Power System Reliability in the Midwest for High Wind/Solar Levels

PROJECT PLAN

May19-24

Midcontinent Independent System Operator

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List of Definitions

Balancing Authority (BA): Combination of buses.

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.

DG: Distributed generation.

DPV: Distributed photovoltaic.

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.

Federal Energy Regulatory Commission (FERC): United States Federal Agency that regulates the interstate transmission of natural gas, oil, and electricity.

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.

Midcontinent Independent System Operator (MISO): Sponsor of this research project. MISO is the system operator that operates within 14 states. Figure 5 shows a map of the MISO region [2].

North American Electric Reliability Corporation (NERC): A nonprofit corporation with the goal of reliability throughout the North American power grid.

Net Load: The difference between the gross load and renewable generation.

PLEXOS: Modeling software that is used by system operators to predict how the grid will be affected by proposed changes.

Python: A computer programming language that will be used to automate part of this project.

Renewable Energy: Energy produced by renewables sources such as wind and solar.

Renewable Integration Impact Assessment (RIIA): a study performed by MISO to look into how renewable energy, based on several projections, will impact the power grid in different ways. [3].

Renewable Energy Penetration: amount of renewable energy that is on the grid or the area. This is given in a percentage form. Thus, 10% renewable penetration indicates that 10% of the generation produced are from renewable energy.

UPV: Utility scale solar photovoltaic.

1 Introductory Material

1.1 Acknowledgement

Special thanks to:

MISO Team: *James O., Armando F., and Brandon H.*

Iowa State Faculty: *Dr. McCalley, Dr. Zambreno*

1.2 Problem Statement

Renewable energy generation is currently the fastest growing source of energy in the US. Coupled with the retirement of older generation plants, there are many unanswered questions relating to the impact of these changes on the US power grid.

The North American Electric Reliability Corporation requires studies from electric grid operators such as MISO to do analysis on resource adequacy, otherwise known as the balance in energy generation and demand. This project will analyze the impact of increasing renewable levels in the energy grid. Researching and developing a comprehensive understanding of how renewable energy technologies affect the grid is the goal behind this study.

1.3 Operating Environment

This project is being conducted within the various computer labs available across Iowa State University. All of the team documents are accessible through the university's online data storage system called CyBox. The team chose CyBox because it promoted connectivity between group members as well as the fact that work could also be done from remote locations if a group member was otherwise unavailable to meet on Iowa State's campus. A virtual machine (VM) was also established that allowed team members to access PLEXOS remotely from separate devices. This means the program was usable by all members without requiring each person to own a high-powered personal computer.

1.4 Intended Users and Intended Uses

The data gathered in this study was collected and processed with the intention of being reported directly to MISO. The results will be encompassed into the already extensive analysis done within MISO's Renewable Integration Impact Assessment (RIIA)[3]. The data finalized by MISO within RIIA is made public, and accessible by anyone wishing to view it. This includes anyone from the general public to MISO Stakeholders whom are directly impacted by this project.

1.5 Assumptions and Limitations

There are many assumptions and limitations associated with the process and completion of this project. For assumptions, there are two main categories; generation siting assumptions and generation performance assumptions such as renewable generation will continue to increase. Generation siting assumptions will be the most important assumptions to document and understand. The project is built upon the base assumptions of where to place new renewable generation to push past the desired penetration levels. These assumptions are based on data like population density, state policies, capacity factor, capacity value, and more as the project continues to mature.

Another important assumption that ties into siting is how the team will perceive renewable generation performance depending upon geographical location, such assumptions as solar generation being better in the south and wind generation being better in the north. This plays a large role into how generation, especially renewable generation, is placed in the industry. The team will need to use historical data to assume the performance of future sites. This historical data will be provided directly from MISO, and allow an insight into the relation between location and generation performance.

Team limitations will include the limited data provided to the team as well as the technical knowledge of each member. However, the largest limitation for this project will be time.

1.6 Expected End Product and Other Deliverables

For each new renewable level studied, an effective load carrying capability (ELCC) of wind and solar will be produced, along with documentation of related assumptions and description of how the new renewable sources were sited. These will be used by MISO as information that can be presented to stakeholders.

Weekly reports with detailed group development. This will allow MISO to track the teams work and findings as milestones are achieved throughout the year.

All codes and scripts will also be delivered to MISO. These can be reused to make finding new data for future studies faster.

One final report encompassing the findings and conclusions of the study, along with a presentation to be given on the team's findings.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

There are several end goals that this project seeks to achieve. The main objective is to analyze the effect of the increase of renewable energy resources, such as wind and solar, into the MISO system on the loss of load expectation (LOLE) target. The team calculated capacity factor, capacity value, and created a grading system that allowed one to quickly determine high-value areas for additional renewable generation. This was done for different levels of renewable penetration, which were simulated with PLEXOS, so one can determine a solid understanding of how it will affect the LOLE.

