Investigating Solutions to Voltage Increase on Distributed Generation Power Systems

PROJECT PLAN

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1 Introduction

1.1 PROJECT STATEMENT

Electric companies that have lightly loaded distribution feeders can experience high voltage as the amount of distributed generation (DG) being installed increases. When power is coming back onto the electric system from the end consumer, it can drive the voltage outside of ANSI limits (ANSI standard C84.1 Range A, 114V to 126V). Additional equipment, system upgrades, or special settings on existing equipment will be needed to bring the voltage on the feeder back within acceptable voltage limits.

1.2 PURPOSE

As distributed generation is becoming increasingly popular, distribution companies with low-loaded feeders are seeing increases in voltages on nearby lines and in some cases, all the way back to the substation. The results of this project should be very beneficial in providing a path forward for distribution companies with low-loaded feeders in ways to allow the amount of distributed generation installed to increase while having a minimal effect on the voltage of the grid in low-loaded systems.

1.3 GOALS

We would like to gain an understanding of distributed generation and its effects on low load distribution systems and determine a way to maximize the amount of DG a rural distribution system can contain using the latest technology. To accomplish this, we will:

- Quantify voltage rise issues in MVEC's feeders with different penetration levels of DG
- Model practical feeders using software such as WindMlil and OpenDSS.
- Explore new technologies such as the implementation of smart inverters and the proper settings.

2 Deliverables

The final deliverables for this project will be:

- A thorough report of our findings and a suggested path forward for Maquoketa Valley Rural Electric Cooperative (MVEC) on ways to allow for increased distributed generation on their system.
- We will also deliver a working system model implementing our solution.
- A cost comparison for the different solutions.

3 Design

Our process will be to model MVEC's system in WindMil and OpenDSS and understand the effects of distributed generation on their system. We will then research technologies that may help keep the voltage on the system within the ANSI system limits. We will then implement these researched technologies into our system models and determine the best way to maintain the system voltage. From the possible solutions, we will then perform a cost analysis to determine the most economically acceptable solution.

3.1 PREVIOUS WORK/LITERATURE

Some research has been done on this topic as it is a problem all across the Earth as many people try to switch to using more renewable energy. It is a common problem on rural distribution systems with low-loaded feeders to see a rise in voltage as either large photovoltaic (PV) installments are added by farmers or many smaller installments are added by a group of neighbors. The problem is that while the sun is out and PV systems are generating their peak amount of energy, the load demand is much smaller than peak demand hours (when people wake up and when they come home from work) causing an excess supply of power on the distribution system. (This information came from a discussion with the MVEC engineering group held on February 19th, 2016) An example of this is the California Independent System Operator "duck curve" seen in Figure 1. It shows that California is facing an overgeneration risk in the coming years as the amount of DG installed in California is predicted to increase. (Denholm, et al, 2015) This can cause a rise in voltage on parts of the system and can even cause a voltage rise at the substation. New research on this subject is occurring and a study done in Australia in 2015 provided a promising starting point for our solution to the problem. The conclusion of the study, which compared various methods to manage the overvoltage on a modelled system stated "a control scheme that implements reactive power absorption reduces curtailment losses whilst reducing overvoltage to a greater extent (compared to an equivalent model without)." (Collins, Ward, 2015). This gives us a good starting point and points us in the direction of the use of smart inverters on the MVEC system.

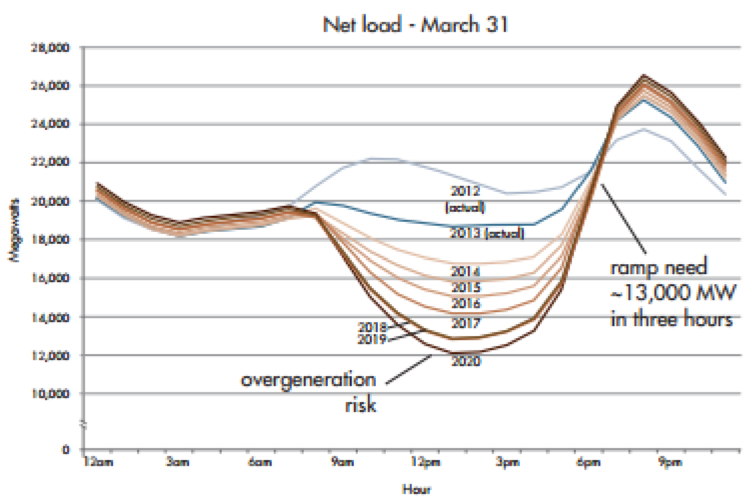

Figure 1 California Independent System Operator "duck chart" that shows the net load and how it sags and is predicted to sag significantly during max PV generation times as the amount of PV increases.

