IOWA STATE UNIVERSITY

sdmay19-24:
Power System Reliability in the Midwest U.S. for High Wind/Solar Levels

Client: Midcontinent Independent System Operator (MISO)
Advisor: Dr. McCalley
Website: http://sdmay19-24.sd.ece.iastate.edu/

Meet Our Senior Design Team

- **Zaran Claes**
- **Shannon Foley**
- **Matthew Huebsch**
- **Shelby Pickering**
- **Ian Rostkowski**
- **David Ticknor**

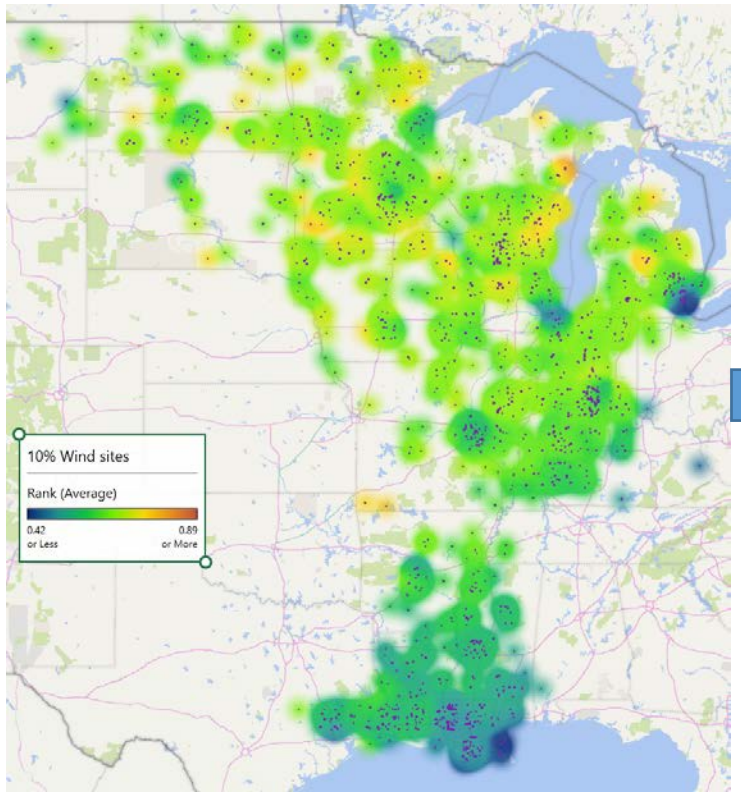
Why this research project?

- Renewable energy is variable, but the grid must remain reliable.
  - Renewable energy such as solar and wind are the fastest growing type of energy
  - Renewable energy is not perfectly predictable because it is based on weather
  - New forms of generation (renewable) are replacing the older (non-renewable) sources that the grid was founded using

- Goal: Analyze and quantify the impact of increasing renewable levels on the Eastern Interconnection power grid for intended users of MISO and their stakeholders

Conceptual Sketch

MISO Region [1]



Siting ranks

Resource Adequacy

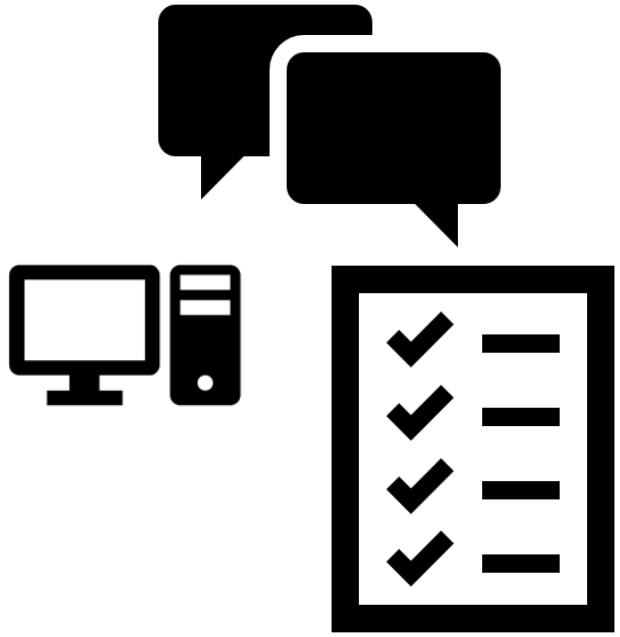
- Loss of Load Expectation (LOLE)
- Effective Load Carrying Capacity (ELCC)

