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# PACIFIC GAS AND ELECTRIC
# INTEGRATION CAPACITY ANALYSIS
# FOR DISTRIBUTION RESOURCE PLANNING

## DEMONSTRATION A – ENHANCED INTEGRATION CAPACITY ANALYSIS

*REPORT: PG&E ICA METHODOLOGY DETAILS AND TECHNICAL ASSUMPTIONS*

*30 September 2016*

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# 1 SUMMARY

The ICA provides a unique approach towards evaluating distribution system limits to host DER across the entirety of a utility's service territory. The specific technique to the methodology has two main goals to ensure a successful and scalable analysis for the Distribution Resource Plan (DRP) which are (1) streamlined efficiency and (2) improved detail and granularity. These two objectives in general can lead to diverging paths, but the goal of the demonstration project is to determine if there is a best path forward to strike a balance between the two.

## 1.a Exploring and Testing Multiple Techniques

There are two calculation techniques being explored within Demo A. These are:

1. **Streamlined Calculation**
    - Simplified or abstracted evaluation based on equivalent algorithms with input from a baseline power flow
    - Requires less processing resources. Enables more batch output insights (e.g., for DER planning where multiple scenarios are needed)
    - May prove less precision in accuracy since resource is not directly modeled
2. **Iterative Simulation**
    - Requires powerful computing through simulation of iterative placement/upsizing of DER in model to simulate very precise conditions with many power flows
    - Good for voltage, but perhaps not necessary for all aspects of evaluation which requires intensive processing power
    - Increased confidence in accuracy due to direct modeling of resource

PG&E views the working group and demo projects as a path to test, compare and improve methodologies. Multiple techniques enhance innovation to tackle problems with a wide range of complexity, especially at this early stage. We may find that an iterative solution can serve more complex problems, while a streamlined calculation can serve simpler problems. Moreover, when multiple methods return similar results, we have increased confidence (triangulation, or convergent validity). PG&E also views a blended approach as more intelligent, less risky and more effective in enabling innovative, valid and efficient outcomes. For instance the streamlined technique can help direct iterative solutions in more effective ways which save time and processing resources.

### 1.a.i Streamlined Calculation

The developed streamlined technique utilizes advanced tools and data obtained from base power flow simulations. It performs analysis in an efficient streamlined approach that does not require directly simulating DER to observe impact. Creating approaches that do not rely on direct modeling and simulation of DER helps to enable system wide scenario analysis with much less processing requirements. For instance, batch power flows are performed to get important complex data such as ampacity flows, voltages, fault duties, and impedances. The final results are determined by inputting this data into streamlined equations to determine final integration capacity values. PG&E views this specific practice as utilizing “layered abstraction” to get very explicit answers with specific datasets. This approach enables streamlined calculation and is flexible given the level of detail in the models.

Performing explicit calculations in abstraction enables a streamlined process that takes significantly less time than iterative processing which also lessens the IT resource needs. As technology and IT innovates and gets better, more scenarios and advanced processing can possibly be incorporated to provide more baseline information and plausible scenarios.

### 1.a.ii Iterative Simulation

The Iterative Simulation is the direct modeling of new resources and iterative simulation for solving a feeder’s distribution hosting capacity. The simulation works by running a Power Flow analysis on a distribution network and iteratively adjusting the DER until a problem is found in the case. This allows for a greater amount of precision at the sacrifice of computational speed.

Due to the precision of this methodology, it is best suited for complex feeders where the streamlined approach has difficulty in streamlining the dynamic voltage device operations on longer circuits. Bulk system analysis can be streamlined by using the streamlined approach to help inform starting and ending points for iterations.

# 2 METHODOLOGY

PG&E's Integration Capacity Analysis methodology has three general steps: (1) establish distribution system level of granularity; (2) model and extract power system data; and (3) evaluate power system criteria to determine DER capacity. The specific processes within each are explained in the sections to follow.

