HIGH PHOTOVOLTAIC INJECTION ON DISTRIBUTION SYSTEMS

DESIGN DOCUMENT

FACULTY ADVISOR

VENKATARAMANA AJJARAPU

INDUSTRY CLIENT

ALLIANT ENERGY

Project Charter

Project Name	High Photo-Voltaic Injection 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	March 13th, 2015	First Iteration of Document
R2.0	April 27th, 2015	Updated to Include Simulation Data

Table of Contents

Project Overview

Abstract

With the increase in consumer green energy there has been a surge in High PV penetration or backflow into distribution systems. The current designs (implemented in the 1950's) of the distribution systems cannot handle the power leaving the customer's inverter and feeding back into the distribution system. This is causing issues to consumer and industry utility equipment changing the power factor and putting the network out of phase. This can also cause issues with customer/utility safety, harmonic imbalance, and fault behavior.

Background

Photovoltaic (PV) solar cells are a cost effective manner to reduce energy costs and carbon emissions. Consequently, this has resulted in an increase in installation of PVs on residential homes and farms. However, there are often times when the PVs generate more power than is being consumed by the resident. To dissipate this excess power, the PV inverters are connected to the distribution grid. This defines a concept called Distributive Generation (DG). DG can result from multiple sources including but not limited to: wind turbines, gas generators, and geothermal generators. However, a vast majority of the DG comes from PV cells.

Initially, the DG was not a huge issue to the power company. In fact, it was beneficial since it allowed the company to provide less power to the distribution feeder. However, with the rapid increase in DG on many distribution feeders, the utilities company have found themselves dealing with a new problem. The DG caused by PV penetration can peak and cause the utility equipment to exceed their rating limit. This can result in damaged equipment, power outages, and loss in capital.

Objective

There are two main objectives to this project. The first involves locating and identifying potential problems to the feeder. Using OpenDSS or equivalent modeling software, tests will be run on the distribution feeder. These tests will determine specific issues that arise when PV penetration increases over time. It will highlight the major issues and where they are located. Once this is determined, the second objective can be completed.

Once the major issues and contingences have been identified, a proper solution can be forged. In order to maintain sustainability and stability, the protection system of this feeder will need to be upgraded to deal with the increase in DG.

System Level Design

System Requirements

Detection and analysis:

The proposed solution would have to be an “active listener.” Meaning that we need to use conventional equipment that already exists on current distribution network that would be able to detect when the network is receiving extra DG power-flow across the lines. With light modification we should be able to employ minimal equipment to customer’s existing setup thereby hopefully limiting additional cost to Alliant Energy and their customer’s.

Functional Requirements and Decomposition

The solution to the issue will require many sub-solutions to achieve our overall goal: Reducing high photo-voltaic feedback through the power distribution grid.

- Phase one:

  Control – this section of the solution will be used to analyze the network and detect potential feedback during peak usage, high demand times, or excess generation by the customer. This system, that may to be added by Alliant Energy, would then send a signal to tell the next phase go into action.

- Phase two:

  Redirecting DC generated power flow – in this portion would tell the customer’s solar array to stop inverting the power to an AC form and use the DC generation to be stored in phase three.

- Phase three:

  Storing excess power – As the customer generates power in this phase it will be stored in a bank of batteries, potentially Lithium+, then once the load on the grid exceeds generation the system can then convert stored power into AC and redistribute the electricity back on to the grid.

Once demand has returned to nominal levels the system will resume normal function until it detects a potential issues.

Nonfunctional Requirements

- Battery bank size and charging constraints.
  Once we have determined the power-flow analysis we be able to determine the size and charging constraints needed for battery storage.

- More TBD

System Analysis

Services

The following data will need to be generated on a real-time basis. Then provided to us as a snapshot over a specified time interval.

- Demand on current load
- DG generation by customers
- Power input by generation
- Key peak times