One sub-goal that came with this project was learning new software such as PLEXOS, kaleidoscope, and management software. While some group members had already attained experience with these programs, others were experiencing it for the first time. As such, a small portion of development went into teaching the inexperienced team members on how to use these tools.

Additionally, at the conclusion of the study, the team planned to write and publish an official paper summarizing the findings of this study. This is something both the team and MISO wanted to see accomplished as it was an opportunity to learn how to write a document summarizing a study as well as be able to use the team's findings for future hiring and research.

2.2 Functional Requirements

By the end of this project, the team is required to have completed the following:

A study worthy of being presented as a package to MISO Energy that could be reused as something that they could present to stakeholders.
A PLEXOS Model that has been tested for accuracy.

A file that contains the scenarios needed to retrieve the data that the team will present from the PLEXOS model.

A Python Script that will automate the finding of ELCC and LOLE

A ranked list of all buses in MISO based on likeliness to build different renewable technologies there.

2.3 Constraints Considerations

- Learn project management – MISO is asking the team to pick some management software to use for this project. This is an opportunity for all team members to learn something new and have further developed skills for future jobs and projects.
- Learn how to write a paper summarizing a large-scale study – MISO would like to see a professional paper at the end of this project to explain the project, as well as learned and used methods that were devised during the process. This is a chance for the team to explain what was learned by each team member as they contributed to the project.
- North Electric Reliability Council (NERC) - This project is required to adhere to NERC standards in relation to the resulting models and proposed changes to the grid. Any plan that fails to uphold NERC standards cannot be considered valid by any reputable entity.

- The involved team for this project seeks to uphold the core ethics of honesty, clarity, and openness, both in its study and in any final documentation. Information gathered by this study will be clear, honest, and is to not be falsified in any way.

2.4 Previous Work and Literature

Towards the beginning of this project, MISO and Dr. McCalley supplied the team with several documents containing examples of similar documented studies as well as general literature about the topic for the team to read, review, and use as reference. Although the previous studies may have been similar, they do not necessarily focus on the topics this project seeks to expand upon. This is why MISO is having the team conduct this project: because it is a very real study that MISO itself has already been addressing in-house and requires further insight on in order to better predict the future for their system. Listed below are the documents that were provided.

1. Capacity Value of Wind Power, *IEEE Transactions on Power Systems [4].*

Part of the project involves making sure the models the team provides match the desired ELCC. This document provides useful information for finding the capacity credit of wind generating facilities, and using these capacities to find the ELCC. The document contains comparisons of each method used using specific historical case studies. A group decision will be made on what method should be used.

2. Maintaining Reliability in the Modern Power System, *U.S. Department of Energy [5].*

The only parts of this document the team will need to on are the sections on power system adequacy, and how the grid must be able to meet peak demand. While PLEXOS covers a lot of the math required to find the reliability of a system, being familiar with the process could help the team model creation. This document contains a lot of information regarding frequency and voltage regulation as well, two aspects that won't be considered in this study.

3. Planning Year 2017-2018 Wind Capacity Credit, *MISO [6].*

This document is a study by MISO on the use of Deterministic vs. Probabilistic methods to find the ELCC. Depending on how the group wants to proceed with the capacity factor and ELCC calculations, this document may be referred to in place of the first document (Capacity Value of Wind Power).

After researching with these documents, the team was able to develop a general scope of the project. These are the best documents for research, but are not the only places we garnered research from. As a result, all design decisions had to be made individually after being researched independently.

2.5 Proposed Design

Currently, renewable energy is the fastest growing type of energy in the United States. This project seeks to answer questions that will highlight the feasibility and potential problems that might arise due to high levels of renewable generation sources being added to the grid. In accordance with industry standard, the final design was planned around the required LOLE standard at 0.1 or "one event in ten years", in other words, only losing load one day in ten years due to lack of generation.

The team's proposed solution to discovering the feasibility of high amounts of renewables in the Eastern Interconnect is the simulation of a simplified grid modeled in the PLEXOS software. This model contains generation and load data of the Eastern Interconnect that was either provided to the team by MISO or that was calculated by the team using the given data. PLEXOS allows the team to run studies on this data and calculate crucial values such as the Effective Load Carrying Capability (ELCC) of wind and solar energy. In the future, this data could be used to site where new wind and solar plants would best be placed.

Alternatives to these operations could be to use a different software. However, if this decision were to be made, the entire framework of the model would have to be recreated from scratch and all team members would have to become accustomed to the new software. The model used in this study had already been built prior to the start of this project by some of the team members for MISO. As a result, this base model was easily accessible and the team already had a decent grounding in operating with PLEXOS.