Requirements

- Functional Requirements
  - PLEXOS Model grid simulation
  - Generation Siting
  - Automation
- Non-Functional Requirements
  - Usability and Readability
  - Data integrity
  - Use siting information to answer questions

Constraints and Considerations

- Access to Data
- Access to software (PLEXOS)
- Clientele contact
- NERC/MISO Standards familiarization
- Industry ready documentation

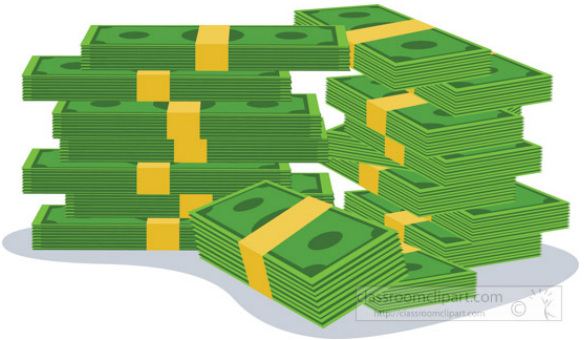


How is this project unique?

- Renewable Siting Criteria
  - Many unique siting considerations
  - Deterministic Siting approach
- Renewable generation mixes
  - Varying splits between Wind and Solar for different penetration levels

Risks and Cost

- No monetary costs
  - PLEXOS provided by Energy Exemplar
  - Virtual Machine provided by Iowa State
  - MISO/FERC/Utility goals documentation is public information
- Risks
  - Productivity
  - Data manipulation errors



Assumptions To Study

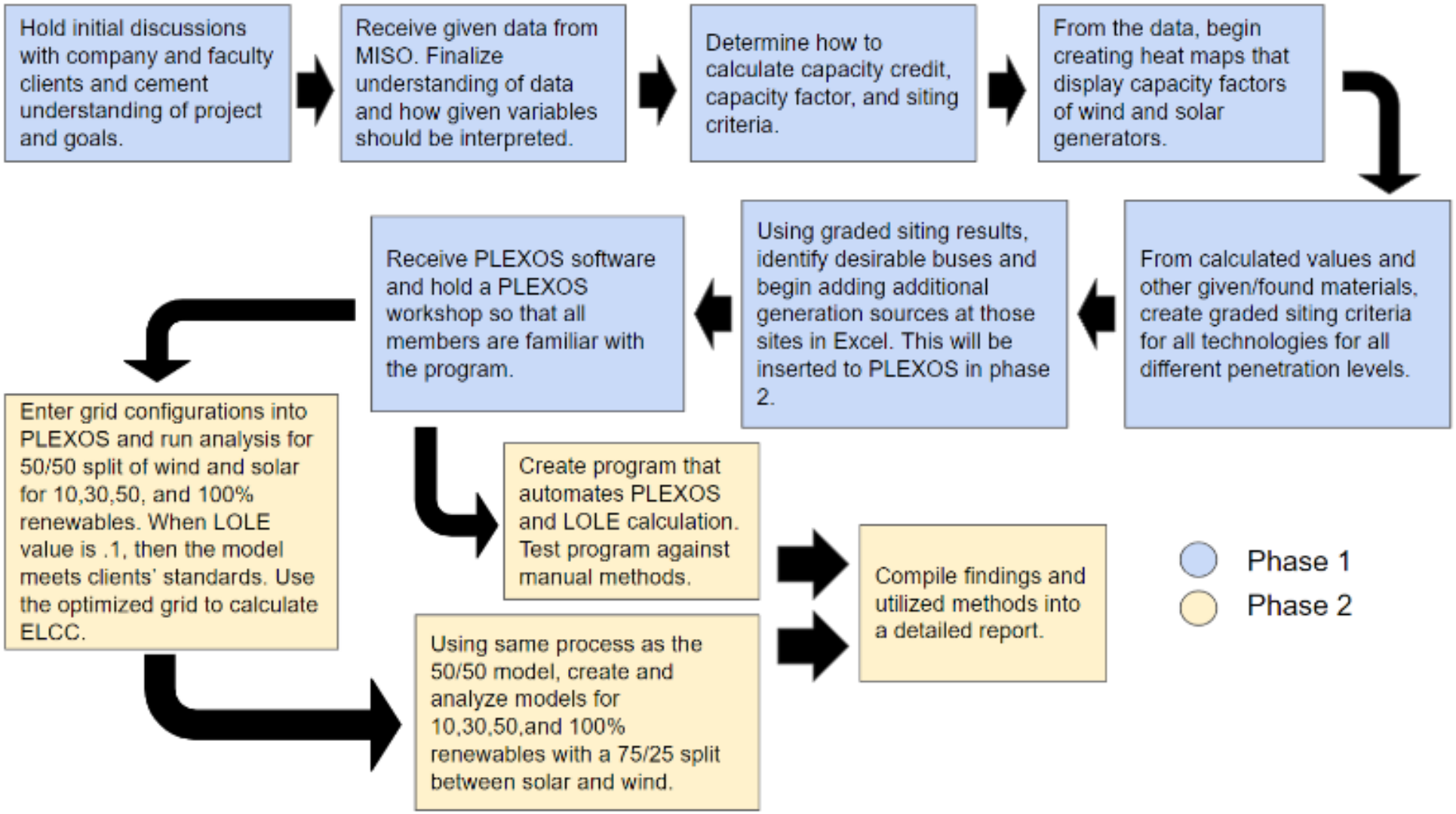
- Future may be 50% wind and 50% solar renewable energy
- Future may be 25% wind and 75% solar renewable energy
- Each future with 10, 30, 50, and 100 percent penetration of renewable energy on the grid
- Hydroelectric energy is always on (subtracted from overall load)
- Additional transmission for new generation is ignored
- Load and generation are always increasing