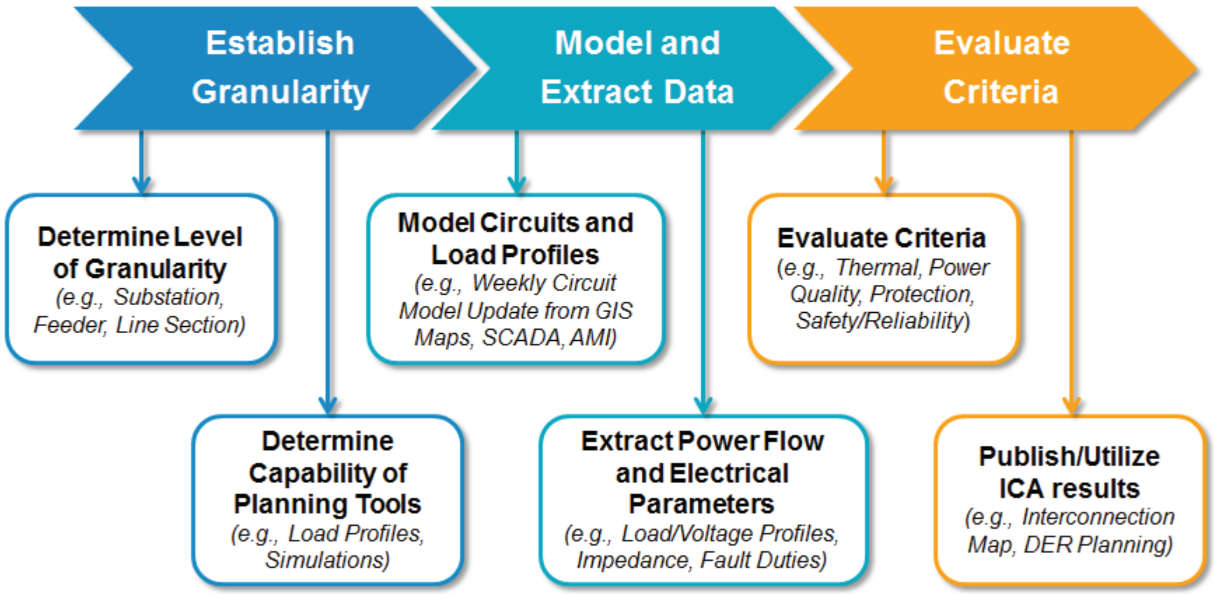



**Figure 1: General Framework of Methodology**

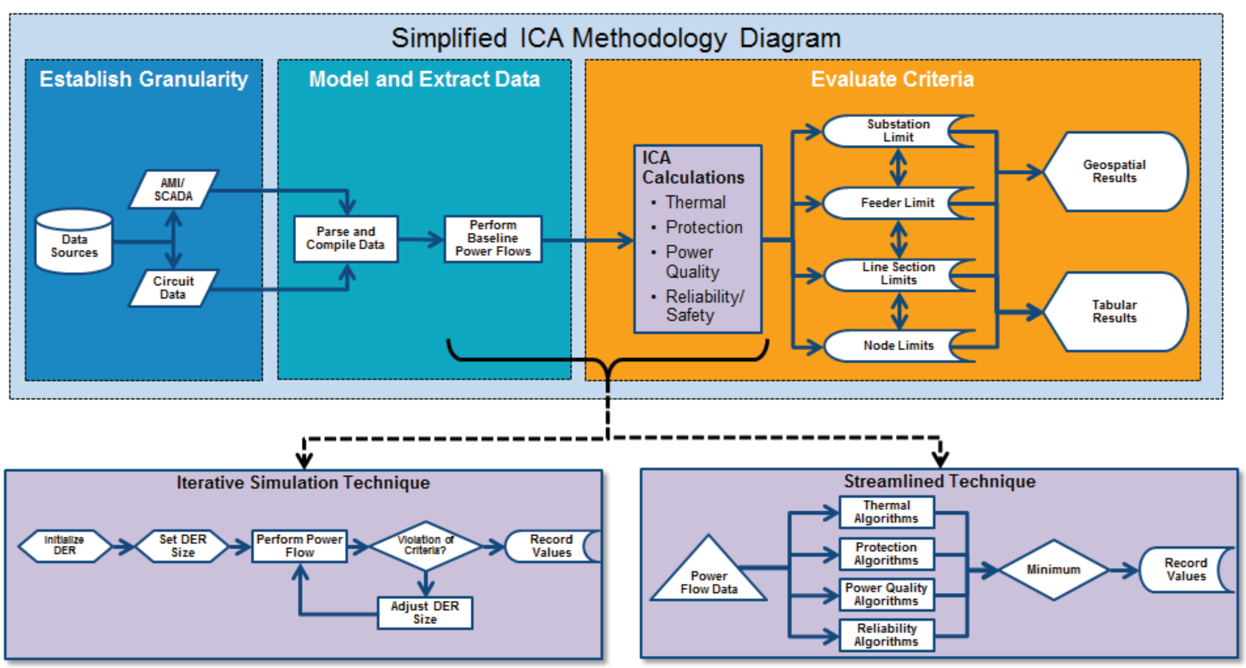



**Figure 2: Methodology Diagram and How Techniques Fit In**

## 2.a Establishing Granularity

The first step in PG&E's ICA methodology is to determine the distribution system level of granularity. The detailed distribution cirucit models in PG&E's toolset allowed for data to be extracted from distribution line sections and even down to each nodes on the primary side of service transformers.

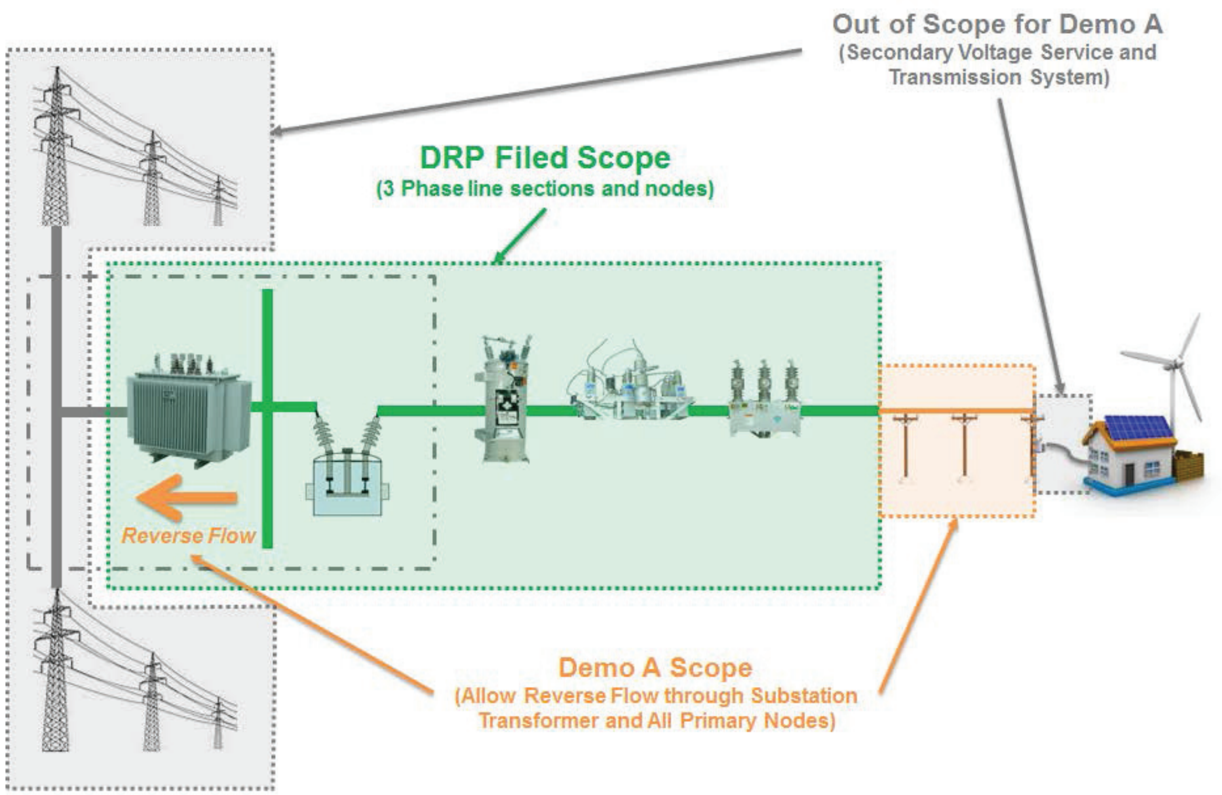



**Figure 3: Granularity of ICA for PG&E in July 1 2015 filing**

This level of granularity allows PG&E to obtain a very granular set of data which can determine the capacity limits for complex feeders, such as long rural feeders. Granularity is not just limited to downstream details, but upstream details as well. PG&E's dataset was sufficient to include analysis up to the substation transformer bank. This is where layered abstraction was useful for inclusion of additional components. PG&E's distribution circuit models are only modeled to the medium voltage bus of the substation. This means that the substation transformer is not specifically modeled. Without performing an evalaution of the transformer in abstract outside of the cirucit models, PG&E would have been limited in the ability to determine limitations from the substation transformer. This was important to consider as there are substations in the PG&E system where substation transformers are more thermally limiting than the circuit breakers and/or getaways that feed the distribution circuits.

One of the main goals of the DRP was to provide insight into very granular locational DER capacity on the distribution system. PG&E intends to explore transmission level analysis in the future to ensure transmission capacity limits are considered as well. If transmission conditions are not considered, locational ICA results totaled together may lead to over estimation of total system DER integration capacity.

It is important to acknowledge these bounds of the analysis and data. As mentioned, without doing so could lead to users compounding results to various system levels that may not have been included. For instance, users could add feeder level results for all feeders at a substation. Without understanding the transmission limits upstream, results could lead to improper siting and sizing decisions.

## 2.b Model and Extract Data

In step two of PG&E's ICA methodology, PG&E models and extracts the power system data needed by using two distribution planning tools. PG&E utilized commercially available tools (CYMDIST and LoadSEER) to extract the necessary level of granularity and detail required for the Distribution Resource Plan.

