

# Impact of High Photovoltaic Penetration on Distribution Systems

Design Document

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## List of Definitions

IEEE: Institute of Electrical and Electronics Engineering

PV: Photovoltaic

GridLAB-D: Power systems software that will often be referred to as GridLab

# 1 Introduction

## 1.1 Acknowledgement

We would like to thank our advisor Professor Dr. Ajjarapu for his constant support and guidance. We as a team have worked on this project for one year and this has been a great opportunity for all of us to learn and grow as better electrical engineers.

## 1.2 Problem and Project Statement

**Problem Statement:** Solar energy is making advances very rapidly in today's world. In Iowa, the solar generation and solar power plants are seen as a potential major source of power, to satisfy the needs of people. In this project we are trying to assess the impact of high penetration solar power generation on the distribution feeders and its effect on the power delivered to the consumers.

**Project Statement:** In order to further understand distribution systems, we are going to simulate them using a power systems software called GridLAB-D. Once we've gotten an understanding of how changing variables such as node voltages and line impedances affect distribution systems, we will begin implementing solar energy into our systems. We will see the effects of high PV penetration at certain times of the day on our distribution systems, such as opposite direction power flow, and over-voltage. In changing different variables of the distribution system in GridLab, we should be able to find solutions to these problems. We will finally be introduced to an actual distribution system owned by Alliant Energy, and simulate their system to suggestions for how to apply solar power to their distribution system.

## 1.3 Operational Environment

For our project, we will not be simulating the operating environments, except for the average amount of solar energy output at different times of the year. This will be a given set of information, and our suggestions for the distribution system will all be taken from a simulation.

## 1.4 Intended Users and Uses

We intend to provide our final product as suggestions for how Alliant Energy can apply solar power to one of their distribution systems. It is up to Alliant Energy how they will use these suggestions, which will be meant to better supply power to the general public.

## 1.5 Assumptions and Limitations

Assumptions:

- Load will not have extreme variances.
- Voltages other than from the power supplied by solar energy will be constantly able to be supplied.
- All components of the distribution system will be working at their rated amount.

Limitations:

- Suggestions cannot drastically change existing infrastructure.
- Distribution system will be in Iowa, and will have to account for the less-than-ideal climate throughout the year.

## 1.6 Expected End Product and Deliverables

We will provide suggestions for how Alliant Energy can implement solar power in one of their distribution systems. Alliant Energy will be supplied with the code for our simulated distribution system that has added solar power. Along with this code, and its results, we will present graphs and data that more clearly demonstrate the value of modeling their future modified distribution system with aspects of our simulated system. Suggestions for both changes to the current distribution system, and how to best add new infrastructure to the system will be given. These solutions will compare community PV and residential PV generation, and will aim to prevent future problems relation to solar generation on the Alliant Energy system. All of this will be delivered in April 2019.

## 2 Specifications and Analysis

### 2.1 Proposed Design

Our proposed design is modeling the distribution feeder using GridLab-D. We have not yet implemented our system in GridLab. The requirements for this are that the system will have all loads connected correctly and with correct line impedance. We will also need to be able to modify the load in accordance with different levels of solar PV penetration. Additions to the system to solve problems that occur from high levels of solar PV penetration will be added as needed.

### 2.2 Design Analysis

So far we have been working on solving by hand the IEEE 4 bus system with a number of modifications as assigned by our advisor. Therefore, we have no results from the eventual system we will be designing in GridLab. We believe that we will be able to correctly implement the system using GridLab and simulate how the system will behave based on different levels of solar PV penetration.

## 3 Testing and Implementation

### 3.1 Interface Specifications

There is not a lot of hardware or software interfacing required for this project. We will not be using any hardware for the project. All measurements and values we obtain will be from GridLab-D, which we will put into excel to analyze. We will also do some calculations in MatLab to ensure that the data we are receiving from GridLab is correct.

### 3.2 Hardware and software

We will be using GridLab, MatLab, GitHub, and Excel for testing our project. GridLab will be used to model and test our distribution feeder node. We will be designing the system and running power flow calculations using this software. Excel will be used to store and analyze the data we get from GridLab. GitHub will be used to store code that we will be using in GridLab. Using MatLab, we will be testing some of the data gathered from GridLab to ensure we are getting the correct values from the software.

