LOLE Modeling and Accreditation Workshop

September 22, 2023

Purpose & Key Takeaways

Purpose: Provide additional education on the LOLE model and process to establish Planning Reserve Margin Requirements

Key Takeaways:

- Loss of Load Expectation analysis is largely driven by load and generation uncertainty
- MISO uses the Strategic Energy Risk Valuation Model (SERVM) Software for LOLE analysis
- Direct-LOL (DLOL) availability is an output from the LOLE model compared to the current UCAP approach, which is established several different ways (Slide 31)
- LOLE modeling will continue to evolve to better capture reliability risks throughout the year

What is LOLE?

Loss of Load Expectation (LOLE) Definition

LOLE is the measure of how often, on average, the available generation capacity is likely to fall short of the load demand

Loss of Load Probability (LOLP) is the probability in a given hour	Sum of the Daily Peak LOLP values is an expectation (LOLE)	Sum of all LOLP values is called Loss of Load Hours (LOLH)

LOLE is used to study Generation (Resource) Adequacy

Generally considered to be the existence of sufficient resources, within a system, to satisfy consumer demand. A product of unit availability, “perfect storm.” The study of low probability, high impact events

MISO calculates three probabilistic risk metrics as part of the LOLE study process

- Loss-of-Load Expectation (LOLE): Measures ***frequency*** of load shed events
- Loss-of-Load Hours (LOLH): Measures ***duration*** of load shed events
- Expected Unserved Energy (EUE): Measures ***magnitude*** of load shed events

1-day in 10-years LOLE Criteria

MISO Resource Adequacy criteria for Planning Reserve target is the industry standard LOLE objective:

<1-day in 10-years

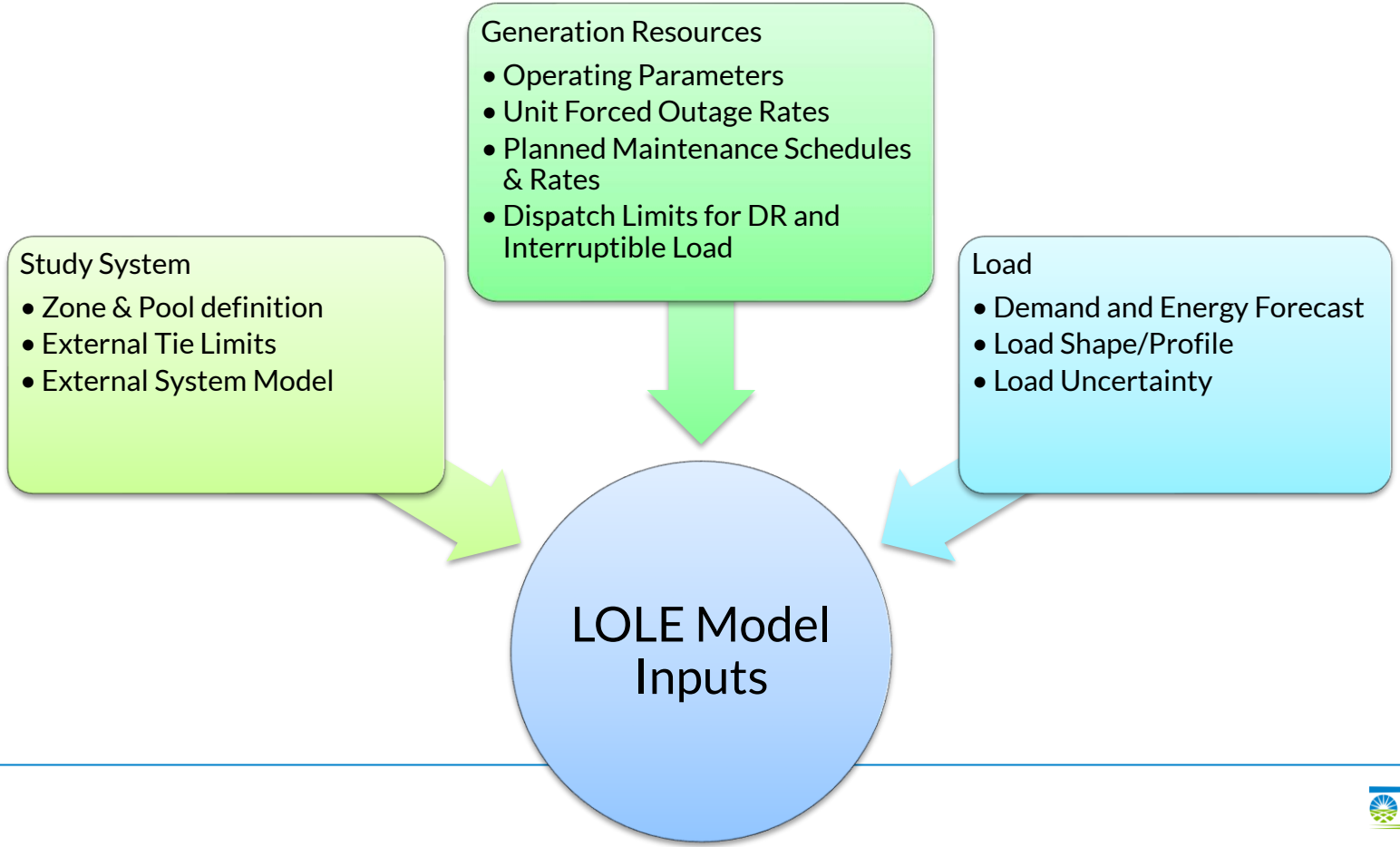
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NERC Standard BAL-502-RF-03

