Integration of Distributed Energy Resources (DERs) and Potential Solutions

Chase Sun
Integrated Grid Planning
Grid Integration and Innovation

PG&E®

Objectives of Renewable Integration

- Maintain current safety and reliability
- Maximize the amount of interconnected renewable resources (both T&D), to meet GHG goals
- Minimize interconnection and system upgrade costs
- Lower energy costs to load customers
- Enhance System power quality and reliability

Pacific Gas & Electric Company (PG&E)

Company Facts

- Fortune 200 company located in San Francisco, CA
- $16.8B in operating revenues in 2015
- Over 20,000 employees

Energy Supply

- Services to 16M people:
  - 5.4M Electric accounts
  - 4.3M Natural Gas accounts
- Peak electricity demand: Approx. 21,000 MW
- Approx. 60% of PG&E's electric supply comes from non-greenhouse gas emitting facilities

Service Territory

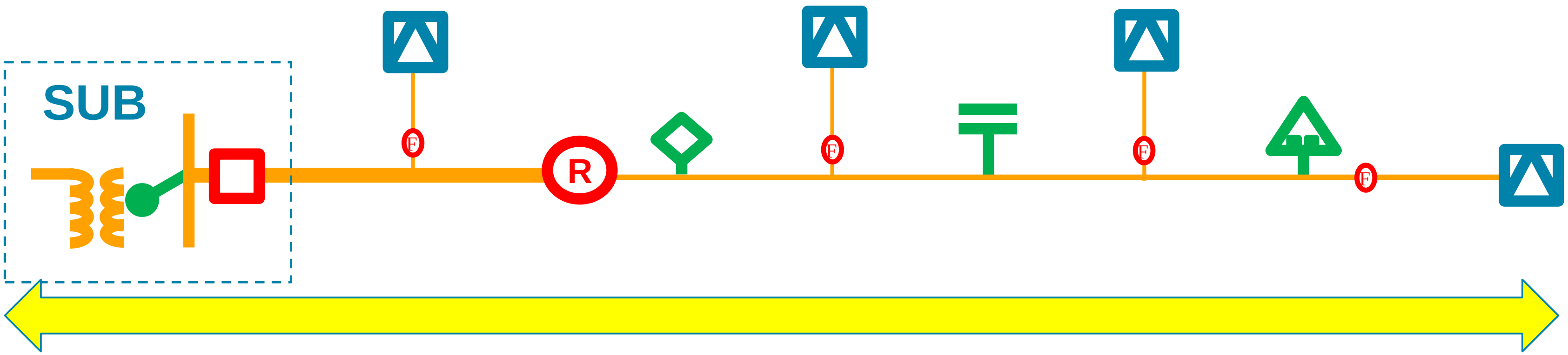
- 70,000 sq. miles with diverse topography
- 160,000 circuit miles of electric trans. and dist. lines
- 49,000 miles of natural gas trans. and dist. pipelines

Source: http://www.pge.com/en/about/company/profile/index.page , CEC California Energy Demand Forecast 2014-2024 Preliminary Forecast and PG&E 2015 10-K filing