### *2.b.i Assumptions and Starting Points*

In order to ensure transparency and consistency within the methodology, the various assumptions and starting point parameters must be expressed. This will ensure parties that are looking to replicate or create comparable results on different datasets know what parameters to implement.

Various data points are used to help inform the power flow analysis. While some parameters are static and do not have any significant variance (i.e. conductor impedance), there are some parameters that could have some variation and need to be set for the analysis (i.e. starting voltage at substation). The sections are a listing of some of the assumptions and starting points PG&E used in the analysis.

#### *2.b.i.1 Substation Model*

Historically, PG&E's distribution circuits in CYME are modeled from the circuit breaker at the substation down to the primary side of customer service transformers. PG&E is in development of upgrading the CYME Gateway to translate the GIS data from the new GIS system being implemented. Included in the scope of this project is to expand the models to the substation components that electrically connect feeders on the same substation transformer. This project is still in development and Demo A is exploring the ability to include and utilize the substation models. While the substation model is not critical to all components of ICA, it does help in providing some more detail in the Power Quality criteria to understand adjacent feeder steady state voltage impacts. Figure 4 shows how CYMDIST utilizes a one-line model layer for subsation components versus the geographic model for distribution lines.

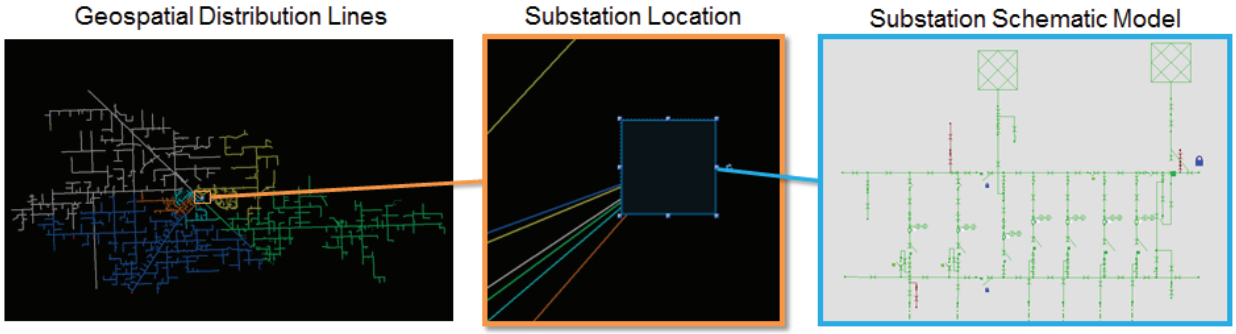



**Figure 4: Substation Models in CYMDIST**

Initial modeling and simulations have shown two learnings about modeling the extra complexities of the substation model:

1. Substation modeling requires simulation and convergence of multiple feeder models in unison versus separately. This increases computation times for each simulation.
2. Modeling the Load Tap Changer (LTC) increases the complexity of the model and does not always allow for convergence of power flow solution to solve

PG&E is attempting to see if these substation models can be effectively incorporated into the analysis for Demo A. Exploration of indirect modeling of the LTC is being performed by directly changing the source voltage based on the sliding scale of load through the substation. This has the same effect of the LTC without needing to directly model it.

*2.b.i.2 Model Source Parameters*

Two main components are necessary for the model source (1) Operating Voltage and (2) Source Impedance.

1. <u>Starting Voltage</u>
   - Sliding scale of voltage from 1.00 to 1.05 per unit
   - Sliding scale depends on load through substation which simulates the load tap changer
2. <u>Source Impedance</u>
   - Extracted from transmission network model distribution bus impedances

As mentioned, the substation LTC can be simulated in the model by dynamically changing the set point of starting voltage based on substation transformer loading. The source impedance helps simulate what the conditions would be based on the transmission characteristics at that location.

#### *2.b.i.3 Feeder Configuration*

Feeder configurations in the model are set to the normal as planned switching states. These configurations are what is used in the interconnection study process. Feeders are not often switched and, when applicable, Operation Engineers evaluate and study for possible issues. Future enhancements of ICA and automated analysis techniques will explore automation of possible abnormal switching configurations. The vast amount of possible switching configurations and computational burden will be an interesting hurdle. This is why PG&E proposed the method of evaluation called “Operational Flexibility” to estimate when possible issues could occur without performing millions of permutations on top of the already lengthy ICA analysis time.

#### *2.b.i.4 Spot Load Demands*

Each distribution service transformer is modeled as a “spot load” in CYMDIST. Historically these spot loads would contain customer specific information which would include monthly consumption values in kW-h. For the model to run power flows, specific kW demand values are needed for each spot load. Load allocations would be run to allocate a specific known demand at the substation to each spot load based on the monthly consumptions.

New Smart Meter data can be utilized with the known hourly consumptions to increase accuracy of allocations to a specific hour. Load allocation methods are still utilized to make sure the spot loads reconcile to a known demand at the substation. This hourly data helps improve the granularity and accuracy of the power flow models.

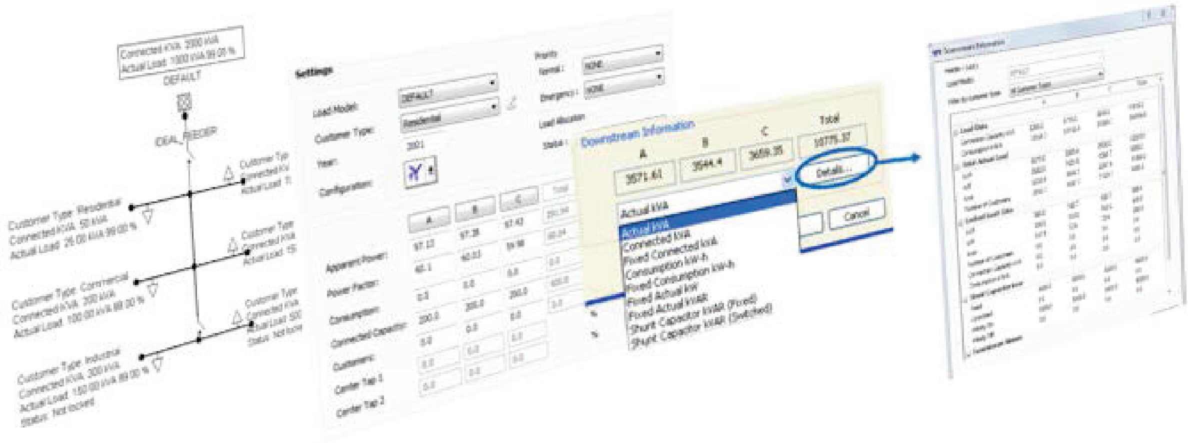


**Figure 5: Spot Load Details in CYMDIST to Input Granular Customer Data**

### *2.b.i.5 Load Shape and Profiles*

The following figures provide a visual example of the load shape profile versus a full detailed yearly profile. Figure 6 shows the real-time hourly profile for a year represented by 8,760 hours that show the actual demand for each hour of the year. Figure 7 shows the load profiles, which are built from the new dataset within the EPIC project. The analysis of this data allows for the creation of the simplified 576 profiles as required for the streamlined ICA assessment.