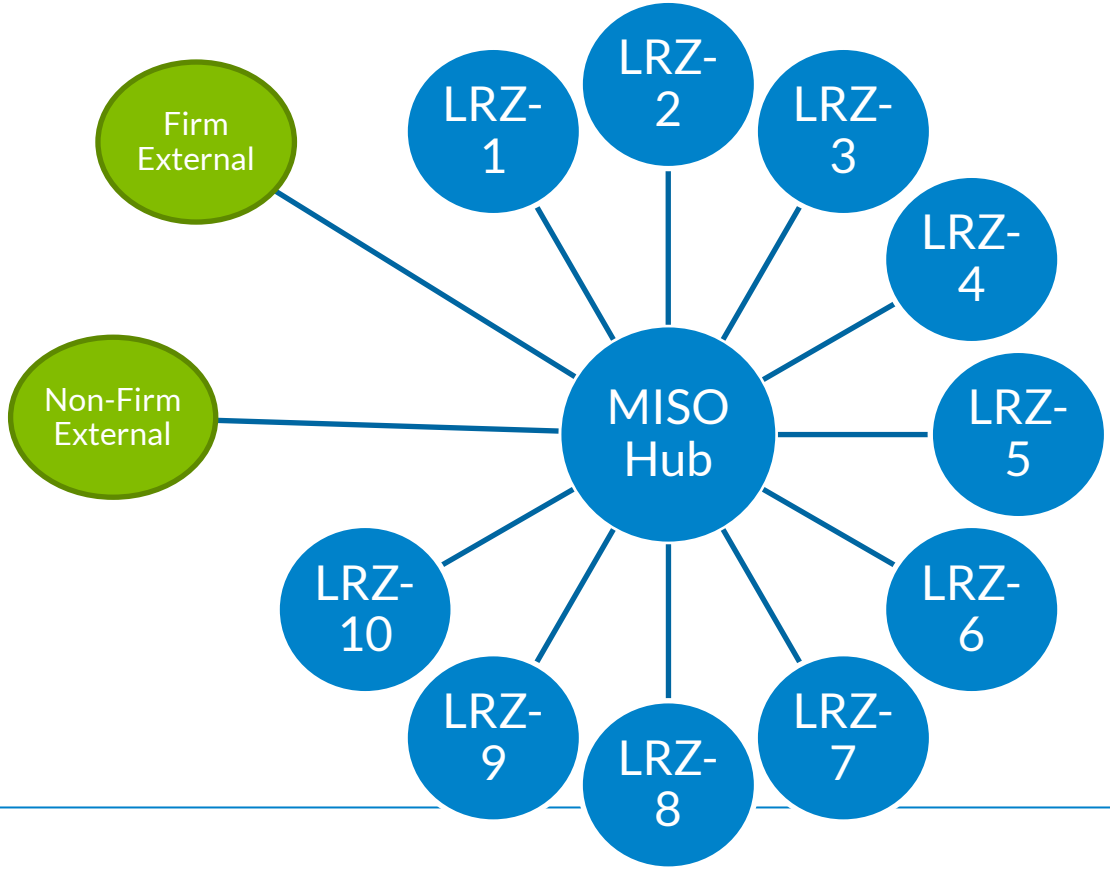
Calculate a planning reserve margin that will result in the sum of the probabilities for Loss-of-Load for the integrated peak hour for all days of each planning year analyzed being equal to 0.1. (This is comparable to a “one day in 10 year” criterion)