### 3.3 Functional Testing

There are three different tests we will be conducting for our project. First, we will test that we correctly implemented the distribution feeder as it currently is. Next, we will be testing how the system behaves after it is modified with different levels of solar PV penetration and what problems, if any, occur. Lastly, for each level of voltage penetration test solutions to the problems that come from the different levels of solar penetration.

For Test 1 to be successful we will have implemented all loads, distribution lines, and other items in the distribution system on GridLab. We will be able to determine if the test is successful by doing calculations to ensure that the numbers are where they should be for the system.

For Test 2 to be successful all of the loads will be correctly modified as they would be with a particular level of solar penetration in the system. By hand calculations as well as common sense will ensure that all of the voltage levels are within acceptable values. Errors in voltage and power flow would not be unexpected at this point, as this test is to check for problems rather than solve them.

Test 3 will be designing and implementing a potential solution to any problems that are found during test 2. The first stage of this step will be designing a solution to prevent whatever overvoltage or reverse power flow that occurred during test 2. Next, we will implement the solution in GridLab. If the solution is successful the overvoltage and/or reverse power flow will be solved by the implemented solution. If there are still problems in the system, the test fails and we will have to restart the test.

### 3.4 Non-Functional Testing

We will have little non-functional testing for this project, as all simulations will be run on GridLab, which is a reliable software. The only testing we will be doing is ensuring all of the code we use in GridLab is entered correctly, which will be checked by using our own calculations.

### 3.5 Process

As of writing this, we have not gotten to the point of testing our system, though we will start building it soon. However, below is the process we will be following the diagram below

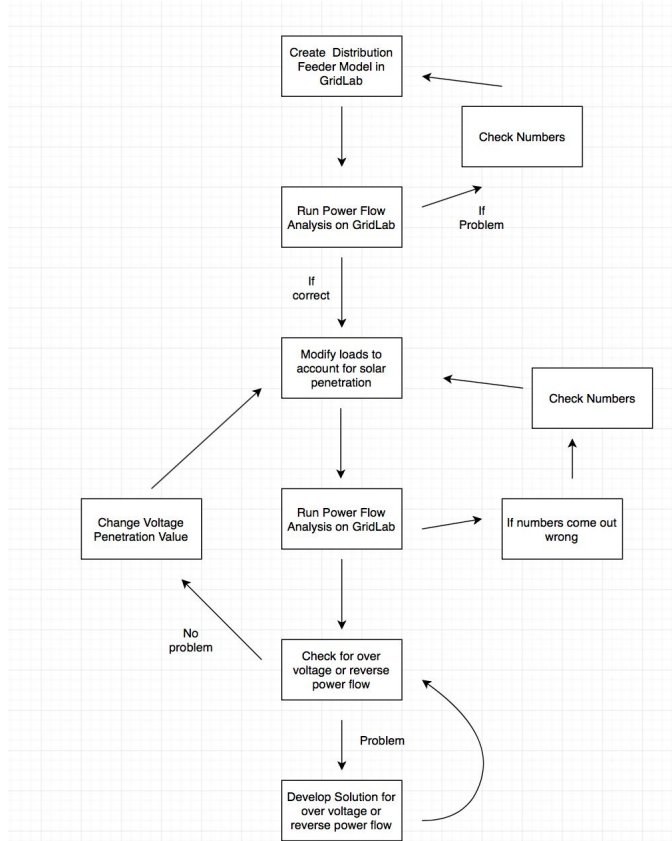


Diagram 1

## 3.6 Results

As of writing this, we have not started the testing phase yet. We have been working on related work for our advisor so that we can tell when we get results that don't make sense, indicating a coding error. This work is also being done to ensure that we have a good understanding of what GridLab is doing, so we can avoid errors.

# 4 Closing Material

## 4.1 Conclusion

The purpose of this project is analyzing the effects of solar generation on utility distribution systems by using GridLAB-D. We will simulate an Alliant-owned distribution feeder by

incorporating a solar generator into the simulation for effect observation, and compare both local PV and residential PV system to determine the best way to integrate solar energy into distribution systems. From the program, we can deduce potential problems of high permeability of solar power in distribution system and try to seek applicable solutions. We are doing basic step to get concepts of power flow and distribution system, and to learn how to use GridLAB-D program, but we will be getting used to it and get data what we want.

## 4.2 References

W. Kersting, Distribution System Modeling and Analysis. Boca Raton: CRC Press, 2017  
p.141-390