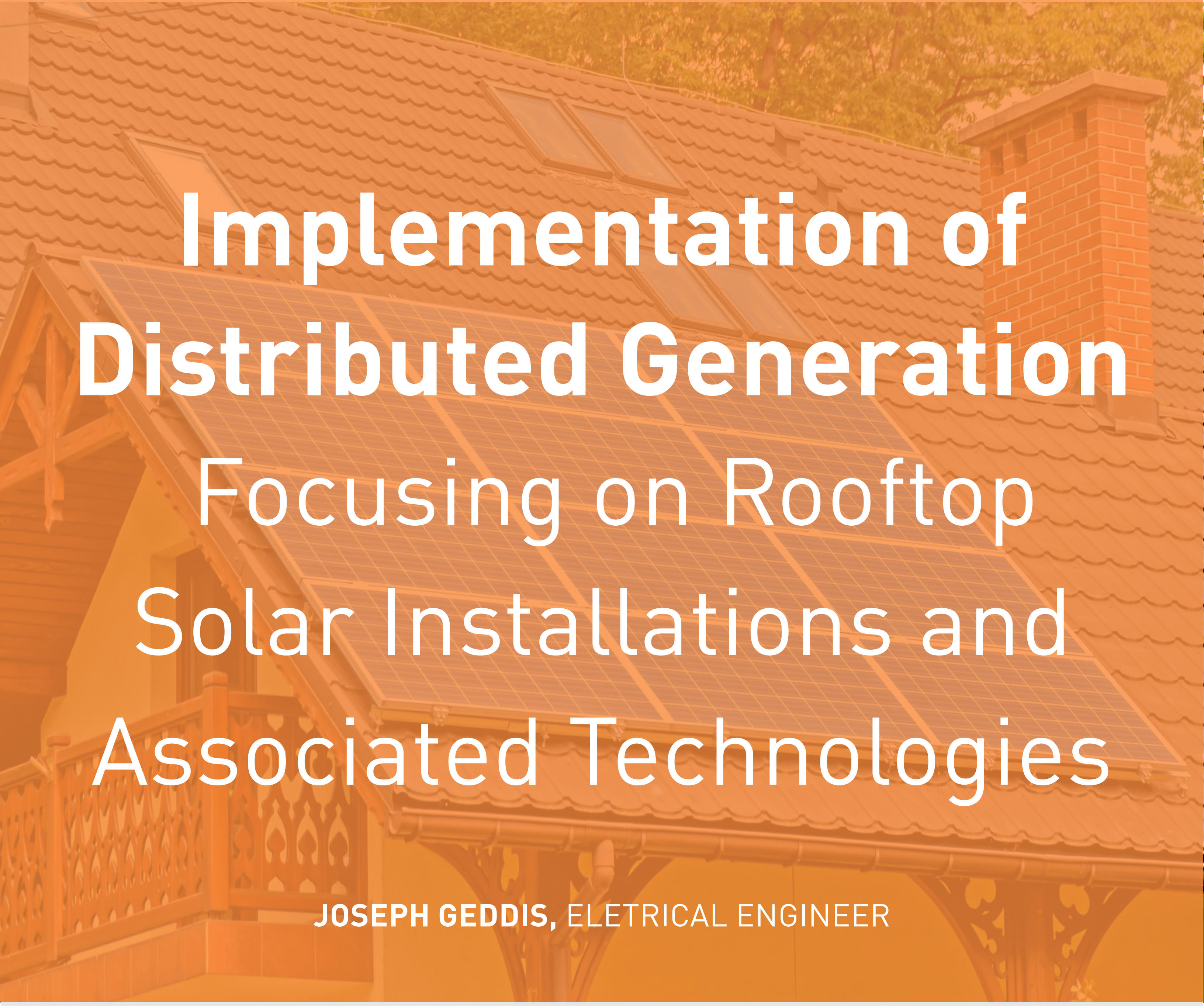

Implementation of Distributed Generation

Focusing on Rooftop Solar Installations and Associated Technologies

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Residential rooftop solar generation installations have been increasing at a fast pace over the last decade. As a result, utility companies are working to accommodate the distributed generation (DG) being connected to the electrical grid. Given that the grid was designed in the mid-1900s, it was never intended to have small scale DG scattered throughout circuits. It was designed to have large, centralized generation plants supply power to the grid on a constant basis and in a one directional power flow from the generation source to the customer. Today, customers are not only consuming power from centralized power plants, but they are also producing power themselves and feeding excess power back onto the electrical grid. DG resources are quickly driving changes in how the grid is used by end users. The rapid change has created several problems for utility companies including overvoltage, efficiency concerns, and voltage fluctuations causing flicker for customers. However, utilities are exploring options to accommodate the rise in DG and, more specifically, residential rooftop photovoltaics (PV). The integration