LOLE Modeling Inputs

LOLE Model Inputs Include:



MISO System LOLE Model



MISO uses the Strategic Energy Risk Valuation Model (SERVM) Software

Managed by Astrapé Consulting

Originated within Southern Company back in the early 1980's

Uses a sequential Monte Carlo simulation

- Steps through time chronologically and randomly drawing unit availability
- Replicating simulation with different sets of random events until statistical convergence is obtained

SERVM resource adequacy metrics consider

- Wide Variation of Load Shapes
- Growth Uncertainty
- Unit Performance

Utilizes a SQL Server database

Loss of Load Expectation analysis is largely driven by two factors, load uncertainty and generation uncertainty

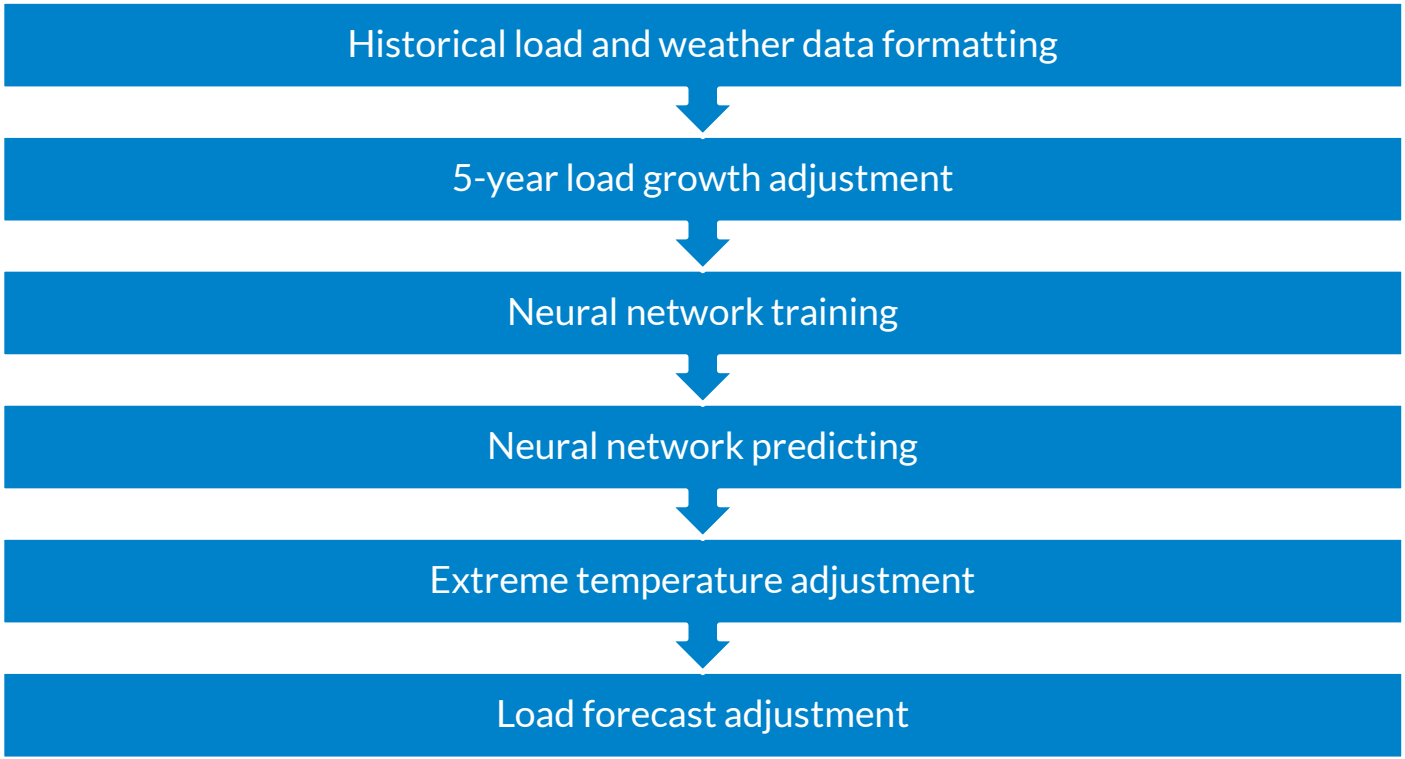
- Accurately capturing uncertainty is crucial to LOLE analysis
- Load Uncertainty
  - Load Shape
  - Weather Uncertainty
  - Economic Uncertainty
- Generation Uncertainty
  - Forced Outages
  - Planned Outages
  - Weather