2.6 Technology Considerations

There are many types of software that exist to analyze data calculations such as LOLE. PLEXOS is the best choice or this project because it is one of the few programs that can be provided free to students and has fairly intuitive GUI. PLEXOS is already used in the industry to make decisions about the power grid, and can therefore be noted as a respectable platform to conduct operations for this project on. This also means that learning PLEXOS is a useful skill for after college, as it is already a known program within the industry. However, a draw-back to PLEXOS is that the software can be difficult to learn for new users, but a detailed guide on how to use the program, as well as team members who had previous experience with the software, serves to mitigate this frustration.

2.7 Safety Considerations

Due to the nature of this project, which consisted entirely of analyzing and referencing data via computers, the team did not have to consider the hazards of working with dangerous electrical or mechanical equipment. While the team reviewed the same safety material and signed an agreement acknowledging the understanding of the danger and availability of tools and facilities provided at Iowa State University, these facilities were never used except as a potential meeting place for the team. Most of the time spent together or working was spent in very safe and low-stakes computer labs located around campus. Because the final product of this project will also be entirely comprised of data and its associated analytics, the team did not have to take efforts to consider the physical wellbeing and safety of those around us or potential users when compared to other groups.

2.8 Task Approach

The following flowchart describes the process of this project.

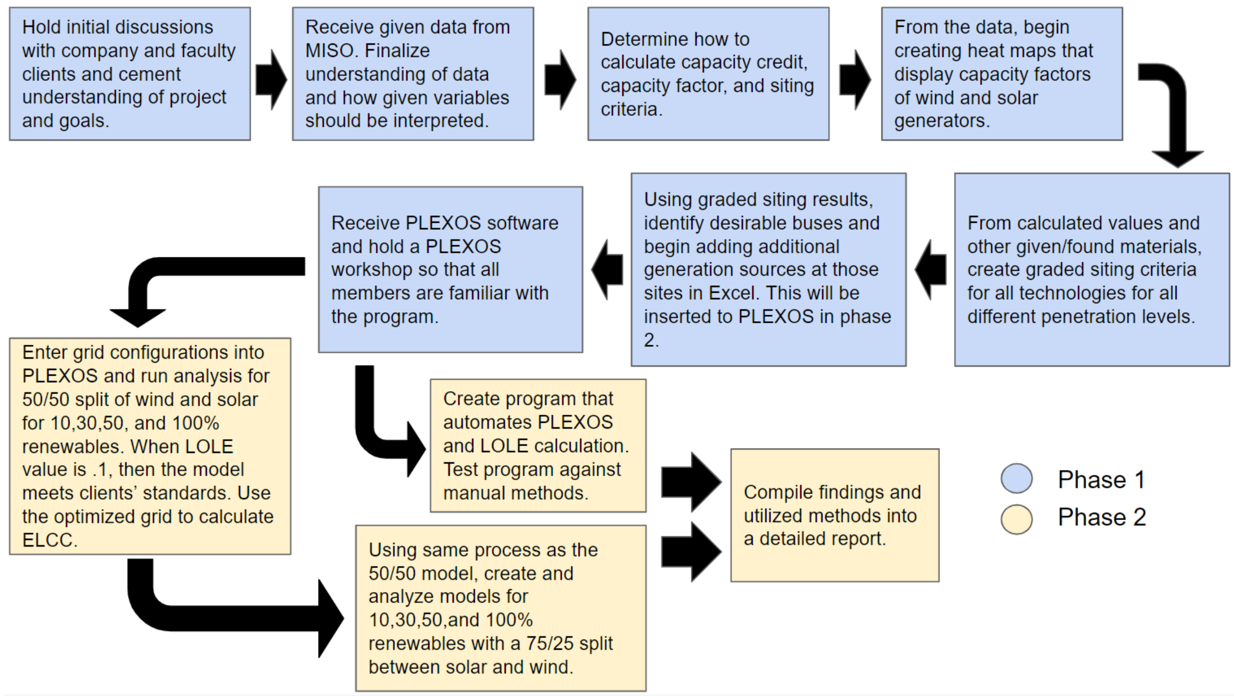

Figure 1: Project Task Approach Method

2.9 Possible Risks and Risk Management

In order to fully complete the project, the team needed to gain access to PLEXOS by submitting various forms and information. All parts of the project that require the use of PLEXOS ran the inherent risk of being stalled by this waiting process. Aside from this however, the only other factors that held influence over the productivity and quality of the project are the group members and their ability to further the project as well as retain control on all other classwork and obligations.

Another source of potential error is the ever-constant human error that comes with all projects. Entering incorrect data or omitting needed factors, are unwanted but sometimes inescapable outcomes. However, the team's access to software like Kaleidoscope that allows the group to map out the data and visually represent it serves as a useful source for fact checking calculated information.

2.10 Project Proposed Milestones and Evaluation Criteria

Milestones for this project were set such that all required data, planning, and understanding were accumulated in order to effectively complete the next section of the project.