Project Milestones / Schedule

- Education Period
- Capacity Credit and Capacity Factor Calculations
- Develop clearly supported siting criteria
- Learn PLEXOS
- Use PLEXOS, siting criteria, and capacity calculations to begin simulating models
- Write final report explaining findings of the study

Project Milestones / Schedule

Project Overview

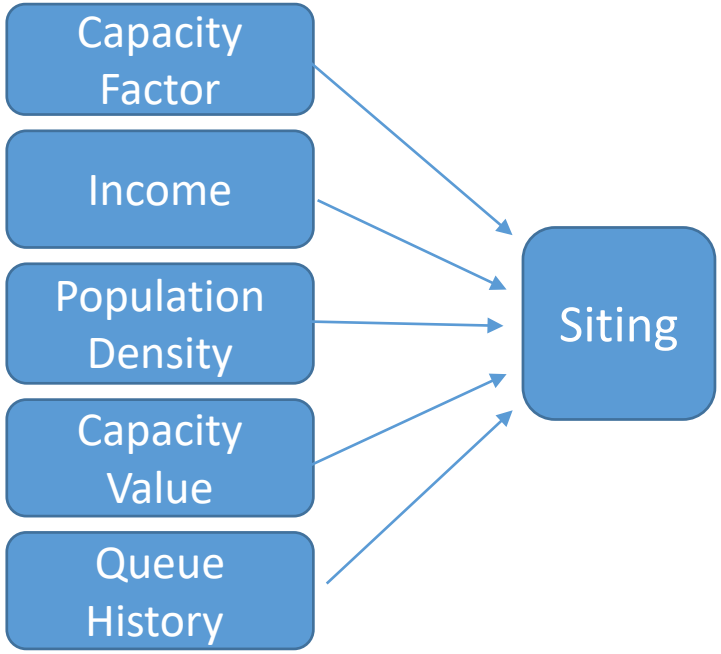


System Design Overview

- Develop siting criteria and equation
- Calculate necessary capacity values and capacity factors
- Rank buses according to siting criteria and equation
- Assign generation to buses in descending order of desirability until penetration level is met
- Add new generation to base PLEXOS model and derive LOLE (loss of load expectation) and ELCC (Expected load carrying capacity)
- Retire unneeded coal and gas plants from the grid

Siting

- Represents how solar and wind may be added to the system
- Uses an equation to rank the data created by the team
- Locations with higher rankings will have solar or wind added to their locations first
- Equation takes 5 factors into account, capacity factor, Income of the area, population density, capacity value, and generation interconnection queue history
- Capacity Factor is generally the most important when siting
- Highly populated areas won't have large scale generation.
- Richer counties will contain rooftop solar