Load Modeling

Load Modeling Framework

- Historic weather years are modeled to capture load uncertainty including:
  - Variance in peak demand
  - Variance in load shape
- Results in more diverse and comprehensive load modeling
  - More accurate shoulder and non-peak load variance and uncertainty
- Neural-Net software is used to “train” data resulting in 30 unique load profiles based on 30 historic weather years
  - Allows the model to evaluate the risk that could materialize in the upcoming Planning Year if similar weather patterns historically observed were to be experienced again
  - i.e., Planning Year 2023-24 risk if 2012 weather were to materialize

Load Training Process



Load Forecast Adjustment

- Average monthly load of the predicted load shapes adjusted to match each LRZ's Module E 50/50 monthly zonal peak load forecasts for study year

- Ratio of 1st years Non-Coincident Peak Forecast to Zonal Coincident Peak Forecast applied to future years Non-Coincident Peak Forecast

Economic Load Uncertainty

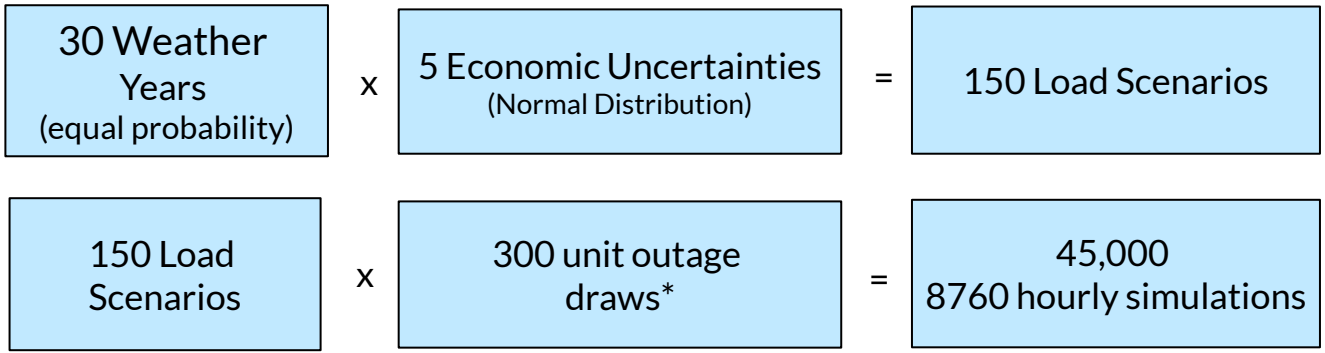
- Projected and actual GDP growth rates used for Economic Uncertainty
  - Use Congressional Budget Office (CBO) projections for historic GDP growth
  - Compare with the actual GDP growth taken from the Bureau of Economic Analysis
  - Translate the GDP forecast error into electric utility forecast error by multiplying by a scalar
    - Rate at which electric load grows in comparison to GDP
  - Calculate the standard deviation of forecast error
  - Using the standard deviation, create a normal distribution of forecast error

Economic Load Uncertainty

- The 2023/24 PY LOLE study showed that the economic load uncertainty modeling resulted in a 0.05 percentage point increase to the MISO Planning Reserve Margin