1. Meet with MISO staff and university faculty in order to determine project mission, learn important terms and processes, and establish methods for future communication.

2. Receive given data and become accustomed to its application. Calculate capacity factor and capacity credit values. Determine other necessary or desired siting criteria and develop a process for selecting key spots to add additional generation.

3. Become accustomed with PLEXOS and begin simulating the power grid model with varying penetration levels of renewables with a 50/50 split between added solar and wind sources. These additions will be representative of the data derived from milestone 2 and will mirror the original findings.

4. Repeat Milestone 3 but with a 75/25 split between solar and wind.
    - Grading criteria for milestones 3 and 4 is largely based on finding an LOLE of .1 and the project affiliated MISO and university staff whose expertise will provide additional insight to any findings.

5. With all data verified by MISO and university staff, as well as the groups regimented criteria, all findings will be culminated into a final report and presented to MISO.

2.11 Project Tracking Procedures

The team planned to meet with MISO and Dr. McCalley on a once-a-week basis for the duration of the project. This was decided upon in order to have consistent contact with experienced individuals who could provide high-quality insight to operations on the project or answer questions for the team.

Additionally, the team frequently documented operations in weekly reports which allowed team members to document individual contributions, logged hours, and state planned contributions for the following week.

A Gantt Chart was created at the beginning of the project which set a loose outline for times that certain milestones would be completed and new sections of the project would begin. This model was also designed to be easily modified incase late changes to the project developed.

2.12 Expected Results and Validation

The results of this study will be information on how MISO can expect or even plan future renewable energy sources to be added to the Eastern Interconnect. A tiered list of geographical coordinates of where additions will be placed, as well as the expected output of those additions, and the already existing sources that will be retired as a result of the additions will be derived for each level of energy penetration for both mixes of wind and solar that were studied. As previously stated, these findings will be verified by checking findings against criteria set out by MISO, the team, and NERC standards. Examples include having a grid model with an LOLE of one outage per ten years, realistic ELCC values and positioning of sources that do not hinder or require building over large amounts of civilian homes.

2.13 Test Plan

Testing in this project will be done by repeatedly running simulations through PLEXOS for the varying energy penetration levels of different mixes of solar and wind. In this study, the team will be modeling renewable penetration levels of 10%, 30%, 50%, and 100%. The modeling will be done with a mix of 50% wind energy and 50% solar energy as well as a mix of 25% wind energy and 75% solar energy.

The team, having already devised a list of buses in order of most desirable to least desirable and the associated amounts of wind and solar delegated to these buses to meet each penetration level for both mixes, will enter the data into the PLEXOS model and run a simulation. PLEXOS will then determine the LOLE of the proposed model, the standard for LOLE is the .1 standard as previously stated. If the proposed model does not have a calculated LOLE of .1, the model will be adjusted and reran consecutively until the desired LOLE value is derived in PLEXOS.

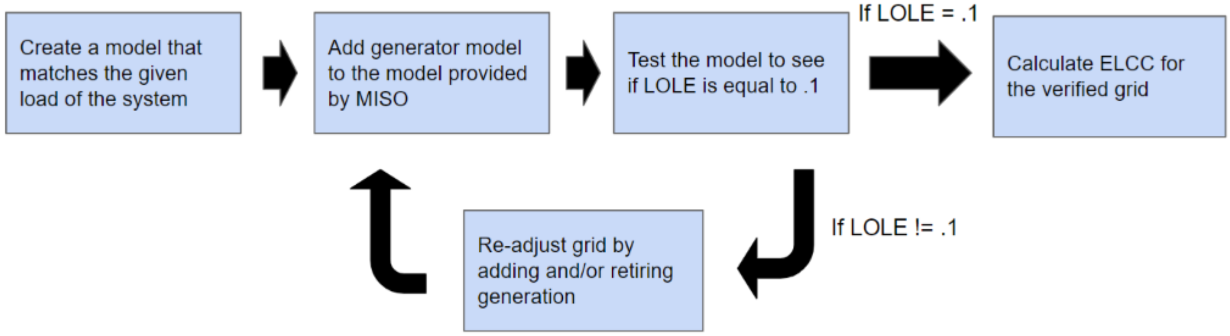

Figure 2: Testing Process

From the verified model, the team will then be able to derive the ELCC values of that model, which is the second core calculation for each penetration level.

