HIGH PHOTO-VOLTAIC PENETRATION AND THE IMPACTS ON DISTRIBUTION SYSTEMS

DESIGN DOCUMENT

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Project Charter

Project Name	High Photo-Voltaic Penetration and the Impacts on Distribution Systems
Project Field	Distribution Protection Systems
Class Group	EE/CprE/SE 492 Senior Design: Dec15 – Group 20

Team Member	**Position and Responsibilities**
Shane Thompson	Team Leader
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Revision	**Date**	**Description**
R1.0	March 13th, 2015	First Iteration of Document
R2.0	December 8th, 2015	Second Iteration of Document

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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, industry and utility equipment by changing the power factor, placing the network out of phase and causing increased voltage levels that exceed system equipment ratings. 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 associated with electricity generation. 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 utility companies 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 Alliant Energy's modeling software (Synergi), 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, which is trying to find a way to alleviate the issues caused by High PV injection can be completed.

Once the major issues and contingences have been identified, a proper solution can be developed. We will plan to look at solving the issues on two levels; within the distribution system or at the PV generation level. Once each level is investigated we will analyze and decide which one makes the most economical since.

System Level Design

System Requirements

This project contained two sources of requirements. The first is the client, Alliant Energy. Alliant Energy is the utility provider for the area. Most requirements from Alliant are focused on keeping their distribution grid up and running. The second source is the customers of Alliant Energy. The customers with solar panels have requirements that mainly focus around safety, cost, and reliability. The requirements of the system are broken down into functional and nonfunctional requirements.

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.

The first functional requirement from Alliant Energy is to make sure the solution has no negative long term effects on the system. These negative effects include high/low voltage levels, power backflow, voltage flicker, and line faults. The main effect focused on in this project is high/low voltage. The second requirement is to keep voltages within the acceptable voltage range. The acceptable voltage ranges are determined by Alliant Energy's standards. The standard is to keep the step down residential voltage between 118.3 V and 126 V. The third functional requirement is to prevent equipment overuse. With the variable generation of solar panels, the voltage levels are constantly fluctuating. This causes line equipment such as voltage regulators and capacitors to constantly switch on and off. Eventually this will cause the life time of equipment to decrease over time.

The other functional requirements are from the perceptive of the customer. There are two functional requirements from the customer. The first one is to provide reliable power to the customer 24/7. This means that the customer's power should never go out. The second requirement is cost. The customer doesn't want to pay any additional costs. They also what to have a reduced utility cost due to their solar generation.

Nonfunctional Requirements

The first nonfunctional requirement is the ease of integration on the system. The solution cannot be a complex system that involves extensive redesign of the electrical grid. By keeping the complexity down, lowers the cost on Alliant Energy. The other nonfunctional requirement is for the safety and reliability of the customer. The solution must provide the customers with reliable power and insure safety for the customers, operator, and installer.

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 and was given in a format that was already incorporated through their software distribution analysis tool, Synergi. From there we analyzed raw data from monthly meter readings stored in a spread sheet that allowed us to observe peak generation times and deduce when demand was at its lowest. With this information we then used Synergi to employ several single phase generators to be placed on the distribution lines. This data is a snapshot of current demand on the gird and will allow us to execute primary analysis. From there we implemented several what if situations and simulations that helped us derive the best overall solution that would achieve the maximum desired result for Alliant.

Interface

Our primary tool will be Synergi. This distribution software will allow us to analyze and review our results after each test or simulation and make modifications and recommendations based on those simulations and results.