Standard Deviation in LFE	Load Forecast Error (LFE) Levels				
	-2.0%	-1.0%	0.0%	1.0%	2.0%
0.90%	Probability assigned to each LFE				
	4.8%	24.1%	42.1%	24.1%	4.8%

SERVM Simulation Framework



**Number of unit outage draws used only as an example and are not fixed*

Generation Modeling

Input Sources

- Generation
  - March 2023 Commercial Model: Base Model
  - 2023/24 Planning Resource Auction (PRA): Eligible Capacity
  - PowerGADS: Unit Statistics
  - Attachment Y: Retirements
  - Generator Interconnection Queue: New Units
  - External Areas Capacity Markets/Contracts: MISO Exports

- External
  - 2023/24 PRA : Firm External Imports
  - Probabilistic distribution of Non-Firm Imports based on historic NSI

GADS Data

- GADS (Generator Availability Data System) is the primary data source for historical generator outages

- GADS reports out:
  - Forced Outage Rate statistics
  - Planned Maintenance statistics
  - Net Dependable Capacity (NDC) for monthly capacity profiles

- If a unit has less than 3 months of seasonal data, it gets assigned the class average forced outage rate and maintenance period corresponding to its resource type, assuming there are at least 30 units reporting outage data to GADS for its class — otherwise, the MISO-wide weighted class average EFORd is used for resource classes represented in GADS with less than 30 active units

Seasonal Forced Outage Rates

- All thermal resources in SERVM are modeled with a distribution of Time-to-Fail (TTF) and Time-to-Repair (TTR) values which are determined from their actual Forced Outage Rates
- For any given unit, SERVM will randomly draw a TTF value and begin counting down until it reaches zero at which point the unit becomes unavailable
  - A TTR value will then be randomly drawn and begin counting down again until it reaches zero at which point the unit will come back online
- SERVM will increase the number of forced outages during extreme cold temperatures to reflect coincident outages observed in real-time during extreme weather events

Renewable Resource Modeling

- Wind and solar resources are modeled with hourly output profiles reflecting their intermittent nature
  - Each of the 30 weather years modeled have a unique hourly output for wind and solar units to align with the load profiles
  - Solar and wind profiles are zonal-specific to reflect renewable generation diversity by region
- Other intermittent resources (run of river hydro, biomass, etc.) are modeled at their UCAP value

Planned Outage Modeling

- SERVM utilizes a flexible Planned Outage modeling approach to account for resources' routine maintenance
  - Unlike Forced Outages, Planned Outages are not randomly drawn
- 80% of Planned Outages are scheduled by optimizing around periods with the potential for high demand across all 30 load shapes (i.e., max of daily net peak demand)
  - This minimizes outages in summer and maximizes outages in the shoulder seasons which aligns with actual planned outage behavior
- The remaining 20% of Planned Outages are scheduled optimally for each of 30 load shapes to reflect flexibility to reschedule outages as needed

Cold Weather Outages

- Astrapé performed an analysis that showed as the temperatures decreased, the average MWs of forced outages for coal and gas increases
- A MW/degree relationship was developed and modeled so that at each temperature, there is a specific MW amount of incremental cold weather outages captured for each zone and technology type
- The incremental cold outages are not assigned to a particular resource but rather represent the aggregate impact on the system for the coal and gas groups analyzed

External Support Modeling

Firm and Non-Firm Imports

- Firm imports from the most recent PRA are included in the LOLE analysis and are modeled as resources
- Non-firm imports are modeled as a probabilistic distribution based on historic imports from the most recent 3 Planning Years
  - As the model steps through the simulated hours, it randomly draws from this distribution of imports to serve the demand
  - Non-firm imports reduce the PRM but relying on neighboring regions to serve some of MISO's demand

SERVM incorporates probabilistic distributions of Non-Firm Support for the 2024/25 PY LOLE Study