3.2 PROPOSED SYSTEM BLOCK DIAGRAM

Our process will be to model MVEC's system in WindMil and OpenDSS and understand the effects of distributed generation on their system. We will then research technologies that may help keep the voltage on the system within the ANSI system limits. We will then implement these researched technologies into our system models and determine the best way to maintain the system voltage. From the results we gather from our models, we will then generate a report about our findings, summarizing the work completed and the results, and including a suggested path forward including a cost analysis of the solutions to the problem. We will also present our findings to several members of MVEC's engineering staff and CEO.

3.3 ASSESSMENT OF PROPOSED METHODS

There are several methods available to model MVEC's system using modeling software. The WindMil software can be used to provide a snapshot of the system under certain distributed generation scenarios while OpenDSS software can be used to analyze the effects of distributed generation on the system with regard to time. We intend to use the WindMil software as a check to our OpenDSS model to ensure the system is modelled correctly and functioning correctly in OpenDSS. We will use the modeling software to test the effects of various voltage controlling options on the system and to determine the most effective and reasonable method to controlling the effects of distributed generation on MVEC's distribution system.

3.4 VALIDATION

From the research done by Collins and Ward (2015) in Australia, we have a general idea of where to start and that using smart inverters should theoretically provide the best results. To confirm our findings we will use other higher knowledge on the topic as a check to make sure our data is implemented and results are reasonable. Since this is a research project, our results should provide validation for our client to install whichever technology we find that best solves the problem, of voltage rise, and the cost analysis performed should show which options are economically feasible for MVEC and their customers to install.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

Keep all elements of the system within ANSI voltage limits under all conditions (114V to 126V).

Accurately model the system under differing load/DG conditions

Solving all instances where model departs from ANSI limits

4.2 NON-FUNCTIONAL

Learning to use modeling software WindMil and OpenDSS

Research into possible solutions to select the most universally applicable

Compiling our data and research to present to our client, MVEC

5 Challenges

Due to problems with obtaining a signed NDA form from Iowa State University and problems with getting the necessary WindMil version, we are behind where we would have liked to be at this point. We also have to learn how to properly use the WindMil and OpenDSS software, as our group has never used either before. We will also have to determine a way to verify that our models are working properly with the data that we are giving them. This may require talking with professors such as Dr. Wang to verify that our results are reasonable per our model.

6 Timeline

See figure 2 for our first semester timeline in the appendix. See figure for the second semester timeline in the appendix..

6.1 FIRST SEMESTER

We need to get the NDA form signed and receive data from MVEC. Complete research on possible methods for solving the voltage problems. We will finish our models using the provided data and prepare them for testing our solutions on in the next semester.

Each group member will be responsible for performing research and learning the modeling software.

6.2 SECOND SEMESTER

During the second semester we will be completing our testing of our proposed methods for solving the voltage issues. We will perform a cost analysis on the solutions to the voltage increase problems to ensure our solutions are reasonably affordable to implement into the distribution system. We will possibly have MVEC try out our best option on their own solar panels to receive real world data. We will finalize our results by writing a comprehensive report on our findings and then presenting that information to MVEC.

Each group member will be responsible for modeling and analyzing the various researched techniques from first semester and reporting to the group which technique proved best. The entire group will be responsible for participating in the creation of the final report and presentation and cost analysis.

7 Conclusions

For this project, we will receive data from MVEC regarding several of their substation systems with various degrees of load and distributed generation already installed. We will then analyze this data using WindMil and OpenDSS while adding additional distributed generation and various researched voltage controls to attempt to maximize the amount of distributed generation on the system without exceeding the ANSI system voltage limits. Our goals are to gain a more in-depth understanding of the effects of distributed generation on various low load systems and to discover an effective way to maintain the voltage as distributed generation increases. We will accomplish this through use of WindMil and OpenDSS software, which leads to another goal for this project of learning to use the listed software to analyze a system model.

8 References

Maquoketa Valley Rural Electric Cooperative Engineers: Mark Scheibe and Jeremy Richert
Meeting held on Friday February 19, 2016 at 1:30pm at the MVEC office in Anamosa, Iowa

Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart
Denholm, Paul ; O'Connell, Matthew ; Brinkman, Gregory ; Jorgenson, Jennie

NREL Technical Report, November 2015

Power conditioning system for grid-connected photovoltaic system
Tang, Xin ; Tsang, K.M. ; Chan, W.L.

Solar Energy, 2013, Vol.96, pp.187-193 [Peer Reviewed Journal]

Dynamical and Voltage Profile Stability of Inverter-Connected Distributed Power Generation
Chung-Ching Chang, Dimitry ; Gorinevsky, Sanjay ; Lall, Sanjay

IEEE Transactions on Smart Grid, July 2014, Vol.5(4), pp.2093-2105

Real and reactive power control of distributed PV inverters for overvoltage prevention and increased renewable generation hosting capacity
Collins, L. ; Ward, J.K.