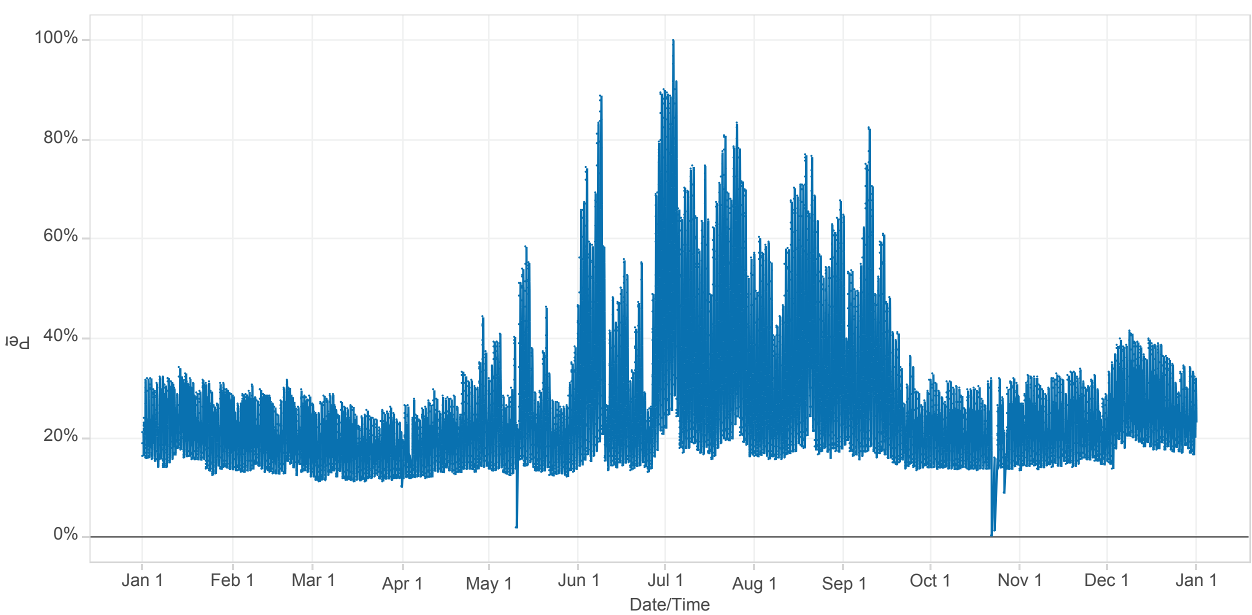



**Figure 6: Historical SCADA (8760 hours)**

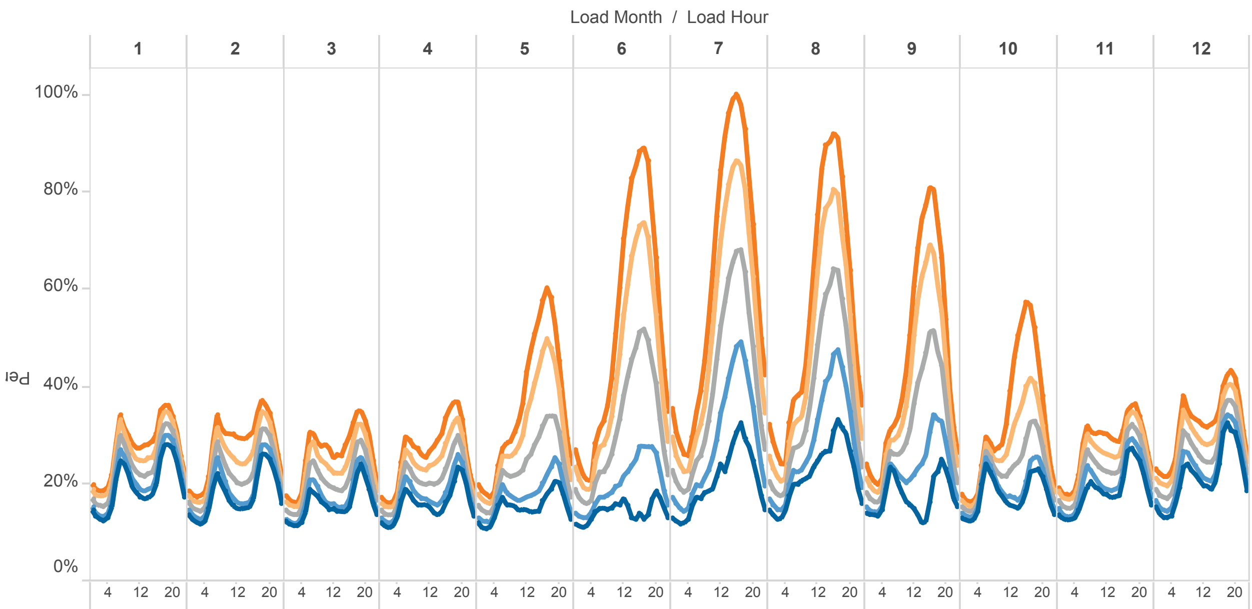



**Figure 7: Statistical Load Shapes built from Historical Data (288*X Hours)**

### *2.b.i.6 Balanced versus Unbalanced Power Flow*

Power flow algorithms have different approaches towards calculating and converging on power flow solutions for the model. The main reason for using one versus the other depends on the availability of phasing data. If phase data is not available, then balanced would be the appropriate technique since the actual phasing imbalance is not known for the circuit. If phasing is available then the appropriate phase conditions can be solved for and provided with an unbalanced power flow.

Currently PG&E does not have the appropriate phasing information for unbalanced power flows so the balanced power flow option is used. In order to ensure proper comparative analysis the option to run either was included.

### *2.b.i.7 DER Parameters*

In order to determine the impact of DER on the system, the analysis must consider a few basic parameters of the DER. The following is the list of parameters that were considered:

- Real Power Consumption (Load) and Real Power Injection (Generation)
    - Results for ICA are geared to be agnostic to DER with final ICA as hourly results
    - The analysis does not necessarily work in the manner of assuming a specific reduction of output/input at a given hour. It evaluates what level of output/input creates an expected violation.
    - DER specific output can be considered in post analysis based on the hourly results to get specific DER results
- Power Factor
    - Base results will be run assuming a unity power factor on
- Fault Contribution (for generators)
    - Fault contribution will assume 120% of nameplate for inverter technologies

## 2.c Evaluate Criteria

Evaluation of power system criteria is a vital aspect for analyzing Integration Capacity. Evaluating the specific criteria is what turns the raw distribution model data into relevant effective values that developers can use. The Distribution Resource Plan established four major categories for which the three major IOUs were to analyze. The four major categories are (1) Thermal, (2) Power Quality/Voltage, (3) Protection, and (4) Safety/Reliability. The following figure shows the sub criteria were established as possible components to consider in the analysis. It also provides an indication of the status and expectation of which technique is best suited. A few criteria are being evaluated to determine feasibility.