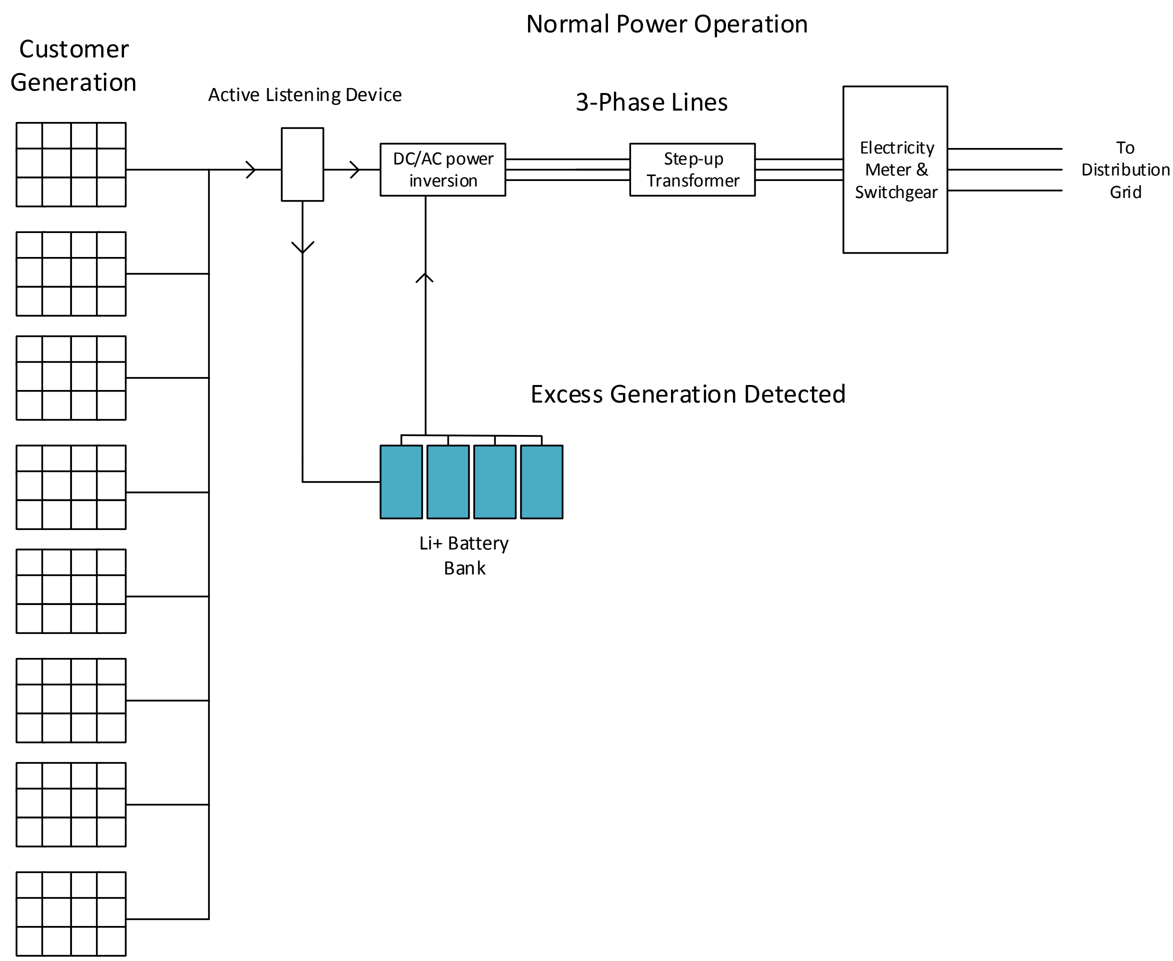
Data

Data will be provided to us from Alliant Energy. Although at this time we do not know how it will be given to us. We do know that will when we do receive it we will most likely have to manually enter it into our distribution analysis tool: OpenDSS. This data will be a snapshot of current demand on the gird and will allow us to execute preliminary analysis. Once this is achieved we will receive updated data weekly to modify and execute our solution.

Interface

Our primary tool will be OpenDSS. This distribution software will allow us to analyze and review our results after each test or simulation.

Block Diagram



Detail Description

For this project, we will be simulating our solution through OpenDSS.

Input and Output

With OpenDSS, we will be inputting the different potential PV levels at different buses. We will do this by attaching PV generators at different nodes and varying the percentage of the load that each one pumps back into the system. With this, we will be able to receive the voltage, current, and power values at all of the different buses.

The program will also allow us to input different load demands over a 24 hour period and receive the changes in what is supplied to the loads during the same period as the amount of PV in the system changes.

Specifications

OpenDSS is compatible with the some of the PC's on campus. Therefore, compatibility will not be an issue, as we plan to consistently be working with the computers on campus that contain OpenDSS.

Simulation

We do not intend for our final product to be a physical model, but instead a simulation in OpenDSS of the Alliant Energy system with critical values under different PV conditions. We will be able to show how the system would act without our solution methods, as opposed to with them.

Challenges

The bulk of our challenges will lie in our knowledge of how to use OpenDSS to its fullest. We will need to make sure we are using the OpenDSS manual to make sure that nothing is left out of the system. We will also need to make sure that OpenDSS is simulating the most real condition possible. If there are certain daily trends or other factors that are crucial to the simulation, we cannot leave them out. Studying the manual will be crucial.

Another area that could prove challenging is code accuracy. We will need to make sure that the correct devices (regulators, capacitors, etc.) are turned on or off when they are supposed to be.

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.

- 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.

Works Cited

1. Ochoa, Dr Luis. "Https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:229196&datastreamId=OpenDSS_Training_-_02_Introduction_to_OpenDSS.PDF." *OpenDSS Training Material*. Dr Luis Ochoa, 1 Feb. 2013. Web. 13 Mar. 2015. <https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:229196&datastreamId=OpenDSS_Training_-_02_Introduction_to_OpenDSS.PDF>.

2. Yost, Colin. "The-Interconnection Nightmare in Hawaii and Why It Matters To The US Residential PV Industry." *Http://www.renewableenergyworld.com*. 1 Feb. 2014. Web. 1 Apr. 2015.

3. "What Happens to Excess Energy Fed Into The Power Grid." *Http://electronics.stackexchange.com*. 1 July 2014. Web. 1 Mar. 2015.

4. "Inverters and Grid Integration." *Http://www.pv-system-tech.com*. 1 Jan. 2014. Web.

5. "Segis Concept Paper." *EERE.energy.gov*. 1 Oct. 2007. Web. 5 Mar. 2015. <https://www1.eere.energy.gov/solar/pdfs/segis_concept_paper.pdf>.