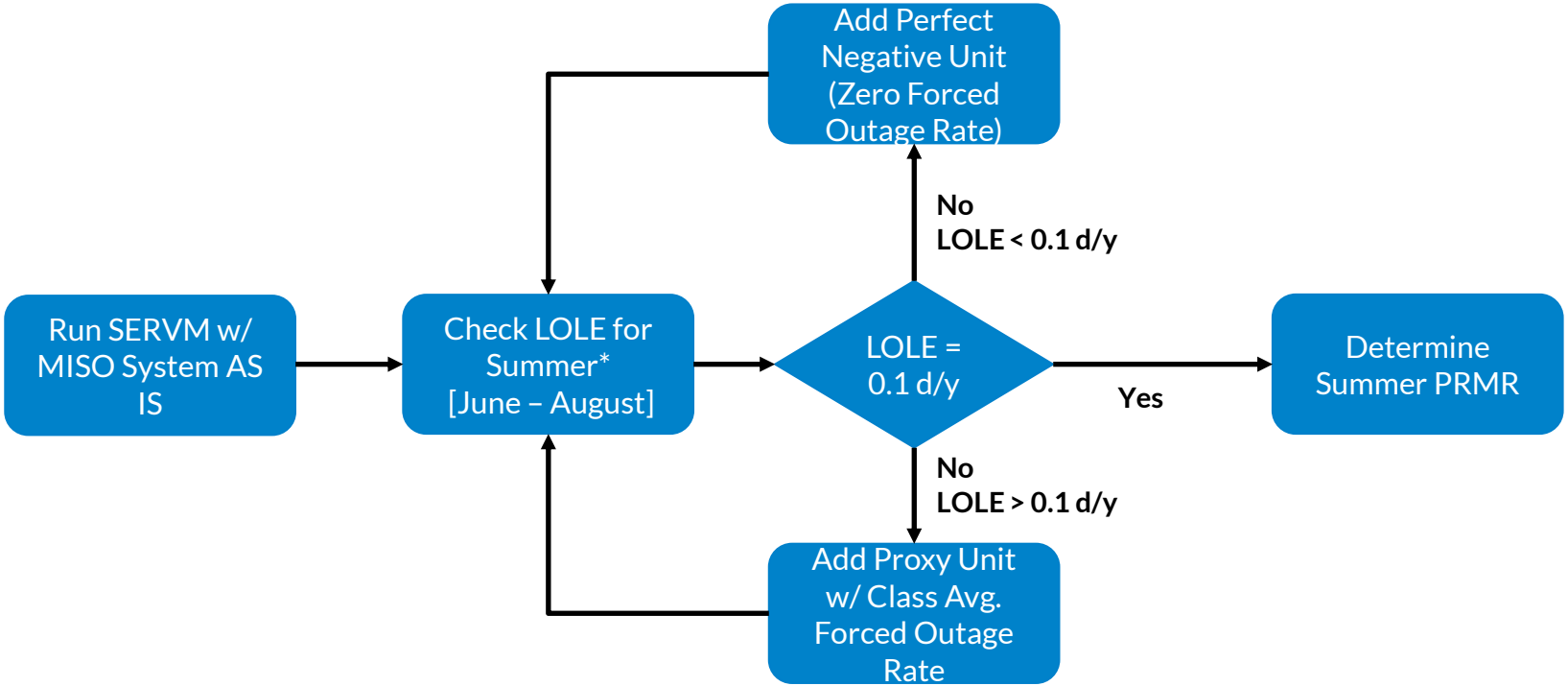
- Historic non-firm imports during historic RA hours are used to create a probabilistic distribution of Non-Firm Support
  - This is done for each of the 4 seasons to capture seasonal variability

- As SERVM steps through the hourly Monte Carlo simulations, the model will randomly draw import values from the seasonal distributions shown below

Season	p5	p10	p25	p50	p75	p90	p95
Summer	1,138	1,440	2,959	4,260	5,198	5,921	6,520
Fall	525	903	1,749	2,601	3,632	4,935	5,748
Winter	9	288	1,223	3,292	5,785	8,097	9,179
Spring	1,384	1,626	2,283	3,717	4,987	6,221	6,497

Capacity Adjustment and PRMR Calculation

Capacity Adjustment Flow Chart



*Each season is determined in the same manner although the non-summer seasons have different LOLE criteria based on seasonal risk distribution and the process changes slightly if risk shows up in the As Is LOLE run

Current determination of Planning Reserve Margin Requirement (PRMR)

- PRMR is established by summing all the capacity in the model (resources and adjustment MW) to reach the reliability criterion
  - PRMR = UCAP MW + Adjustment MW
- Each resource class uses a different methodology to establish capacity for the requirement calculation