TABLE 2-4
POWER SYSTEM CRITERIA TO EVALUATE CAPACITY LIMITS

| Power System Criteria | Initial Analysis | Potential Future Analysis |
|---|---|---|
| **Thermal** | ✓ | ✓ |
| – Substation Transformer | ✓ | ✓ |
| – Circuit Breaker | ✓ | ✓ |
| – Primary Conductor | ✓ | ✓ |
| – Main Line Devices | ✓ | ✓ |
| – Tap Line Devices | ✓ | ✓ |
| – Service Transformer | | ✓ |
| – Secondary Conductor | | ✓ |
| – Transmission Line | | ✓ |
| **Voltage / Power Quality** | ✓ | ✓ |
| – Transient Voltage | ✓ | ✓ |
| – Steady State Voltage | | ✓ |
| – Voltage Regulator Impact | | ✓ |
| – Substation Load Tap Changer Impact | | ✓ |
| – Harmonic Resonance / Distortion | | ✓ |
| – Transmission Voltage Impact | | ✓ |
| **Protection** | ✓ | ✓ |
| – Protective Relay Reduction of Reach | ✓ | ✓ |
| – Fuse Coordination | | ✓ |
| – Sympathetic Tripping | | ✓ |
| – Transmission Protection | | ✓ |
| **Safety/Reliability** | ✓ | ✓ |
| – Islanding | ✓ | ✓ |
| – Transmission Penetration | ✓ | ✓ |
| – Operational Flexibility | ✓ | ✓ |
| – Transmission System Frequency | | ✓ |
| – Transmission System Recovery | | ✓ |

**Figure 8: Power System Criteria to Explore in Evaluating Capacity Limits (from DRP 2015 Filing)**

### *2.c.i Thermal Criteria*

Thermal Criteria determines whether a particular resource causes a change in power flow to exceed any equipment thermal ratings. Exceeding these limits would cause equipment to potentially be damaged or fail.

Assessing thermal equipment loading is essential in distribution planning. When delivered power through a certain asset is determined to exceed its thermal rating, mitigation measures must be performed to alleviate the thermal overload. This evaluation uses normal ratings for devices.

An hour-by-hour calculation is performed to determine the difference between the loading of the asset and the thermal limit. This establishes a set of capacities for each hour. Since the goal is to find the most limiting capacity value, the minimum capacity of the hourly set is taken as the thermal limitation for the integration capacity result.

| | |
|---|---|
| **Streamlined** | $kW\ Load\ Limit\ [t] = \left(Thermal\ Capability\ - (Load[t] - Generation\ [t])\right)$<br>$kW\ Generation\ Limit\ [t] = \left(Thermal\ Capability\ + (Load[t] - Generation\ [t])\right)$ |
| **Iterative** | • *Tool flags for thermal over-loading/over-generation* |

As a note the “Load” and “Generation” in these equations are referring to gross profiles. The “Load - Generation” could be thought of or replaced by net load. Load and Generation was stored and evaluated separately to help evaluate contingency scenarios which are discussed in the safety and reliability section.

The equations above are split in order to ascertain both over loading limitations and over generating limitations as they relate to the thermal capabilities of the asset. This is important as DERs are considered to be loading resources such as Electric Vehicles (EVs) and Storage technologies that have loading components to them.

### *2.c.ii Power Quality Analysis*

DER planning must include power quality analysis so that new resources are evaluated for sufficient voltage and quality of service. This type of analysis ensures that facilities and customer equipment is not damaged by operating outside of allowable power quality and voltage limits.

#### *2.c.ii.1 Transient Voltage*

Transient voltage is evaluated to ensure deviations from loads and resources on the grid do not cause harm or affect power quality to nearby customers. PG&E has an internal standard that evaluates the specific electrical conditions of the point of interconnection along with expected behavior of the facility. The standard equation is fundamentally derived from Ohm’s law. The behavior of the facility (frequency of deviations) dictates what limit to use as the deviation threshold. The equation used for voltage fluctuations is as follows:

| | |
|---|---|
| **Streamlined** | $$kW\ Limit = \frac{\left(Deviation\ Threshold\ (\%)\ * {V_{LL}}^2\right)}{(R * PF_{DER} + X * \sin(\cos^{-1}(PF_{DER})))} * PF_{DER}$$ |
| **Iterative** | • *This is not a steady state voltage condition and not suitable for iterative steady state power flow simulation*<br>• *Exploring alternative methods if applicable and/or feasible* |

The coding has been made such that a specific threshold can be adjusted to account for the threshold that is deemed appropriate. The deviation threshold currently utilized is 3%. This value is from Table 3 on page 22 of IEEE Standard 1453-2015 *"IEEE Recommended Practice for the Analysis of Fluctuating Installations on Power Systems.*" This value can be used as a common threshold for comparative analysis.

As a note, the nature of this criterion is configuration based and not dependent on power flow conditions. This is why all the dynamic voltage devices must be locked. This adds additional power flows to the iterative method that may not necessarily be needed. It will be evaluated to see if this is necessary given the additional complexity needed. Some example cases will determine the accuracy of streamlined versus iterative.

### *2.c.ii.2 Steady State Voltage*

Steady state voltage changes can also be generally estimated by using the same fundamental Ohm's Law principles. The difference would only be in determination of what the threshold value would be. In this case "deviation threshold" used in the voltage fluctuation formula would be "voltage headroom." This limit is determined by the headroom of voltage from the simulated voltage at the node to the Electric Rule 2 voltage violation limits.

| | |
|---|---|
| **Streamlined** | $$kW\ Limit\ [t] = \frac{\left(Voltage\ Headroom\ [t]\ (per\ unit)\ * {V_{LL}}^2\right)}{(R * PF_{DER} + X * \sin(\cos^{-1}(PF_{DER})))} * PF_{DER}$$ $$Voltage\ Headroom\ [t] = \frac{\lvert Rule\ 2\ Limit - Node\ Voltage[t]\rvert}{Base\ Voltage}$$ |
| **Iterative** | • *Tool flags for steady state over-voltage and under-voltage conditions* |

### *2.c.ii.3 Voltage Regulator Impact*

Voltage regulators monitor specific conditions of the grid and dynamically adjust voltage. One of these conditions is current in order to estimate what the lowest voltage downstream would be. Historically the assumption was that current flow was always in the forward direction which assumes a voltage drop downstream. Now with reverse flow the voltage change is now reversed as well. If the regulator does not have the proper settings to understand this it will regulate the voltage improperly. Regulators now have options to consider the reverse flow conditions properly and manage the voltage while generation is downstream. When regulators do not have these settings and see reverse flow the analysis will flag for issues.

| | |
|---|---|
| **Streamlined** | $kW\ Limit\ [t] = (Load[t] - Generation\ [t])\ \mid\ where\ limit > 0$ |
| **Iterative** | • *Flag for reverse current through voltage regulator*<br>o *Applied only to devices without distributed generation mode settings* |

### *2.c.iii Protection Criteria*

Protection Criteria determines when DER resources may reduce the ability of existing protection to monitor the grid and promptly disconnect areas when abnormal conditions occur such as when a car-hit pole causes a downed power line. DER planning must account for impacts to protection schemes to keep employees, public, and assets safe from potential electrical disturbances on the distribution system.