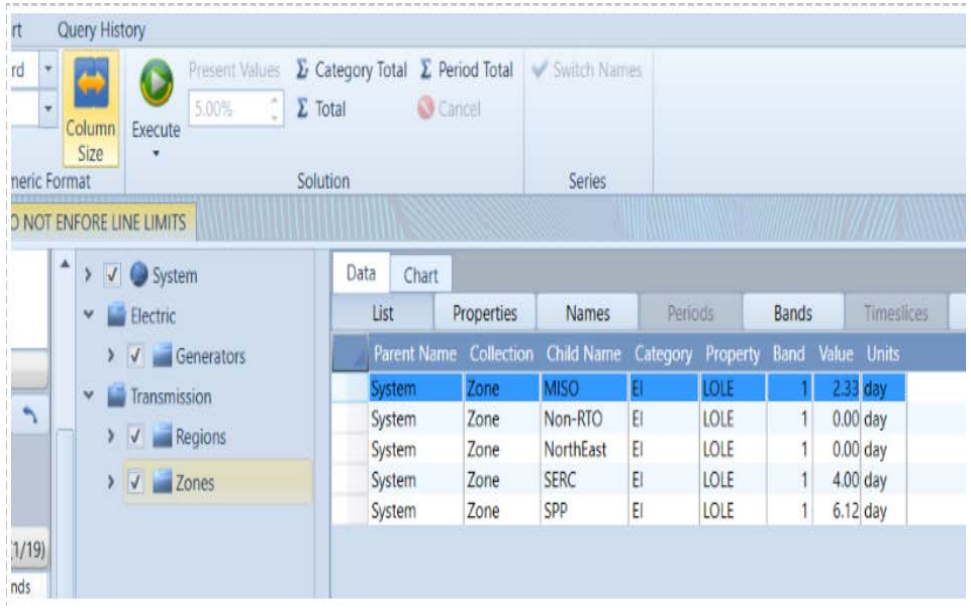


Creating a Model to Match the Future Load

- Tasked with designing possible future of MISO grid at varied levels of renewable energy penetration (10%, 30%, 50%, 100%)
- Only factoring in new wind and solar renewables
- While siting new generation, the peak load must be met
- Does not guarantee completeness, but is a good benchmark
- Best sites will be built on first

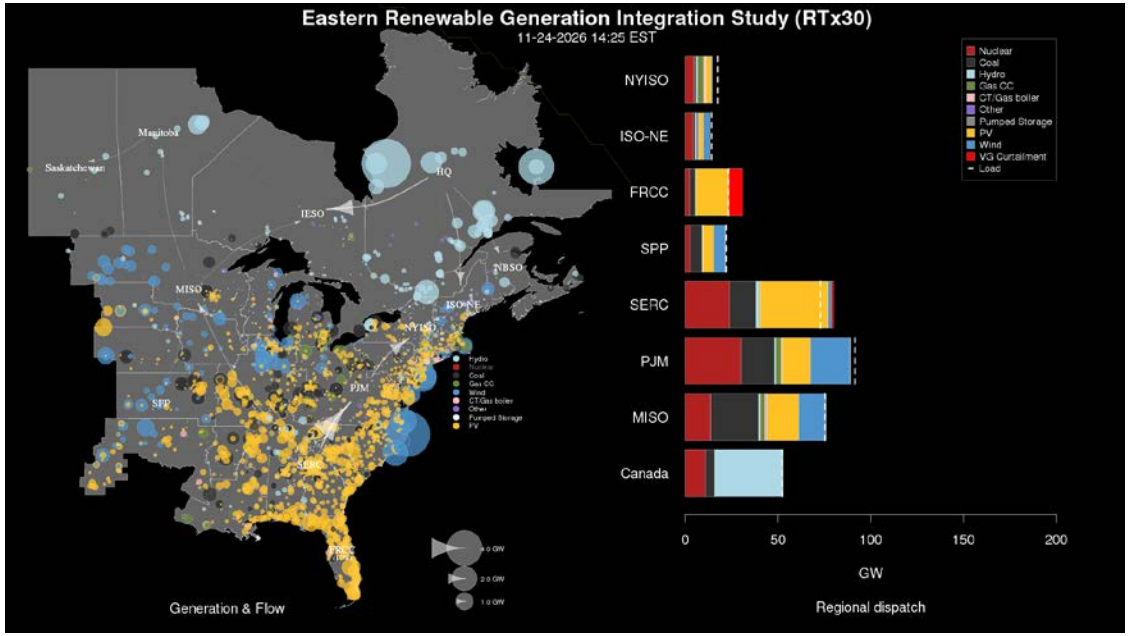
Detailed Design and Testing: Entering Data into PLEXOS and Re-working the Model