Figure 1: Residential rooftop solar generation installation.

of an increased amount of DG onto existing electrical distribution systems will have more difficulties, but the innovation of the electrical generation industry will force utility electric providers to evolve with these technologies.

A key issue with solar installations is that the peak generating time for solar generators is between 10:00 am and 1:00 pm[1], which is during the low load time of the day for electric utilities. This can create a problem with voltage levels at the point of interconnection for customers because their peak voltage will be during the peak generating timeframe for the PV system. As we evolve to meet new demands, a new technology has emerged that can potentially mitigate and allow widespread use of residential rooftop solar installations. The new technology must be tested and accepted by testing laboratories and electrical utilities alike, but it will offer benefits to both the customer and utility when implemented properly. This isn't the only innovation in this area. Emerging technologies for rooftop solar designs include batteries, smart inverters, and variable inverter settings. These technologies can be coupled with a strategic redesign of the utility distribution system leveraging conservation voltage reduction (CVR) and capacitors.

Voltage levels are mandated to be delivered to residential customers at +/-5% of 120V base voltage, i.e. between 114V – 126V[2]. When the grid is operating and utilized by customers in the manner it was designed for in the mid-1900s, there are minimal voltage issues. The problem arises when DG systems are connected that create a voltage rise while back feeding power onto the grid. This issue is exacerbated further when solar generators back feed power onto the grid while the grid is at its peak voltage of the day. Customers may now experience prolonged periods of time above the mandated 126V at the Point of Common Coupling (PCC). The Power Quality Distributed Generation Workbook from the Electric Power Research Institute (EPRI) is one method to analyze the voltage rise caused by a solar generator or any DG system. If the voltage rise is too high, there are options to lower the voltage rise from the DG system or lower the circuit voltage during low load times to fall within the allowable voltage bandwidth.

Companies within the distributed generation industry are developing new technologies that work with the current distribution systems to allow for the connection of more residential photovoltaic systems.

One method to lower the circuit voltage is to implement CVR, also known as voltage optimization (VO). Many times, on longer circuits or circuits with lower primary voltages (i.e. 5kV), the PCC voltage at loads near the substation will be 126V to ensure the customers at the furthest point from the substation have an acceptable voltage during peak usage times. This means that some customers toward the front end of the circuit are already at 126V at their service point. With these customers at 126V, there is no voltage headroom to implement a rooftop solar installation that will result in voltage rise to the secondary distribution system[3]. Depending on the secondary circuit design, the voltage rise caused by DG systems could push the customer with PV and their neighbors above 126V. This is in violation of the regulated voltage bandwidth and can damage sensitive electronics within these homes. CVR would effectively allow substations to provide power to customers at a lower starting voltage while remaining in the allowed voltage bandwidth[4]. The disadvantages to using CVR are the costs and implementation time associated with this undertaking. Power utilities have thousands of circuits that essentially need to be redesigned to allow for effective CVR to take place.

As mentioned above, companies within the DG industry are developing new technologies that work with current distribution systems to allow for the connection of more residential PV systems. These technologies include: variable settings on inverters, smart inverters and battery storage for PV systems.

Figure 2: Home solar panel installation.