#### *2.c.iii.1 Reduction of Reach for Relays*

If a fault occurs electrically downstream of a distribution protection device, the device has the function of detecting and isolating the affected downstream circuit from the rest of the system. To do this effectively, the device must have a defined Minimum Trip current such that it does not trip accidentally during normal peak loading conditions but can still detect the lowest fault current possible within its defined protection zone and trip quickly enough to safely isolate the affected system. If a DER is a generating resource and is placed electrically downstream of the protection device, it is a source of power that can contribute to a fault and lower the fault contribution seen by upstream protection devices; it may cause the distribution protection device to not operate as designed. If the DER or aggregate of DER beyond a protection device has a large enough contribution it may prevent the device from recording enough fault current from the utility to isolate the system safely.

| | |
|---|---|
| **Streamlined** | $kW\ Limit = \frac{Reduction\ Threshold\ \% \ * I_{Fault\ Duty} * \ kV_{LL} \ * \ \sqrt{3}}{\left(\frac{Fault\ Current_{DER}}{Rated\ Current_{DER}}\right)} * PF_{DER}$ |
| **Iterative** | • *Tool flags for fault current lower than prescribed limits* |

The streamlined formula follows the screening concept that possible issues may arise when DER fault current is a certain percentage of fault duty. The formula allows for the threshold to be set to the specified limits. The standard reduction threshold used in the streamlined method is 10%. This is the specified limit in Electric Rule 21.

The iterative method will do a more dynamic fault flow which helps understand the specific fault contribution that would occur based on the impedance between the fault and the generator. It will check to ensure that protective device fault current exceeds the minimum trip value by a specific threshold as prescribed by protection standards.

### *2.c.iv Safety and Reliability Criteria*

Safety and Reliability must also be analyzed as part of Integration Capacity. High penetration scenarios of DER have the potential to cause excess back flow and reliance on load masking that can result in congestion and affect reliability during system events. PG&E currently evaluates Safety and Reliability to ensure that PG&E is reliably serving all customers with quality power, while keeping its customers and the public safe. This criterion is evaluated by (1) ensuring improper islanding conditions are not created, (2) penetration to the transmission system is limited, and (3) limiting excessive reverse flow throughout the circuit on transferrable lines.

#### *2.c.iv.1 Out of Phase Reclosing / Islanding*

Interconnection protection standards require that generators trip off in 2 seconds or less to ensure proper safety and reliability on the distribution system. Not doing so can create unsafe conditions and possible public harm or equipment damage when PG&E's protection devices reclose to restore line. Given the transient and complex nature of this criterion, the tools are not adequately setup to definitively determine the limit to which this will occur. Much research and evaluation has gone into establishing a set of criteria to ensure the proper safety margins are kept to not allow a possible unintentional island to occur. Currently the main condition that is of concern is when machine generation is present. This condition along with loading conditions establishes when certain mitigations must occur. PG&E follows its Distribution Interconnection Handbook standard TD-2306B-002[1] on Distributed Generation Protection requirements to analyze this screen.

*2.c.iv.2 Operational Flexibility Limits*

The IOUs were encouraged to evaluate limits on operational flexibility to ensure proper reliability during abnormal configuration conditions. When certain line sections are electrically isolated from the grid for repair, other line sections are connected to other grid source paths or substations to continue service to customers.

High penetrations of DERs have the potential to back feed into the abnormally connected substation where possible issues are not mitigated. Limiting these possible issues could be achieved by limiting the amount of back feed through the abnormal switching points. This is calculated by determining the minimum load beyond switchable line devices and not allowing the generation to exceed that load. When a line section is switched over, the amount of generation will only serve the local load and not generate power through the tie point towards the abnormal source. In essence, this will not limit the amount of generation that can be placed on each substation, but disperse the allowable generation across all line sections connected to the substation. This is an important aspect of reliability that needs to be addressed for high penetration scenarios of DER.

| | |
|---|---|
| **Streamlined** | $kW\ Limit\ [t] = (Load[t] - Generation\ [t])\ \mid\ where\ limit > 0$ |
| **Iterative** | • *Flag for negative current through device*<br>○ *Applied only to SCADA capable devices* |

The IOUs recognize that this is more of a heuristic approach. While heuristic approaches were not encouraged, the IOUs have established that non-heuristic approaches to analyzing this issue are quite process intensive and will significantly hinder the ability to achieve efficient results. Improvements to this method can be explored, but the IOUs recommend dismissing the criteria because of the current heuristic nature. Dismissing only ignores the problem and doesn't allow for proper solutions to ensure safety and reliability. As the ICA methodology is improved overtime, this criterion can be explored to be analyzed in non-heuristic approaches.

[1] https://www.pge.com/en_US/business/services/alternatives-to-pge/generate-your-own-power/distributed-generation/distribution-handbook.page

## 2.d Calculate ICA Results and Display on Online Maps

### *2.d.i Final Processing of Criteria Calculations*

The analysis looks at various layers of the system. The final processing ensures that if there are limitations upstream that are dependent on downstream conditions (i.e. reduction of reach for a recloser) than all the downstream nodes are limited by that condition. This approach is more relevant for streamlined and blended approaches where analysis is more abstract and not always connected through the simulation as in the iterative approach. Figure 9 depicts the general process that is used to obtain the final set of results.

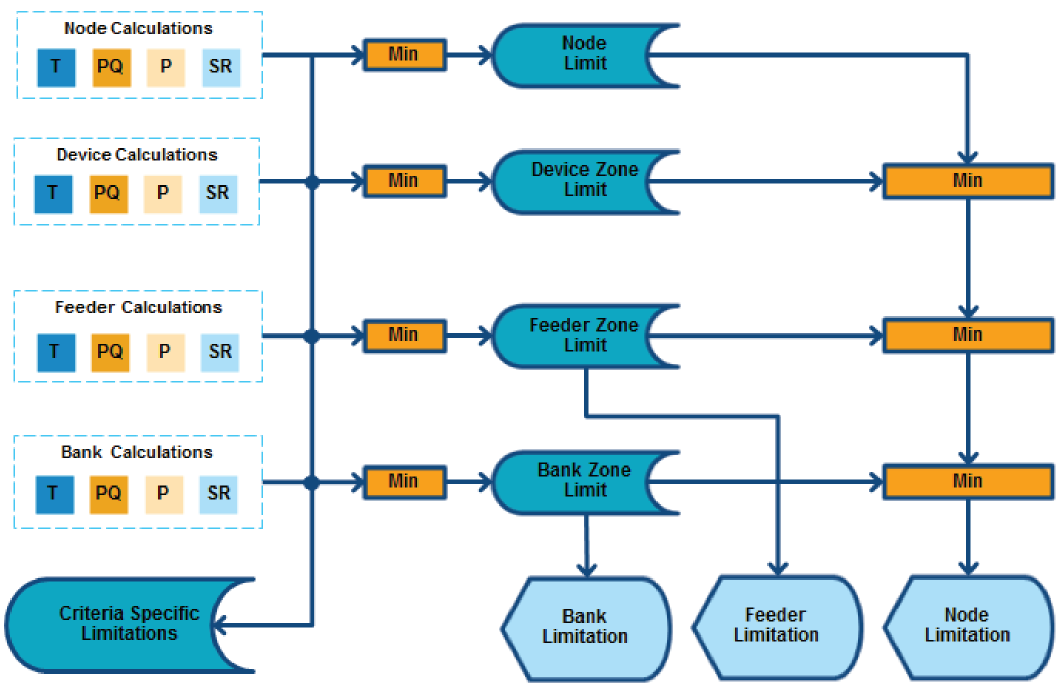



**Figure 9: Abstraction Technique for Integrating Results across System Layers**

### *2.d.ii Results and Online Map Data*

The IOUs will follow what was outlined in the proposal set forth at the July 25th ICA Working Group meeting. The proposal can be found at:

http://drpwg.org/wp-content/uploads/2016/07/Demo-A-Mapping-Proposal.docx

# 3 DEMO A PROJECT STATUS

This chapter provides a status update and some of the initial learnings from the ongoing Demo A work. More detailed discussion about results and analysis of findings will be in the final Demo A report.

## 3.a Project Status

The following learning objectives for demo A:

1.) **Reverse Flow at T&D Interface:** DER Capacity with and without limiting reverse power beyond substation bus bar. PG&E also wishes to include discussion/consideration of Transmission hosting capacity limitations where possible in the ICA Working Group. This is important as to not overestimate locational transmission reverse flow capabilities without explicitly analyzing within ICA.

2.) **Diverse Locations:** Evaluate two Distribution Planning Areas (DPAs) covering broad range of electrical characteristics and load profiles. PG&E proposes to analyze its Chico and Chowchilla DPAs. These areas range from shorter urban circuits with small amounts of devices and residential loading to longer rural circuits with many devices and industrial/agricultural loading.

3.) **Incorporate Portfolios and New Technology:** Methods for evaluating different DER portfolios and the impact of Smart Inverters. PG&E will evaluate the DER and portfolios listed in the May 2nd Ruling as well as additional DER agreed upon by the ICA Working Group as important to DER development.

4.) **Consistent Maps and Outputs:** Consistent and readable maps to the public with similar data and visual aspects. PG&E will work with the other IOUs and the ICA Working Group to develop an interface that is consistent as well as easy to interpret, based on guidance from the working group as to the needs of the DER community.

5.) **Computational Efficiency:** Evaluate methods for faster and more accurate update process that works for entire service territory. PG&E will assess computational requirements for desired spatial granularity, single phase inclusion, and DER scenario analysis.

6.) **Comparative Analysis:** Benchmark for consistency and validation across techniques and IOUs. As noted in the comparative analysis section, PDG&E will be running multiple analyses to compare both methodologies on its own system, as well as with the other IOUs for consistency of results.

7.) **Locational Load Shapes:** Utilize Smart Meters for localized load shapes, which include at a minimum peak and minimum load shapes

8.) **Future Roadmap:** Determine roadmap and timelines for future ICA achievements based on demonstration learnings. Through the ICA working group, PG&E will collaboratively review and develop recommendations for future ICA improvements.

The following table provides an overview of the status and key points of each of the objectives

**Table 1: Objective Statuses and Key Points**

| Objective | Status | Key Points |
|---|---|---|
| 1 | In Progress | • Capabilities being built to turn limits based on reverse flow on and off in order to comply with this objective<br>• Discussions need to occur to ensure understanding from commission and stakeholders that the results of these analyses can't guarantee no impacts on Transmission system |
| 2 | Complete | • Objective is complete as to finding diverse locations |
| 3 | In Progress | • Evaluated new approach to DER specific analysis with post processing on hourly results.<br>• This is in contrast to having specific DER profiles as inputs to be evaluated.<br>• New proposal is to perform post process analysis to determine DER specific values<br>• Smart Inverter analysis adjusted to be performed on a single circuit (preferably with low voltage ICA) after base analysis is complete.<br>• The example will help inform long term discussions on Smart Inverters |
| 4 | In Progress | • IOUs to be consistent with proposed data mapping proposal<br>• Agreement that map is to display substation load profiles and only worst case ICA for generation and load due to data size issues on maps.<br>• Full ICA profiles are to be available for download<br>• Initial data set shows that the data files are quite large |
| 5 | In Progress | • Use of CYME Server and Cloud computing help improve computational times<br>• Streamlined methods are more helpful for some criteria where iterative are more helpful for others<br>• Streamlined methods can be used to provide a starting point for iterative methods in order to reduce iterations<br>• Evaluation results have been pushed out two weeks in order to finish up additional changes required to achieve more alignment. |
| 6 | Delayed | • Efforts have revealed obstacles in vendor proprietary conversion of distribution circuit models across tools; even setting up the publicly available IEEE 123 test feeder across utilities' power system modeling tools (e.g., CYME and SYNERGI) have posed significant challenges.<br>• Since IOUs are also still in progress of developing the new and further aligned ICA methodology, there is limited time to expand on the conversion of additional feeders used for comparative analysis given the DRP Demo A timeframes.<br>• The IOUs propose that in order to timely publish DRP Demo A results, the DRP Demo A comparative analysis only consider the IEEE 123 test feeder.<br>• IOUs are open to discuss evaluating additional circuits after Demo A, but after consulting with industry experts and vendors the IOUs feel this is not necessary.<br>• The purpose of the IEEE 123 test feeder was designed for these purposes and the vendors have mentioned the potential learnings from the analysis of additional distribution circuits is likely to be far less incrementally valuable than the effort to set up the models between the utilities. |
| 7 | Complete | • PG&E has been using locational load shapes in LoadSEER for about 5 years<br>• Smart Meter history has penetrated enough of PG&E territory and has about three years of history<br>• EPIC 2.23 analyzed all this history to update and enhance the locational load shapes<br>• Load shapes can be built and analyzed at the customer premise or aggregated all the way up to system level<br>• Smart Meter information cannot be used in isolation and requires SCADA for reconciling actual conditions |
| 8 | Not Yet Started | • Some initial discussions have started, but core discussions may rely on learnings from Demo |

### 3.a.i Gantt Chart for Project

The following Gantt chart provides the timeline context of the objectives within Demo A. Most of the objectives are on schedule except for 5.3, 5.4, and 6. The tasks for Iterative and Streamlined evaluation will be finishing up in the first half of October. This is to complete some of the additional changes needed for more alignment in methodology. The comparative analysis task is expected to be at risk given the unforeseen additional effort required to create identical power flow models across the tools and utilities.