Resource Type	Method to establish capacity for PRMR*
Thermal/BTMG	GVTC * (1-EFORd)
Wind/Solar	Effective Load Carrying Capability (ELCC)
Run-of-River/Biomass	Hourly output during peak hours
Demand Response	Seasonal capability and # of calls
Storage	GVTC * 95% or hourly output during peak hours
External Resources	Firm external seasonal capability

MISO Planning Reserve Margin (PRM)	PY 23/24 Summer	Formula Key
MISO System Peak Demand (MW)	123,711	[A]
Thermal (MW)	114,415	[B]
Run-of-River (MW)	966	[C]
Wind (MW)	4,639	[D]
Solar (MW)	2,151	[E]
Storage (MW)	28	[F]
BTMG (MW)	4,196	[G]
Demand Response (MW)	7,397	[H]
Firm External Support (MW)	1,707	[I]
Adj. {1d in 10yr} (MW)	(2,650)	[J]
PRMR (MW)	132,849	[K]=sum [B] through [J]
MISO PRM%	7.4%	[L]=([K]-[A])/[A]

*July for Summer, September for Fall, January for Winter and May for Spring

Reference Materials

- Past LOLE 101 Trainings
- Loss of Load Expectation Report
- Wind Capacity Report
- Loss of Load Expectation Working Group (LOLEWG)
- Supplemental LOLE Materials
- MISO Resource Adequacy Page
- BPM 011 - Resource Adequacy
- MISO Tariff: Module E-1
- NERC Standard BAL-502-RF-03

Resource Accreditation Reform

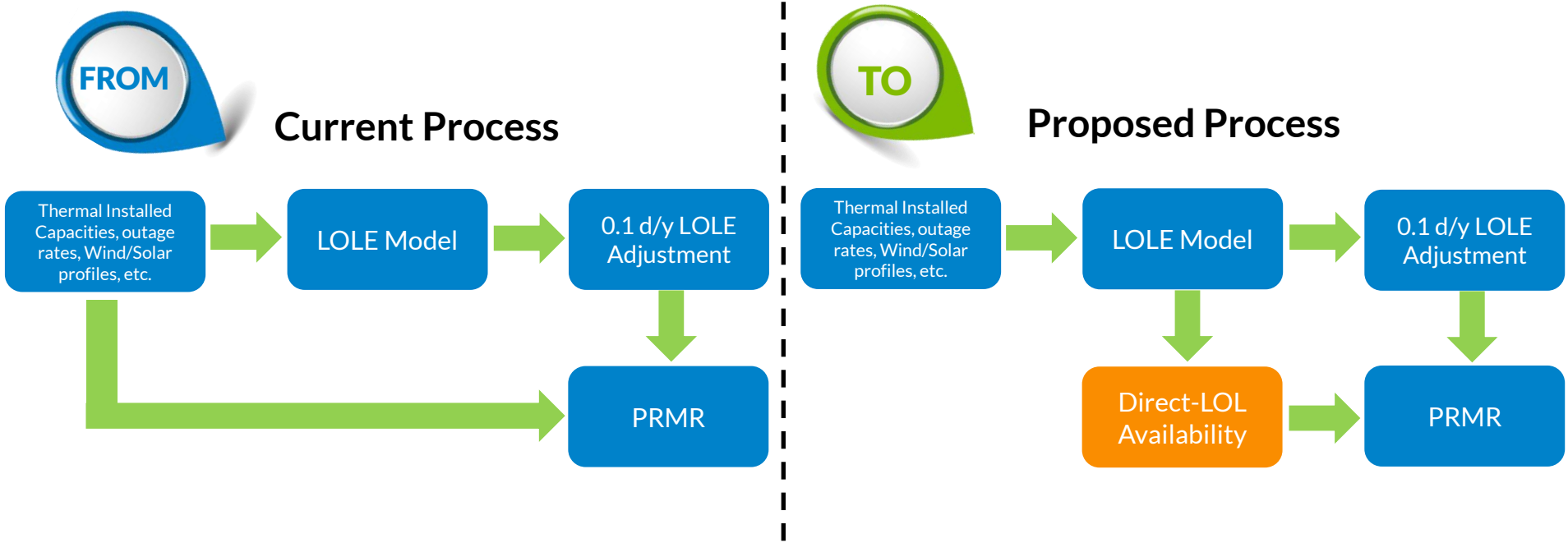
Future determination of Planning Reserve Margin Requirement (PRMR)