- Add model created to existing model provided by MISO into PLEXOS
- Used to calculate LOLE
- Want MISO zone to match 0.1 for value in PLEXOS, meaning one day in ten years.
- Re-work and adjust the model as needed until LOLE is met
  - Adjustments can involve adding more generation, or retiring old plants



Testing and Evaluation Plan: Non-Functional Testing

- Calculate ELCC from simulation outputs. See that the ELCC matches the load of the system
- Plan to automate this process with code in Python
- Running sanity checks on system using Kaleidoscope



Review of Process

To recap...

- Used load and generation data to develop Capacity Credit and Capacity factor values.
- Used these values, and other available information, to design criteria for siting renewable penetration.
- In phase 2, use PLEXOS to derive LOLE and ELCC and analyze the resulting grids.

Project Status

Phase 1

- Capacity calculations: complete
- Siting criteria: complete
- Ranking based on siting criteria: in progress

Phase 2

- Model generation in PLEXOS: to be completed
  - Generation model mixes
- Model Analysis: to be completed
  - LOLE and ELCC
- Final Report: to be completed

Task Responsibilities for Each Member

- **Shannon Foley –** PLEXOS Admin and verification
- **Matthew Huebsch** – Team Scribe
- **Shelby Pickering** – Analysis Documentation
- **Ian Rostkowski –** Scheduler and task management
- **David Ticknor** – Team Contact
- **Zaran Claes** – Enjoying his Co-op away from school!

Thank you!

Appendix

Definitions

- *Capacity Credit:* Ratio of average energy production during peak net load conditions over the installed capacity Reported as a percentage or a number between 0 and 1.
- *Capacity Factor*: Ratio of actual energy production in a year divided over the total energy production in a year Reported as a percentage or a number between 0 and 1.
- *Eastern Interconnect:* one of the 3 major grid interconnections in the United States. It borders the Western Interconnection on the border of Nebraska and Colorado and stretches North-South from Mexico to the Upper Canada. Figure 4 shows the land area for the EI [1].
- *Expected Load Carrying Capability (ELCC):* The largest amount of load that the grid could produce if all generators were turned up to highest performance.
- *Loss of Load Expectation (LOLE):* A NERC requirement that states that any location cannot expect to have a loss of load (under-generation) that is greater than one event in 10 years.
- *PLEXOS:* Modeling software that is used by system operators to predict how the grid will be affected by proposed changes.

NERC BAL-502-RFC-02

A. **Introduction**

1. Title: **Planning Resource Adequacy Analysis, Assessment and Documentation**

2. Number: **BAL-502-RFC-02**

3. Purpose:

To establish common criteria, based on "one day in ten year" loss of Load expectation principles, for the analysis, assessment and documentation of Resource Adequacy for Load in the Reliability*First* Corporation (RFC) region

4. Applicability

4.1 Planning Coordinator

5. Effective Date:

5.1 Upon RFC Board approval

B. **Requirements**

R1 The Planning Coordinator shall perform and document a Resource Adequacy analysis annually. The Resource Adequacy analysis shall *[Violation Risk Factor: Medium]*:

R1.1 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[1] analyzed (per R1.2) being equal to 0.1. (This is comparable to a "one day in 10 year" criterion).

R1.1.1 The utilization of Direct Control Load Management or curtailment of Interruptible Demand shall not contribute to the loss of Load probability.