Block Diagrams

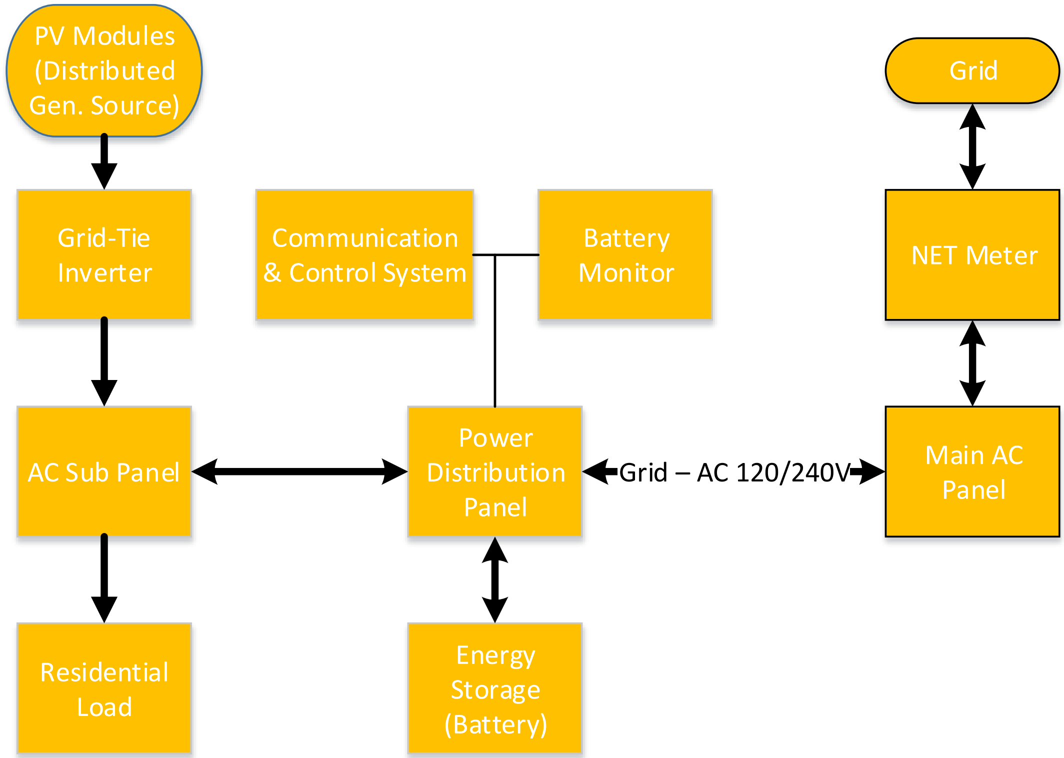

Figure 1: Basic Overview of Decision Scheme for Solar Inverters

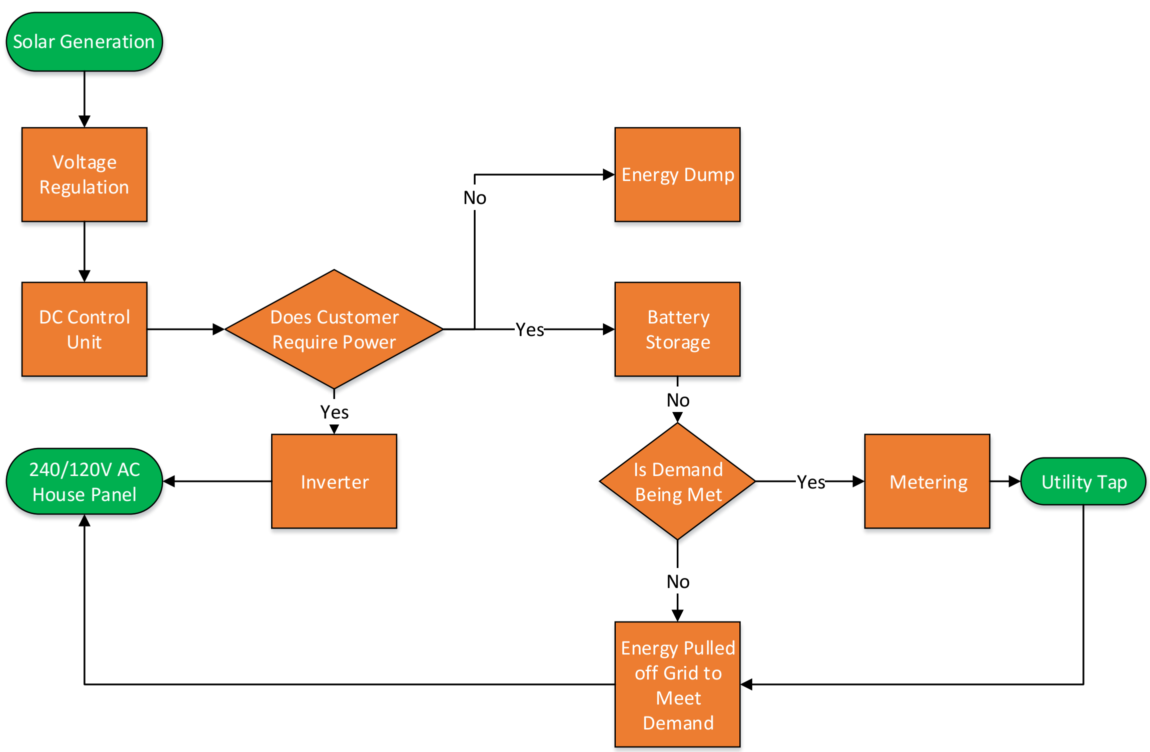

Figure 2: High Level Overview of Solar Generation and the Decisions Made to Tie the Energy to the Gird or Customer's Home

Detail Description

For our solution, smart inverters will need to be installed on the PV sites in order to insure that the voltage level is controlled.

Input and Output

The input for our system would be the PV generation. This generation will flow through a grid-tie inverter and into an AC sub panel. This sub panel will then determine how much of the PV generation is required for the residential load, and how much is left over after the load is considered.

The leftover generation will be sent to a power distribution panel that will determine where it should go from there. If there is a battery storage system in place, then generation will be stored there.

All leftover generation from this point will flow to the main AC panel, through the net meter, and then back onto the grid.

Specifications

The inverter will need to be acceptable by Alliant's standards. Alliant would like this to be a standard that they can reuse for similar instances in the future. Therefore, we need to insure that a specific type of smart inverter is pleasing to Alliant.

Final Product

We believe the Conext XW+ is the best option for solving this problem. The Conext XW+ is a sine wave inverter manufactured by Schneider Electric that is available for both commercial and residential use. This inverter can be used for off-grid, grid back-up, and grid interactive applications.

The Conext XW+ is a DC to AC inverter, battery charger, and transfer switch. It can be used with renewable energy sources in a hybrid environment.

This inverter can manage and prioritize energy sources, while delivering a true sine wave output. It can also operate in up to a 70˚C climates, and it's support functionality will help out with small generators with heavy loads.

Our final product will be a combination of simulations of the problems that currently exist on the system and what a typical inverter of this type could do to solve this.

Challenges

The bulk of our challenges appeared when it came to options versus money. Increasing the voltage on the lines would be a pretty end-all solution. However, it would cost Alliant too much money for our group to assume that this option would be the most ideal. Therefore, we settled on smart inverters.

Another area that included some challenges was trying to simulate future growth. When simulating this, we tried to pretend like future PV sites would be distributed all over the model. However, this could very well not be the case. Many customers in a small land area could decide to install PV sites at the same time. The placement of PV sites on the grid really determines the results, and different placement could mean more problem areas.

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