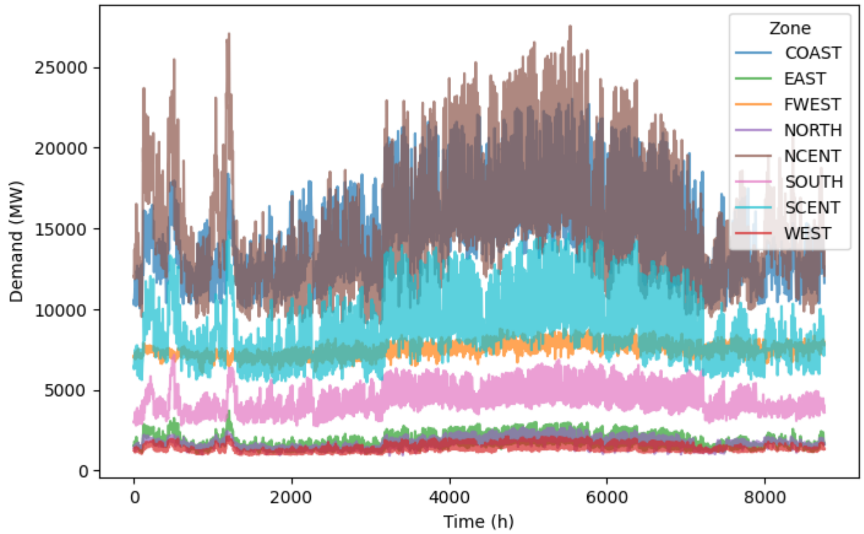

Figure 1: Full-year demand by zone $Demand_{zt}$

Table 1 presents the current technology-specific capacity reported in 2025 [1]. Latitude and longitude information for individual generators are used to assign and cluster generation capacity by weather zone, based on the maps reported by ERCOT [6]

Table 1: Process Capacity C_{pz}^{max}, Inventory Capacity R_{rz}^{max}

	Process $p \in \mathcal{P}$					
Region $z \in \mathcal{Z}$	solar_generation	wind_generation	turbine	burn_coal	fission	chemical_energy
COAST	2631.1	394.2	21052.9	2736.8	0.0	2858.5
EAST	459.2	0.0	7419.1	2379.6	0.0	403.0
FWEST	5561.3	1133.4	3504.6	0.0	0.0	2103
NCENT	4572.1	2251.8	14158.0	2857.8	2430.0	2151
NORTH	5758.2	6704.1	5840.4	1116.0	0.0	1729.6
SCENT	3198.5	365.7	12000.4	3178.5	0.0	1792.4
SOUTH	2878.9	8884.3	8755.7	622.4	2708.6	1542.7
WEST	4177.1	15380.2	390.5	0.0	0.0	1639

Table 2 displays a technology-specific operating, cycling and emission parameters, based on published datasets [4, 3, 2].

Table 3 highlights the initial inventory of resources that can be stored specified to initialize the time horizon. Batteries are initialized as empty, hence the energy stored is zero. Gas, coal and uranium are assumed to be available in unconstrained amounts under normal supply chains conditions, hence a large arbitrary number is selected. Conversely, a predefined amount of reserve stored gas is specified and lower as inherently constrained by mid-term reserve-related decisions. Hence, the framework can be used to elucidate how mid-term allocation of storage may suffice to fulfill power demand; however, this is subject to the length or frequency of the disruption investigated. Furthermore, it is also assumed that the initial inventory is the same across zones, although this can be modified making inventory data zone-specific.

Table 2: Technology cost, cycling costs and emissions parameters

Process $p \in \mathcal{P}$	Startup $StartUpEx_p$ (\$/MW)	Time ℓ_p^{Act} (h)	Shutdown $ShutDownEx_p$ (\$/MW)	Time ℓ_p^{Deact} (h)	Fixed O&M $FOpEx_p$ (\$/MW/y)	Variable O&M $VOpEx_p$ (\$/MWh)	CO_2 em_p (gCO_2/kWh)
burn_coal	65	42	1	10	9.98	9.3	820
turbine	50	24	1	10	3.98	2.5	490
fission	—	—	—	—	20.18	2.8	0
wind_generation	—	—	—	—	3.47	0.0	0
solar_generation	—	—	—	—	2.38	0.0	0
chemical_energy	—	—	—	—	4.98	—	—

Table 3: Initial Inventory Inv_{rz}^0 (MWh)

Region $z \in \mathcal{Z}$	Resource $r \in \mathcal{R}^{\mathcal{S}}$ chemical_energy	gas_well	gas_stored	coal	uranium
All Zones	0	1e8	5e5	1e8	1e8

Figure 2 displays representative capacity factors for solar and wind technologies, which are based on datasets for 2025 retrieved via the Open-Meteo API [7]. These are used to capture hourly-based renewable variations and locality aspects for the purpose of model development. This work uses the first $T_{total} = 2000$ hours.