By the closing end of the project, the group intends to have this process fully automated via a Python script that will continually run simulations in search of an LOLE value of .1 and be capable of calculating the ELCC.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

* = an automatically calculated cell

	TASK NAME	START DATE	END DATE	START ON DAY*	DURATION* (WORK DAYS)
Phase 1		8/27/2018	12/5/2018		
	Meet MISO Staff + Learn Important Terms	8/27/2018	9/3/2018	0	7
	Calculate Capacity Factor & Credit	9/3/2018	9/17/2018	7	14
	Generate Heat Maps	9/17/2018	9/24/2018	21	7
	Recalculate and Regenerate Heat Maps (Due to bad data)	9/24/2018	10/1/2018	28	7
	Create Siting Criteria	10/1/2018	10/21/2018	35	20
	Siting Criteria Calculations	10/21/2018	11/5/2018	55	15
	List Busses in Order of Desirability	11/5/2018	11/12/2018	70	7
	Grouped Busses for Penetration Models + Calculated Averages	11/12/2018	11/26/2018	77	14
	Phase 1 Report & Presentation + Run MT Model	11/26/2018	12/5/2018	91	9
Phase 2		1/14/2019	5/1/2019		
	10% 50/50 Model	1/14/2019	1/21/2019	140	7
	30% 50/50 Model	1/14/2019	1/28/2019	140	14
	50% 50/50 Model	1/14/2019	2/11/2019	140	28
	100% 50/50 Model	1/14/2019	3/4/2019	140	49
	10% 25/75 Model	3/4/2019	3/11/2019	189	7
	30% 25/75 Model	3/4/2019	3/18/2019	189	14
	50% 25/75 Model	3/4/2019	4/1/2019	189	28
	100% 25/75 Model	3/4/2019	4/15/2019	189	42
	Python Automation Code	1/14/2019	2/25/2019	140	42
	Final Documentation + Presentation	4/15/2019	5/1/2019	231	16

Figure 3: Senior Design Timeline

The project has been split up into two halves, or "phases," that will take place during fall semester of 2018 and spring semester of 2019 respectively. Phase 1 focused primarily on the group preparing and setting the foundation for what can be considered the major part of the project, that being the grid modeling and simulation in PLEXOS that also allows the group to calculate LOLE and ELCC values in order to validate the makeup of the model.

The groundwork itself included getting every member an understanding of the mission statement of the project as well as the many terms and considerations that are commonplace within the power industry and the project.

Afterwards, the rest of phase 1 was put towards calculating needed values and gathering other related data in order to create and utilize siting criteria for placing additional generation sources across the grid. This began with calculating average capacity factor and average capacity credit values from the years of 2007 to 2012 for wind, rooftop solar, fixed solar, and tracking solar sources. With given geographical coordinates of where the connections for these sources could be placed, the team was able to generate heat maps that visually displayed the highest and lowest yielding areas for each technology.

Unfortunately, the data that was used for the first round of heat maps was not of the quality MISO or the group had originally thought, and the group had to use another week to recalculate and regenerate the capacity values and heat maps with higher quality data. After calculation for capacity values were completed, capacity factors also needed to be calculated. With calculations complete and a better understanding of what areas were best for what technology, the group moved forward to create siting criteria that would be considered in order to rank each connection site.

The team decided that each generation type would require its own intricacies in regards to calculating a siting "grade." Examples of changes would be having a higher focus on available landmass for wind or fixed and tracking solar farms while high population density was favorably for rooftop generation. However, the largest factor in the grading of all technologies was the calculated capacity factor for the given bus. From the grading system, which was implemented in Microsoft Excel, the team was able to list the generation sites in order of most desirable to least desirable according to the created criteria.

Finally, the group was able to obtain PLEXOS licenses for each team member, and the team began to delve into working with the program by practicing with another model.

In Phase two, the team will be fully prepared to undertake the operation of PLEXOS and will begin to simulate the models created according to the graded siting criteria. The models for both mixes will be run in parallel with each other, as by finishing the 10% model for a given mix means that the model for 30% penetration is already a third done and so forth for all other penetration models.

3.2 Feasibility Assessment

As previously stated, in order to increase chances of a high-quality final product, the project has been split up into two sections: Phase one and Phase two, with each phase having a specific turn-in at the end.

The purpose of Phase 1 is to allow group members a chance to familiarize themselves with the vocabulary that is intrinsic of this type of project as well as the various software programs that need to be utilized. The final turn-in for Phase 1 will be a report detailing the calculations and other criteria that was either given or created by the group in order to finalize the siting criteria for the siting grading system that will be used to determine the order in which the team adds generation to individual buses. The thresholds the group will be looking to achieve for each penetration level will also be calculated and the amount of expected generation that will be achieved from each bus will be calculated and summed to ensure the threshold is being met.

By Phase 2, the group will hopefully have a deeper understanding of how to utilize PLEXOS and will have documentation on what renewable sources should be added to which bus for all 10%, 30%, 50% and 100% penetration levels for both the 50%/50% and 25%/75% mixes of solar and wind. The team will then proceed to simulate these models in PLEXOS and until an appropriate LOLE value of .1 is achieved- this value signaling that the grid is in fact functional by modern standards. From the data in PLEXOS, the team will then also be able to calculate the ELCC for the renewable sources within the grids. The team will delegate 7 weeks to the 50%/50% model due to the fact that it will be the team's first time attempting this process. Afterwards, with gained experience, the 25%/75% model should be expected to take 6 weeks. The rest of Phase 2 will then go towards finalizing the final turn in of the project. The final turn in will be a finalized report containing the data gathered from Phases 1 and 2, as well as the group's conclusions regarding the siting and capacity additions made and which configuration of siting and penetration level is currently best.

