High Photovoltaic Penetration and the Impacts on Distribution Systems

PROJECT PLAN

Faculty Advisor

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Industry Client

Alliant Energy

Project Charter

Project Name	High Photovoltaic Penetration and the Impacts on Distribution Systems
Project Field	Distribution Protection Systems
Class Group	EE/CprE/SE 491 Senior Design: Dec15 – Group 20

Team Member	Position and Responsibilities
Shane Thompson	Team Leader
Alec Walczak	Communications Leader
Brad Bender	Webmaster
Joe Near	Concepts Holder

Revision	Date	Description
R1.0	February 20, 2015	First Iteration of Document
R2.0	April 7, 2015	Updated to Include New Information

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System Requirements

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- Potential Solutions
    - Control System – This solution introduces a possible sensing mechanism that will detect return power/voltage into the distribution feeders and reroute energy into a capacitor bank. When the system is at low usage will distribute the energy back into the system.
    - Load Shedding - Otherwise, if a consumer is generating enough energy to be fed back onto the grid, a sensor could be used to disengage them from the grid temporarily allowing them to draw their own load/demand from their green energy generation. Once the load exceeds the maximum allowance of generation, or the demand on the load is greater on the grid, the system will re-engage the customer and allow their excess to be fed in to the system. Otherwise allow them to use power to make up the gap that their system isn't able to deal with.
    - Redirect DG Power Flow – Another idea is to reline the homes that are providing additional energy onto the grid that will allow the energy to flow back into the nearest substation and have it redistributed to the power grid.
    - Storing of Excess Power – This potential solution is a combination of the two previous, with a possible twist. As the consumer/customer generates power, it will be stored in a DC form in a bank of batteries. Once load has reached a specific amount of demand, a voltage inverter converts the power into an AC signal and is sent in to the distribution grid as its own signal. This will help compensate the additional demand on utility lines particularly in high peak times, such as summer and winter months.

These solutions feed into one another, and could potentially be sub-solutions of the overall goal.

Assessment of Proposed Solution

The ultimate goal of this design solution is to limit and/or eliminate damage caused by High PV Penetration. Once a solution has been settled on then we can narrow down possible design flaws and feasibility issues. Some that come to mind now are the following:

- Control System – Cost of implementation, where should it be placed, how many are needed, etc. Can a cost effective and reasonable solution be reached? If true, then this could have real world practicality and could be added for low cost to the consumer and providers.

- Load Shedding – Loss of energy, potential issues with power factor and system stability.

- Redirect DG Power Flow – Extra line placement. Could potentially have issues with having to change major parts of infrastructure and equipment. Could be the simplest answer, but would cause more of a visual issue with excess power lines present in residential neighborhoods. Could also cause concern with consumers on "health risks" associated with high voltage lines in their backyards.

- Storing of Excess Power – Cost and issues with customers not wanting excess equipment on their property without compensation.

Validation and Acceptance Test

The goal of this portion is to associate a successful or unsuccessful tests to demonstrate proof of concept and/or feasibility of the solution or combination of the solutions. For this we will need access to various types of simulation software including DSS and PSS/E. A successful test could show that simulations pass within reasonable constraints.

System Interface

Overview

At the moment, no data has been provided. For this project, data from one or more distribution feeders is needed. The data will have to include:

- A map of the feeder lines
- P, V, Q, and Theta values at all buses
- Locations of:
  - Capacitor Banks
  - Breakers
  - Relays
  - Substations
  - Existing DG Sources

Technical Approach

The specifications of the system are still undermined. However, they can be represented in a general sense. In the distribution system there will be multiple variables given. These include load demands, power input, and percentage of houses with DG. Using this information, the maximum penetration back into the system and subsequent substation can be calculated. Once the maximum penetration is calculated, designs specifications can be drawn up and a solution can be determined.