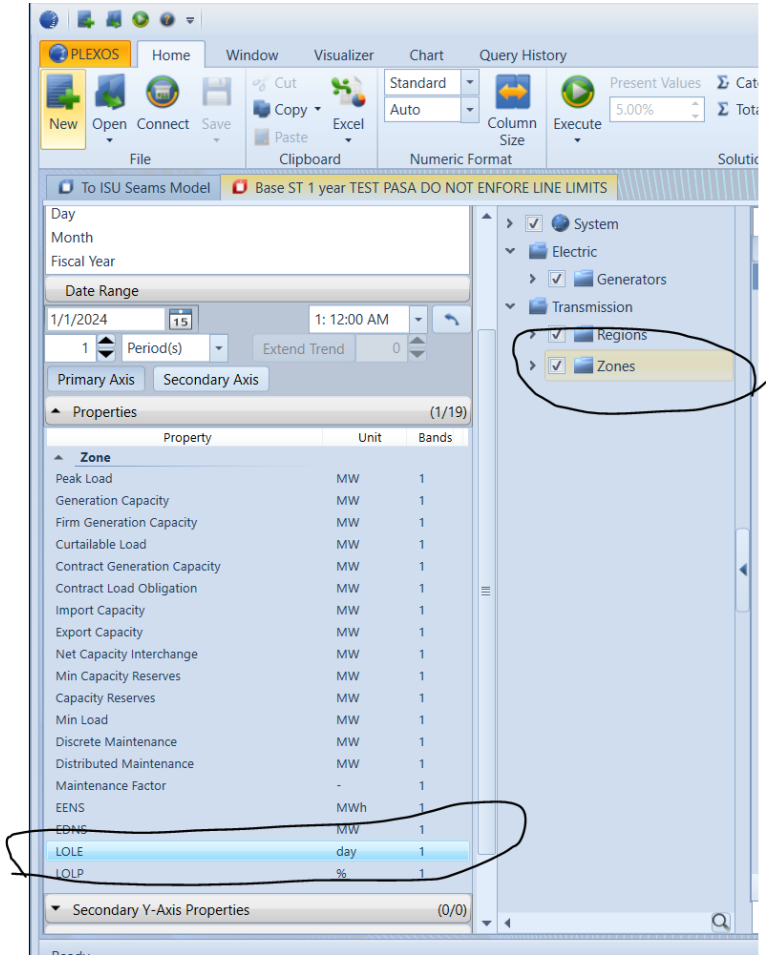
R1.1.2 The planning reserve margin developed from R1.1 shall be expressed as a percentage of the median[2] forecast peak Net Internal Demand (planning reserve margin).

Sources Cited

1. [1]"MISO announces $2.7 billion expansion, includes $170 million in Arkansas upgrades - Talk Business & Politics", *Talk Business & Politics*, 2018. [Online]. Available: https://talkbusiness.net/2015/12/miso-announces-2-7-billion-expansion-includes-170-million-in-arkansas-upgrades/. [Accessed: 05- Dec- 2018].
2. "Eastern Interconnection," *Wikipedia*, 05-Jan-2018. [Online]. Available: https://en.wikipedia.org/wiki/Eastern_Interconnection. [Accessed: 03-Dec-2018].
2. "Regional Transmission Organizations (RTO)/Independent System Operators (ISO)," *FERC: About FERC - What FERC Does*, 18-Oct-2018. [Online]. Available: https://www.ferc.gov/industries/electric/indus-act/rto.asp. [Accessed: 03-Dec-2018].
3. J. Bakke, "Renewable Integration Impact Assessment," MISO Energy, tech., Apr. 2018.
4. C. D'Annunzio, "Capacity Value of Wind Power," *IEEE Transactions on Power Systems*, vol. 26, no. 2, May 2011.
5. "Maintaining Reliability in the Modern Power System," *Reliability Report - US Department of Energy*, Dec. 2016.
6. "Planning Year 2017-2018 Wind Capacity Credit," *MISO Capacity Report*, Dec. 2017.
7. *IEEE Recommended Practice for the Electrical Design and Operation of Windfarm Generating Stations*, IEEE 1094-1991, 1991
8. *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems,* IEEE 493-1997, 1997.
9. *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants,* IEEE 141-1993, 1993.
10. NERC, "Standard BAL-502-RF-03." [Online]. Available: https://www.nerc.com/pa/Stand/Reliability Standards/BAL-502-RF-03.pdf. [Accessed: Dec-2018].
11. *Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity*, IEEE 762–2006, 2006

Testing and Evaluation Plan: Functional Testing

- Run simulation of model in PLEXOS
- Ensure that the model created is valid, and that PLEXOS doesn't give any errors found within the model
- Obtain LOLE for MISO zone from PLEXOS under list of properties found during simulation
- Run tests for each level of penetration, and each re-work of the model



Limitations

- Time
- Given data is restricted to 2007 through 2012
- Simplified 80 bus system
- Where generation can be sited
- How much generation can be added
- Which generators are retired and the order in which they are retired