Major challenges that will be encountered in this project stem from the fact that some group members do not have the industry experience that the other group members do. Therefore, a portion of time needs to be carved out to allow the less experienced group members to acquaint themselves with some of the given software and common vocabulary used in this project. To remedy this, the first 4 weeks of the project will be split up into 2 learning periods where the group will focus on the vocabulary and important topics associated with the project and the second term will focus on working with the required software.

3.3 Personnel Effort Requirements

Task	Description	Time Frame
Learning Period	Team will spend time understanding project mission and learning key terms	1 Week
Calculate Capacity Factor and Capacity Credit	Calculate yearly and peak generation averages for use in siting criteria	2 Weeks
Generate Heat Maps	Generate visual references to help the team and others visualize desirable locations siting	1 Week
Develop Siting Criteria	Decide on important factors that will be considered when identifying desirable locations	3 Weeks
Develop Rating System from Siting Criteria and List Buses	From siting criteria, create a regimented system by which the buses in the grid can be judged on desirability	3 Weeks
Group Buses for Additional Generation for Penetration Models	Document how much generation will be added to which buses in accordance to the criteria grading system	2 Weeks
PLEXOS Introduction	Assure each team member is familiar with PLEXOS and will be able to utilize the program in Phase 2 spring semester	1 Week
50/50 Wind and Solar Model	Create and analyze a power grid model with an even split of wind and solar generation for 10, 30, 50, and 100% energy penetration.	7 Weeks
25/75 Wind and Solar Model	Create and analyze a power grid model with a 1: 3 ratio of wind to solar generation for 10, 30, 50, and 100% energy penetration.	6 Weeks
Python Automation Project	Develop a Python script to automate the analysis process of the grid models	1 Week

Table 1: Task time estimates

All group members will be able to work on the main project to some degree. Some group members have positions that require them to handle things for the group that do not directly relate to working with PLEXOS or calculating ELCC or LOLE values, while others do. As a result, the latter mentioned group members may put more effort towards the main project and constructing the varying penetration grids than those who are expected to lead other group members or work on needed side-projects such as automation.

With this in mind, each group member is still required to put their best effort towards their given tasks and to assist the rest of the group in ensuring the project is completed in an efficient and timely manner. If a group member is unable to complete their work, or productivity begins to slow down, group members may have to take over rolls for others or put in more time when needed to stay on course. This will hopefully be a last resort measure, as the purpose for splitting up work among the group members and assigning lead roles that correlate to each individual's interests and strengths is to avoid unnecessary drops in productivity.

3.4 Other Resource Requirements

Required resources include:

- PLEXOS software for modeling and running calculations on grid configurations
- Associated data for PLEXOS including siting and generation data for a 2024 model that will be scaled back to represent 2018 data.
- Open source NREL data regarding weather patterns for predicating solar and wind generation
- CyBox collaboration platform for working on documentation
- R-Studio & Kaleidoscope for creating locational maps of the Eastern Interconnection

3.5 Financial Requirements

There are no financial necessities for this project. All assets used are either open-source programs or were given to the group at no expense.

3.6 Standards to Follow

IEEE 1094-1991: IEEE Recommended Practice for the Electrical Design and Operation of Windfarm Generating Stations. [7]

To create the grid, the team has to create imaginary wind farm sites that were likely to be set up in the future, according to different variables at different locations. This standard provides recommended practices for the creation sound, economic design setups for interconnecting multiple wind farms. While siting generating plants for the grid, the team may have to refer to this document in order to ensure that the proposed design matches the criteria presented by this standard.

IEEE 493-1997: IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems [8]

A large part of the project MISO has commissioned the team to do has to do with finding the reliability of a proposed system, up to a certain economically feasible point. This engineering standards provides data "cost vs reliability" studies that the team can refer to when making decisions that would affect the reliability of the grid, and decide if the cost of it is preferable.

IEEE 141-1993 - IEEE Recommended Practice for Electric Power Distribution for Industrial Plants [9]

One end goal of the project is to find older, less efficient power plants that will be un-needed after enough new renewable generation comes onto the grid and retire these plants. The team would need to refer to this document, as it provides information on how these plants are set up, and could provide insight on what effect the retirement of a major source could have on the grid.

NERC Standard BAL-502-RF-03 [10]

NERC has many standards on energy balancing and resource adequacy. Standard BAL-502-RF-03 [4] is one we are particularly interested in adhering to. This is because it talks about a planning reserve margin for LOLE. The standard we will adhere to is comparable to a one day in ten-year LOLE expectation.