Process Details

The first step towards solving this issue is to model the current system's base case. This will allow for a preliminary understanding of the system. It will determine key points on the system such as areas of extreme sensitivity and areas of flexibility. After the preliminary analysis is completed, the next step is to perform a growth analysis. This will simulate what the system will look like after a few years. There are many things that can change; however, the most important aspect to look at here is the increase in DG. Assuming trends are consistent, the amount of DG sources will rapidly increase. Using the growth analysis the peak voltage and real power can be determined.

The next step is to determine the best possible solution for the system. Using the peak voltage and real power imposed on the system, a feasible cost range, and other potential design constraints, a solution is determined. Multiple solutions will be simulated and tested. Once a proper solution is determined it will be proposed to the client.

Work Breakdown Structure

Project Schedule

We intend for the first part of this project to be completed by May of 2015. We were intending to allow until March to wait to receive the actual layout of the system in order that we may analyze it. However, this ended up taking a bit longer. Therefore, we spent March getting an idea of how to use Open DSS. Now, we will spend the next two weeks plugging in a sample 13-bus system into Open DSS and analyzing that system in order to have an idea of how to use Open DSS efficiently.

Once we have the points plugged in, we will then take a look at the High PV effects on a system like this one. That way we will have a general idea of the issues that arise and what to look for when working on the actual system.

We will hopefully receive the actual system from Alliant Energy by the end of the semester, this will give us some time this spring to brainstorm solutions and even start plugging points into Open DSS.

In terms of the Fall 2015 semester, we intend to use that semester in order to design a workable solution and get the entire system with the solution simulated in Open DSS. Our final product will be this simulation, as we cannot build a full working model of the system. The model will show the effect of High PV and how a solution like ours will help. Below is our latest timeline for the rest of the semester (until May)

Week	1	2	3	4	5	6	7	8	9	10
Find Project	■	■	■	■						
Finalize Design Details					■	■				
Work with Open DSS					■	■				
Analyze Simulation Results							■	■		
Brainstorm Solutions							■	■	■	
Test Solutions										■

Feasibility

We feel that this project is a quite feasible on our side. We have the design tools necessary to accomplish the task, and have taken the right classes in order for our design process to go smoothly. We have some design experience in our group, so we should be able to adapt somewhat smoothly.

The probability that a project like this one is actually implemented by a company in the industry in order to solve a real world issue is not really up to us. Since companies in the power-planning industry typically take on many projects at a time, there is the possibility that a project like ours will not be at the top of one of these companies' list. However, we feel that with the research available, there is a strong possibility that a project like this could be adapted to work under a company's standards and end up actually implemented in the real world.

All in all, the feasibility of our project depends on many industrial factors, but luckily no factors at the student level. Therefore, the ability for us to design a project like this is rather high.

Cost Considerations

We have yet to fully nail down a hard number for the total cost of a solution due to having several possible solutions to the problem of High PV Penetration. Below is a list of possible solutions and some cost that we would possibly incur.

- Control System – Relay with CTs or other detection interface to route PV injections off the grid and then re-introduce to the grid for power usage. Capacitor banks for temporary storage

- Load Shedding - Relay with CTs or other detection interface. Also would have to have some sort of Automatic Transfer switch similar to the one's used in redundant power generation systems to transfer back and forth from the grid when the customer's own power generation does not meet their demand.

- Redirect DG Power Flow – Relay with CTs or other detection interface to route PV injections off the grid and then re-introduce to the grid for power usage. Additional Power distribution equipment to add and remove the injections when load restrictions apply.

- Storing of Excess Power – Relay with CTs or other detection interface to place or remove power from the grid during peak and off peak hours depending on the amount of power the customer is generating. Also, with this solution battery storage, maintenance, and waste disposal would have to be considered.

Market and Literature Survey

Software Research

Open DSS- Software that will help us perform the power analysis of the distribution system.

Literature

1. NREL Technical Paper NREL/TP-5500-54742- Case Studies on 10MW Plant near Carlsbad, NM, Fort Collins, CO, Colorado State University, Kapa's Solar Project Kaua'I Hawaii, 2MW Plant in Fontana, CA.
2. NREL Technical Paper NREL/TP-581-42305