- PRMR will continue to be established by summing all the capacity in the model and adjustment MW to reach reliability criterion
- However, each resource class will use the Direct-LOL (DLOL) methodology to establish capacity for the requirement calculation
  - PRMR = DLOL MW + Adjustment MW

Resource Type	Method to establish capacity for PRMR*
Gas, Coal, Hydro, Nuclear, Pumped Storage, Solar, Wind, Storage, Run-of-River, Biomass	Availability during loss of load hours (DLOL)
Demand Response	Seasonal capability and # of calls (ongoing discussion at the RASC for LMR accreditation)
BTMG	GVTC * (1 – seasonal EFORd) (ongoing discussion at the RASC for LMR accreditation)
External Resources	Firm external seasonal capability

*July for Summer, September for Fall, January for Winter and May for Spring

The current process utilizes Unforced Capacity (UCAP) as an input into the LOLE model and the PRMR calculation, while the proposed Direct-LOL methodology utilizes an output from the LOLE model for the PRMR calculation



UCAP: Unforced Capacity | LOLE: Loss of Load Expectation | LOL: Loss of Load

Seasonal Direct-LOL results* by resource class will vary depending on input assumptions to the Loss of Load Expectation (LOLE) model and modeled resource mix

PY23-24 Resource Class	Summer - 2,703 hrs		Fall - 265 hrs		Winter - 201 hrs		Spring - 240 hrs	
	UCAP	DLOL	UCAP	DLOL	UCAP	DLOL	UCAP	DLOL
Gas	91%	89%	89%	88%	84%	70%	88%	72%
Coal	92%	91%	91%	87%	90%	72%	89%	74%
Hydro	97%	97%	97%	99%	42%	69%	62%	74%
Nuclear	95%	90%	96%	83%	95%	84%	92%	77%
Pumped Storage	99%	98%	91%	98%	94%	47%	89%	70%
Solar	45%	36%	25%	28%	6%	0%	15%	15%
Wind	18%	11%	23%	15%	40%	13%	23%	16%
Storage	95%	93%	95%	90%	95%	90%	95%	97%
Run-of-River	100%	100%	100%	100%	100%	100%	100%	100%

Resource class results expected to change as LOLE modeling enhancements are made to better reflect reliability risks across the year and the changing fleet, e.g., storage results expected to decrease

UCAP = current accreditation methodology by resource type

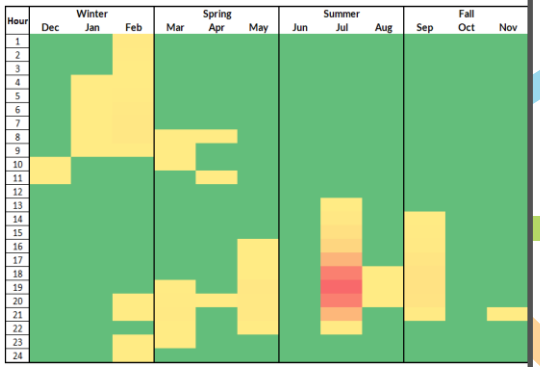
*Results have shifted slightly from the August 2023 RASC due to weighting of Load Forecast Error

The planned reforms better leverage the risk model, with future modeling improvements naturally driving more efficiency in the outcomes

Inputs

RISK MODEL

LOLE



Future Enhancements

- Fuel Limitations
- Correlated outages
- Unit modeling (ramp, notification time, etc.)
- Extreme weather

Accreditation

Current
- Thermal units - UCAP and performance during risky hours
- Wind- Average ELCC

Future
- Availability during highest risk hours in the probabilistic models
- Past performance for unit level

Planning Reserve Margin Requirement

Current
- Requirement based on peak

Future
- Based on risky hours

Translation to PRA

Current
- Percentage based

Future
- MW based, TBD

KEY: *ELCC = Effective Load Carrying Capability*
LOLE = Loss of Load Expectation

Contact Information

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