IEEE 762–2006 - Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity [111]

For reporting generating unit outages. This standard provides a methodology for the interpretation of electric generating unit performance data.

4 Concluding Materials

4.1 Conclusion

With renewable resources being the fastest growing energy resource in the US, and many older generation units retiring, there is an uncertainty on what the grid of the future will look and behave like. In recent years the conversation on understanding these changes has been rapidly changing and beginning to dive into the specificities of topics.

This project aims to be a part of that conversation, by expanding the knowledge on resource adequacy of the energy grid for varying levels of renewable penetration.

This will be done by closely working with MISO and advisors at Iowa state. The models created will estimate future grid of the Midwest, including new levels of Renewable mixes. These models will allow one to directly study the impact of adding large amounts of renewable generation sources by utilizing PLEXOS to understand the LOLE and ELCC of the additional renewables. This project plan lays out the intended steps the team followed in order to help grow the understanding of future changes on the energy grid.

4.2 References

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4.3 Appendices

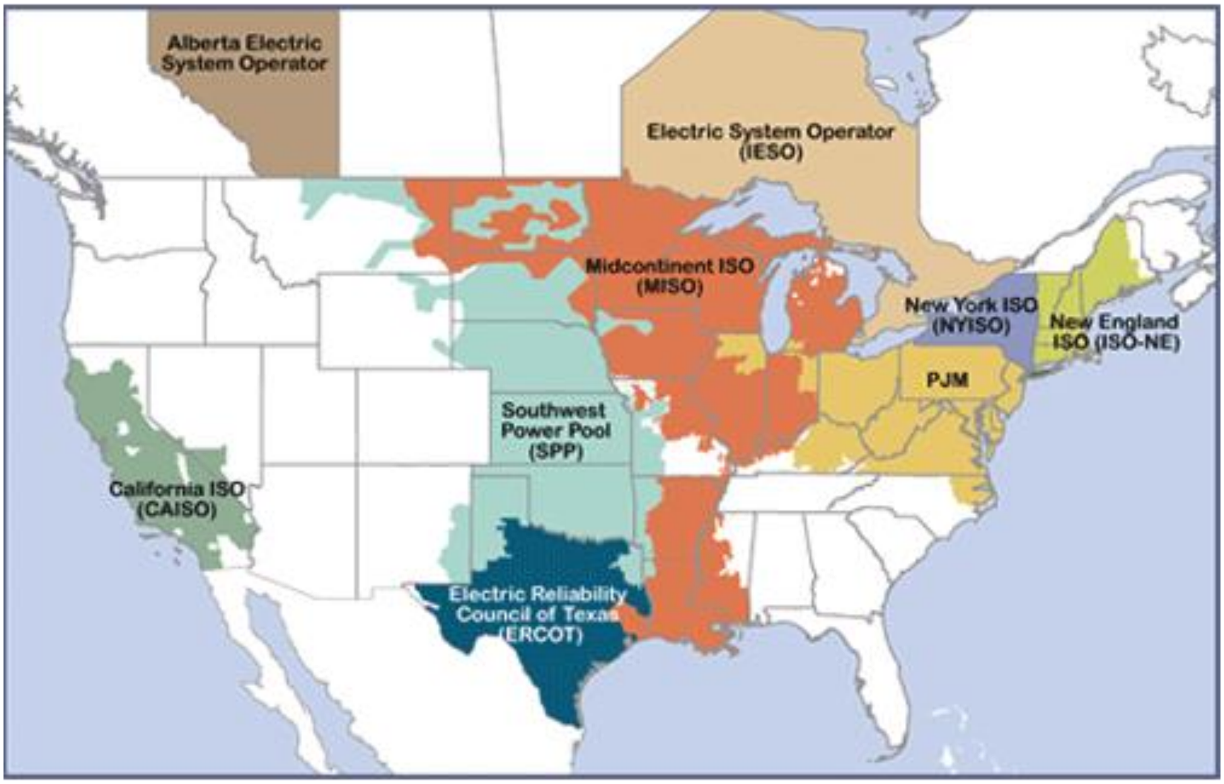

Figure 4: Map of the North American Power Grids and RTOs [2]