Existing Distribution System Design Challenges

Challenges

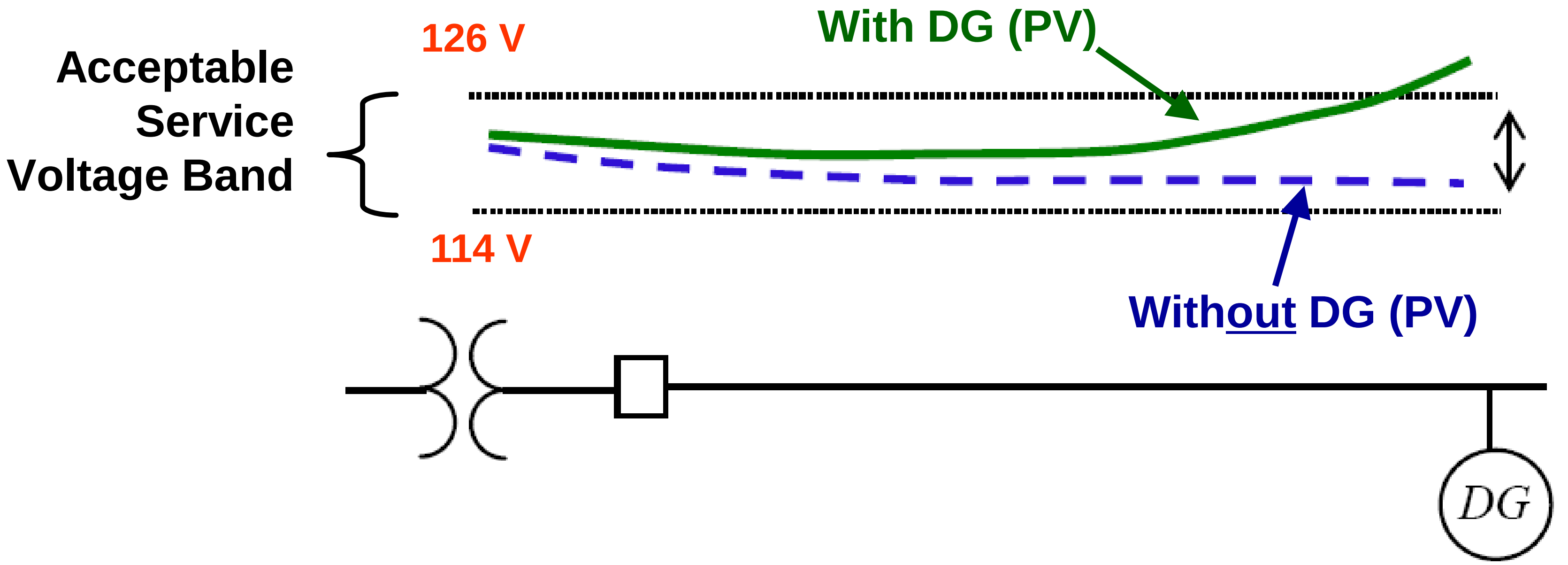
- System designed to serve load and regulate voltage radially, from a single source, with progressively smaller conductors, sized to carry local radial load, to ensure affordability.
- Most of the distribution conductors are small and susceptible to large voltage fluctuations due to moderate power flow
- System is regulated to +/- 5% of nominal voltage, using tap changing regulators, to provide proper steady state voltage automatically, from zero to full load, to distribution customer equipment.
- System not designed for bi-directional flow associated with generation.
- PG&E limits the distribution voltage fluctuations by relying on load diversity and limiting the largest single load that can be operated at a given time.
- DER presents challenges when there is reverse flow that cause higher voltage than anticipated in the original design.



DG Voltage Concerns

Electric Rule 2

Nominal Two-Wire And Multi-Wire Service Voltage	Minimum Voltage To All Services	Maximum Service Voltage On Residential And Commercial Distribution Circuits		Maximum Service Voltage On Agricultural And Industrial Distribution Circuits
		Class A	Class B	
120	114	120	126	126
208	197	208	218	218
240	228	240	252	252
277	263	277	291	291
480	456	480	504	504



Existing Requirements – Rule 21

If the DG is operating within the existing distribution system design parameters, with no reverse flow, it has minimal system impact.

Rule identified low impact conditions and provided simplified requirements to allow small DG units at low penetration levels to be interconnected quickly as long as safety issues are addressed.

Typically, there are sufficient existing design & operating margin to accommodate the small DG units when they trip off-line.

This significantly simplified the review & approval process and reduced the interconnect review time for the small units.

Typically, the small NEM PV units < than 30 kW can be approved and interconnected in < than 5 Working Days.

1. Majority of the existing inverters designed for low penetration, grid interactive mode, set at unity power factor and certified not to operate when the grid is de-energized (certified anti-islanding)
2. Grid interactive inverters produce the maximum available energy and rely on the grid for voltage and frequency support, as well as back-up service when the DGs are not generating.
3. Some inverters are designed for stand-alone operation and have the capability to follow load and regulate voltage after they are isolated from the gird. But schemes are more customized, costly and complex; requiring more engineering.