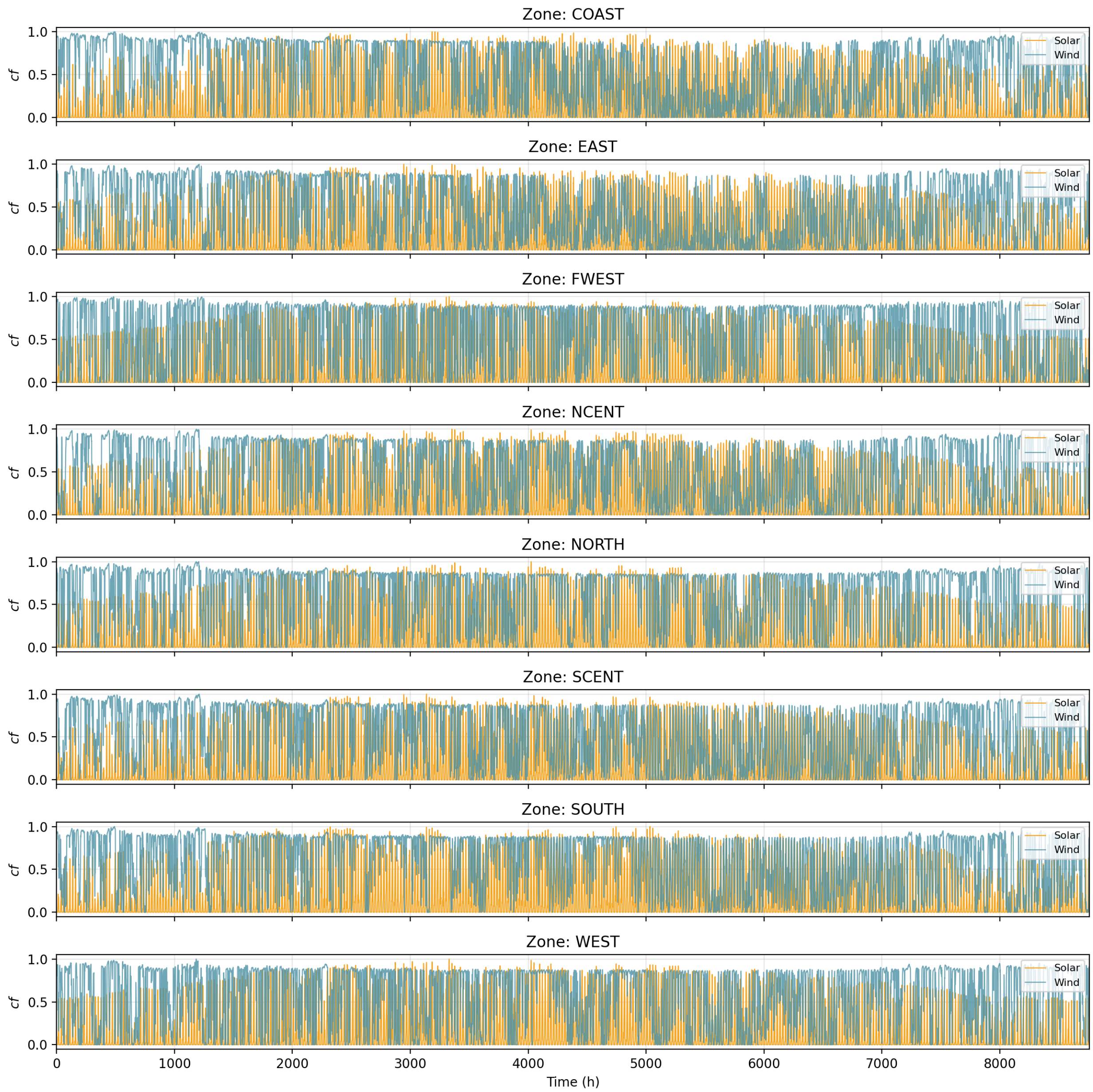

Figure 2: Representative solar and wind capacity factors by zone cf_{rtz}.

References

[1] U.S. Energy Information Administration. *Preliminary Monthly Electric Generator Inventory (based on Form EIA-860M as a supplement to Form EIA-860*. Tech. rep. 2026.

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[6] Electric Reliability Council of Texas. *ERCOT Weather Zone Map*. Tech. rep. 2025.

[7] Patrick Zippenfenig. *Open-Meteo.com Weather API*. 2023. DOI: `10.5281/zenodo.7970649`. URL: `https://open-meteo.com/`.