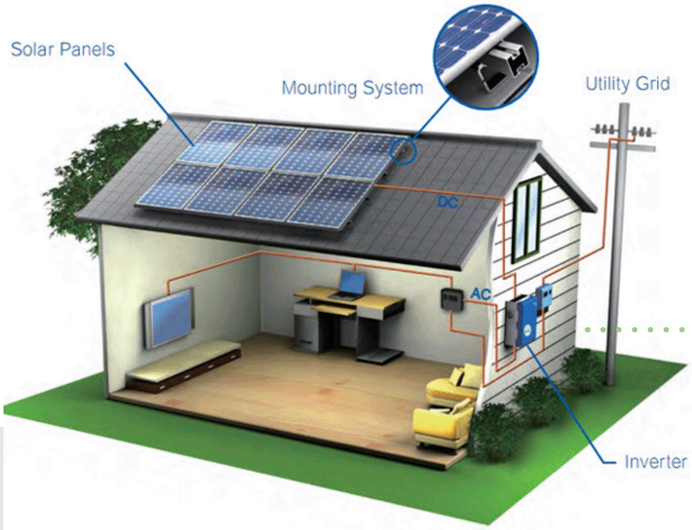

Figure 3: Typical components of a residential solar electric system.

Figure 4: Close-up view of an inverter, meter and disconnect switch.

INVERTER SETTINGS

One factor that can be changed to allow for interconnection and back feeding onto the electrical grid is the power factor setting of the inverter. The power factor can be altered to curtail generation back feeding to the utility system to minimize the voltage rise. A non-unity leading power factor produces real power along with reactive power to effectively reduce voltage rise. The increase in reactive power must be minimized to ensure the stability of the electrical utility system. The reduced power factor will slightly reduce the net metering credits (customer payback) produced by the PV system, but it will allow for a safe and reliable connection to the electrical grid. The reduced power factor setting needs to be within the allowed power factor setting determined by the electrical utility.

SMART INVERTERS

One of the main components of a PV system is the inverter. An inverter converts direct current (DC) power produced by the PV system to alternating current (AC) power that can be used to feed a residential electrical system or feed back onto the electrical grid for net metering credits. Inverter manufacturers are developing smart inverters that control the output of power from the PV system onto the grid or even switch where the PV generation is sent (i.e. batteries). Smart inverters are capable of a variety of different modes to function in, but the key part of the design is to sense the grid voltage and frequency incorporated with a feedback mechanism that allows the smart inverter to change the power output characteristics to create a stable grid. Controls within the smart inverter can minimize, or even stop, the back feed of power onto the distribution system which curtails any voltage rise associated with the PV system, with reference to the Utility distribution system. The main downside is that net metering credits are now being minimized, or completely stopped, from accruing and the utility customer is not realizing the full benefits of the PV system. The output control of the inverter would have to monitor the voltage level at the point of interconnection with the utility to sense when back feeding can and cannot take place. The minimization of the net metering credits won't take place all the time, only when the circuit is experiencing high

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voltage during the low load times of the year or day.

BATTERY STORAGE

One of the more useful ways for the customer to minimize the voltage rise is to install a battery bank connected to the PV system that charges when excess generation is produced. The excess generation is not fed onto the utility grid, but instead charges the battery bank which is then discharged during daily peak generation hours (i.e. 5:00 pm -9:00 pm) or used as emergency backup during a loss of utility power. The disadvantages to battery usage are price and battery storage locations. The use of batteries allows for customers to realize the full benefit to having a rooftop PV system while avoiding issues from the utility, namely high voltage during low load times. Utility customers are still able to offset their bill by using the power generated from the PV system, and the customer has excess power stored as emergency backup.

As alternative energy sources progress into the future and the residential availability of DG increases, new challenges will be introduced into the implementation of these systems. One challenge that has already been identified is how inverters function. Currently, inverters match the grid voltage and frequency, which allow the inverter to feed power onto the grid at the same frequency and a slightly higher voltage. As DG and other inverter-based generation become more prominent, inverters will need to drive voltage and, more importantly, frequency of the grid. Large centralized synchronous generators currently drive the grid frequency. These generators create enough mechanical inertia for a stable grid frequency. Large generation plants will eventually be phased out of operation as generation becomes more localized with residential DG systems. We live in a fast-changing world. Equipment like smart inverters, batteries and grid feedback devices will be crucial to the development of the electrical grid moving forward.

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Joseph Geddis is one of Primera's electrical engineering experts. His expertise is the result of nearly 5 years of experience with projects from the proposal stage to the commissioning stage and power delivery to equipment or customers. His experience includes project proposals for plant wide electrical distribution systems, ETAP studies, power delivery center design, factory acceptance tests for electrical equipment, field testing/commissioning/ troubleshooting, identification of risk areas and cost saving opportunities for electrical designs.

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