Renewable Energy, September 2015, Vol.81, pp.464-471 [Peer Reviewed Journal]

9 Appendices

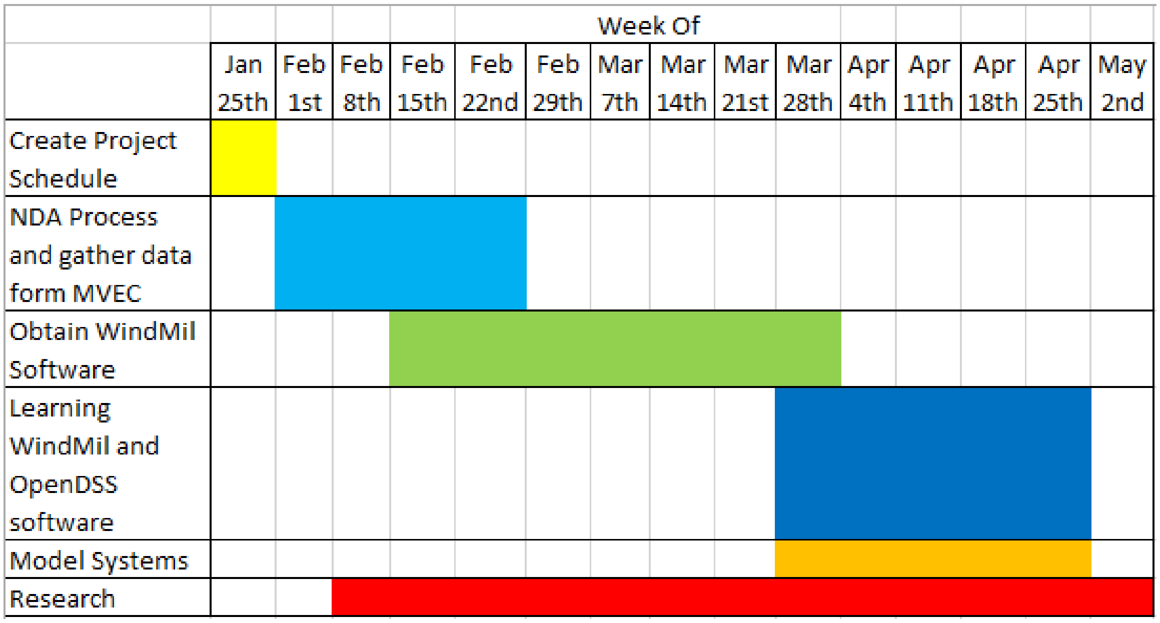

Figure 2: Gantt chart of first semester.

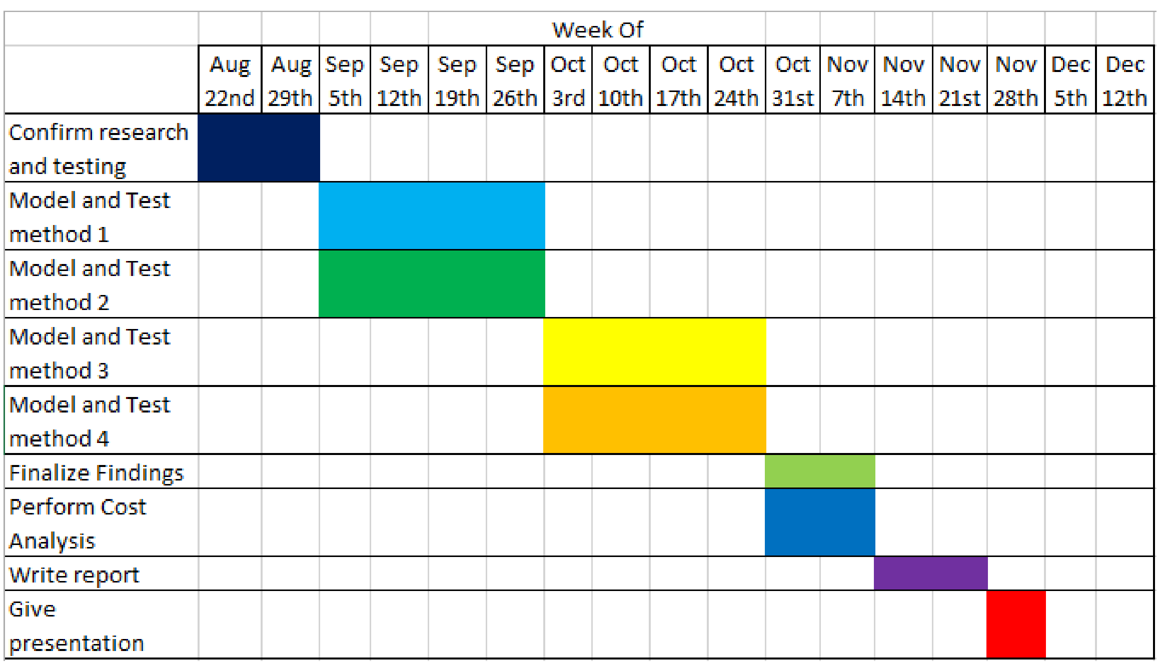

Figure 3: Gantt chart of second semester.