Existing Power Systems Characteristics & Requirements

Existing AC Grid Characteristics

- Distribution system was designed to serve load in a radial (tree) configuration and collected all of the loads to capture load diversity. This configuration allowed the lowest level of total generation capacity to be needed. On a per kW basis, generation was the most expensive component on the power system.
- Transmission system was designed in a mesh configuration with multiple paths and big conductors for bi-directional flow and reliably tied the expensive generators to the grid and the loads. This configuration allowed the lowest cost generation resources to be used and also reduced the amount of redundant generation needed for reliable operation.

AC Grid Requirements (Including microgrids)

Load and generation on the grid must be dynamically balanced at all times.

1. Adjust total generation output level, add reserve generation or curtail generation to match total load (traditional set-up)
2. Adjust load level by shedding load, or insert load banks (used only during emergency conditions)
3. Grid utilization voltage and frequency and power system equipment maintained within design limits

Preparing for the Future

Anticipated Changes

- **At higher penetration, cumulative DER impacts are no longer negligible**
- **Current interconnection requirements are being revised or revised (IEEE 1547, UL1741 and Rule 21)**
- **Ride through capability being expanded to avoid common mode failure**
- **Smart Inverter functionality mandatory by 9/8/17, certified to UL-1741 SA**

At high penetrations, there may be opportunities to realize more DER benefits. But DERs may need to designed and operated to meet power system and resiliency needs, instead of simply providing the maximum amount of as available power which is the current DER operating mode. Unless designed for a specific application, the generators may not provide the expected benefits.

Emerging Issues and Questions

At what local penetration level should utility start to actively consider microgrid operation? Simplified assumptions of 20% PV capacity factor and 40% load factor are used in the table below.

% PV Penetration Level	% of daily load energy supplied	% load that needs to be shed to enable continuous microgrid operation
50%	25%	75%
100%	50%	50%
200%	100%	0%

- Based on the tabulation above, PV penetration below 50% may not yield significant benefit for microgrid/resiliency operation since 75% of the load will need to be shed. But if the critical load is less than 25%, and/or a shorter duration support is acceptable, microgrid mode may be viable. The above simplified assessment did not take storage conversion losses into account, nor the need for potential larger storage inverters to carry the momentary motor loads.

What are the incremental benefits of microgrid operation and the associated costs to enable this mode of operation?

For feeder/area microgrids, which customer load should be tripped if there are insufficient renewable DG in the local area?

What is the proper mix between transmission and distribution connected renewable generation from a ratepayer perspective?

Potential Solutions to Minimize Adverse Impact and Reduce Cost

1. **Limit behind the meter installations to non-export**
   - Allow the distribution system to operate with power flow in one direction and may significantly reduce the adverse impacts and associated mitigation costs.
2. **Connect larger installations to large mainline conductors close to substations.**
3. **Connect the large units with dedicated feeders to avoid causing voltage problems with other distribution customers.**
4. **Install batteries on larger PV installations and modify the inverter design to ramp power up and down gradually to minimize voltage flicker, as needed.**
   - Allow the voltage regulators sufficient time to correct for voltage fluctuations due to sudden PV/wind output changes during cloud movements/wind gusts. There may be some increase in wear and tear on the existing voltage regulators.
5. **Use smart inverters, volt/var and volt/watt, to control reverse flow voltage within limits.**
6. **Use storage for load/generation peak shaving and short term UPS applications.**
7. **Design the PV to align the PV output closer to load peak.**
8. **For microgrid applications, consider using fuel-based generators, in addition to short term storage, for infrequent long outage support.**
9. **At high system-wide PV penetrations, use TOU rates to shift the load peak close to noon and minimize the need to deploy expensive batteries.**

Enable a broader set of DG capabilities, including storage, to fully utilize resources to support the grid.

Questions?