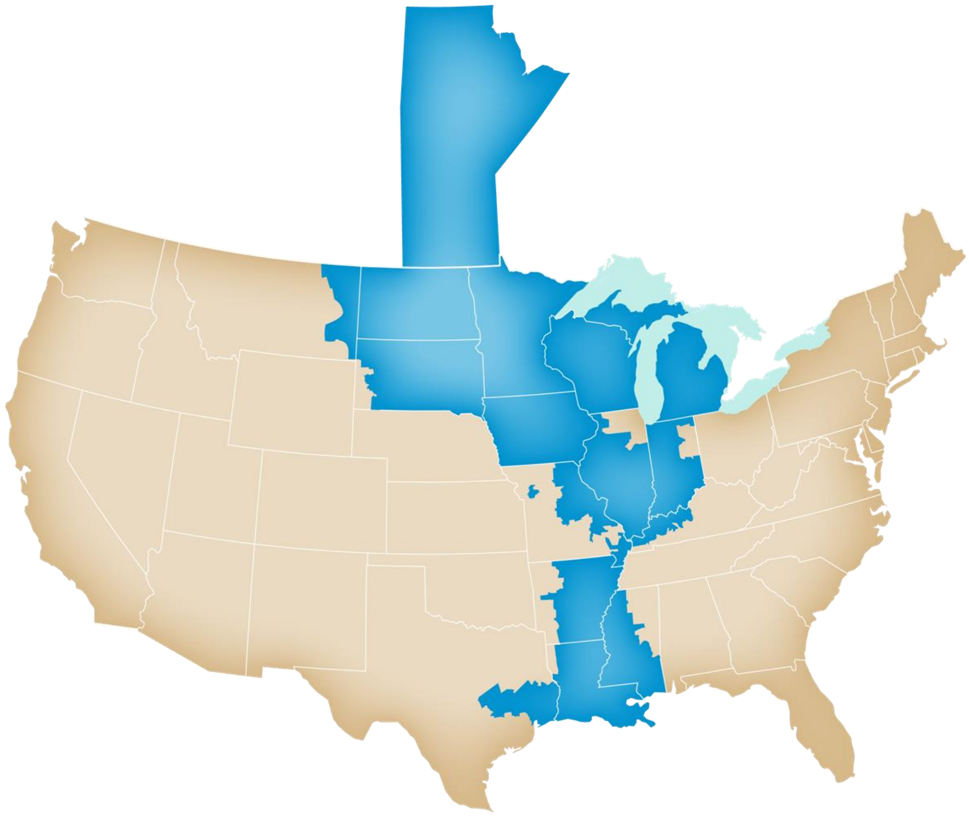

Figure 5: Map of MISO Energy regulation area [1]

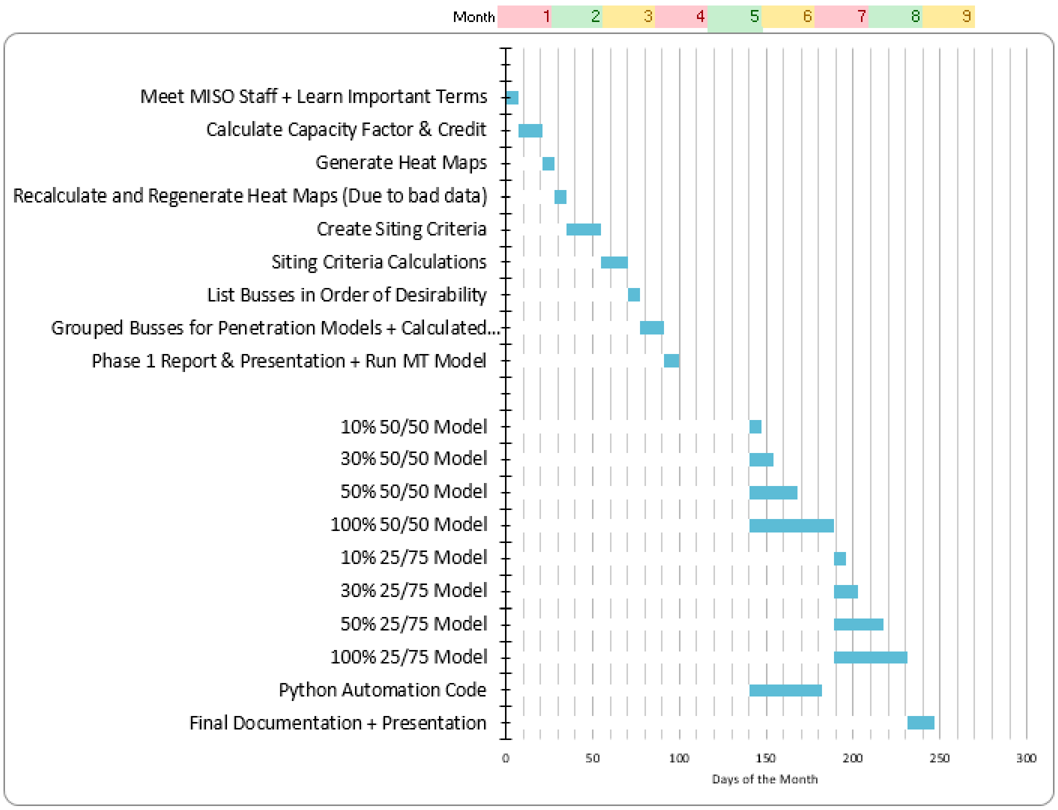

Figure 6: Senior Design Gantt Chart