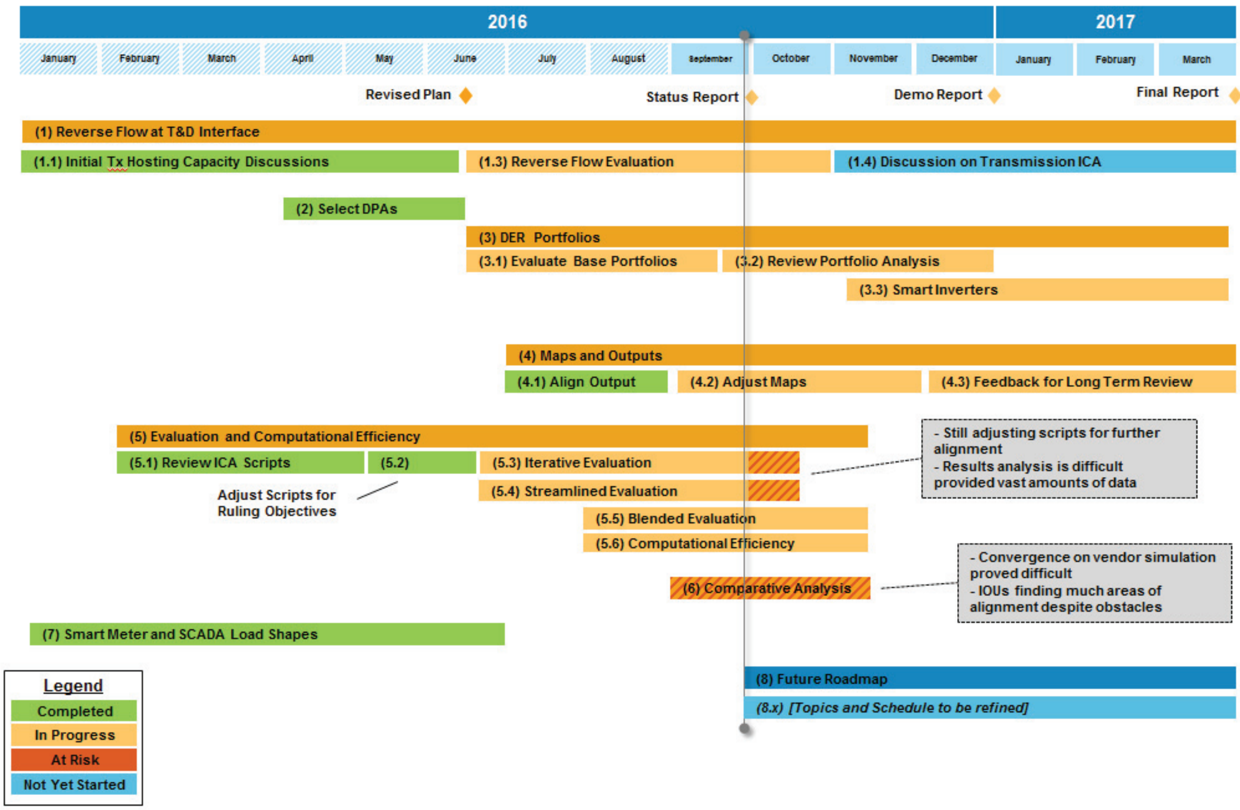



**Figure 10: PG&E Demo A Gantt Chart with Status**

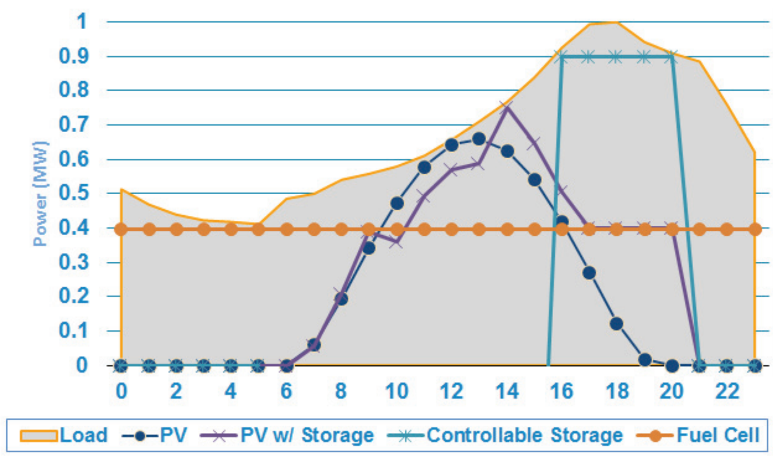
## 3.b Initial Findings and Learnings

This section provides a little context on some of the initial learnings and findings during the project.

### *3.b.i DER Specific Impact and Limitations*

One of the goals of the commission in regards to ICA is to determine the impact of various DER types and portfolios.

For the initial DRP, PG&E uses specific hour-by-hour DER profiles to analyze Integration Capacity. The level of impact to the system is different for DERs with different output profiles. Figure 11 below depicts how different DER could have different integration capacity limitations by comparing the DER output and how it coincides with a load profile. While the hosting capacity can be affected by many factors this figure isolates visuals to just reverse flow penetration for ease of discussion. This figure shows that, depending on the DER, there are different hours when the limit is occurring and that it produces different capacity limitations.




| DER | Limiting Hour | Max Capacity |
|---|---|---|
| PV | 12 PM | 0.66 MW |
| PV w/ Storage | 2 PM | 0.75 MW |
| Controllable Storage | 4 PM | 0.90 MW |
| Fuel Cell | 5 AM | 0.40 MW |

**Figure 11: DER Limits Depend on Profile Shapes**

The earlier discussions on ICA from stakeholder engagement and CPUC workshops revealed a great opportunity to better understand the broader application to various DERs and portfolios. This was to expand the results to not just provide the most limiting value, but to expand the results to be hourly and expose the various limits within each category. Figure 12 depicts what the proposed output would be for a particular location. This would be in contrast to just providing the most limiting value which in this case would be 0.

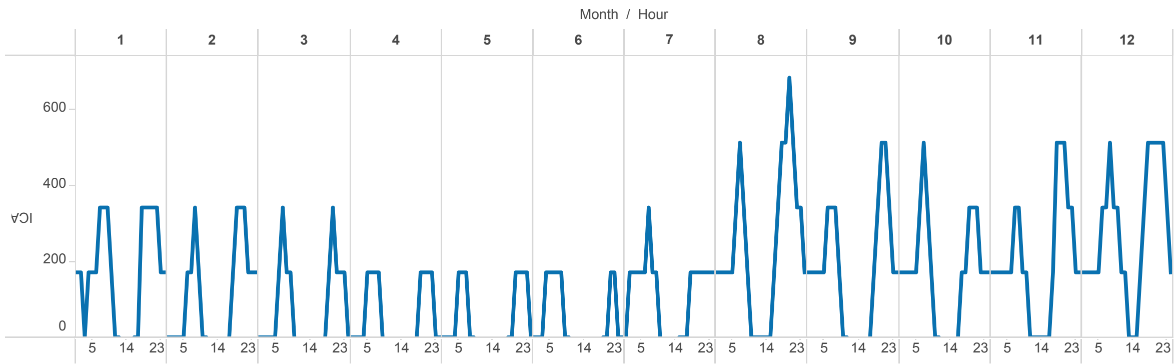



Figure 12: Hourly ICA Profile

In order to streamline the analysis, the IOUs explored utilizing the hourly results in a manner that would not require additional analyses to be performed for each DER type. Figure 13 below is an attempt to visualize how this concept is applied. The hourly output profile of the DER is evaluated against the hourly ICA profile.

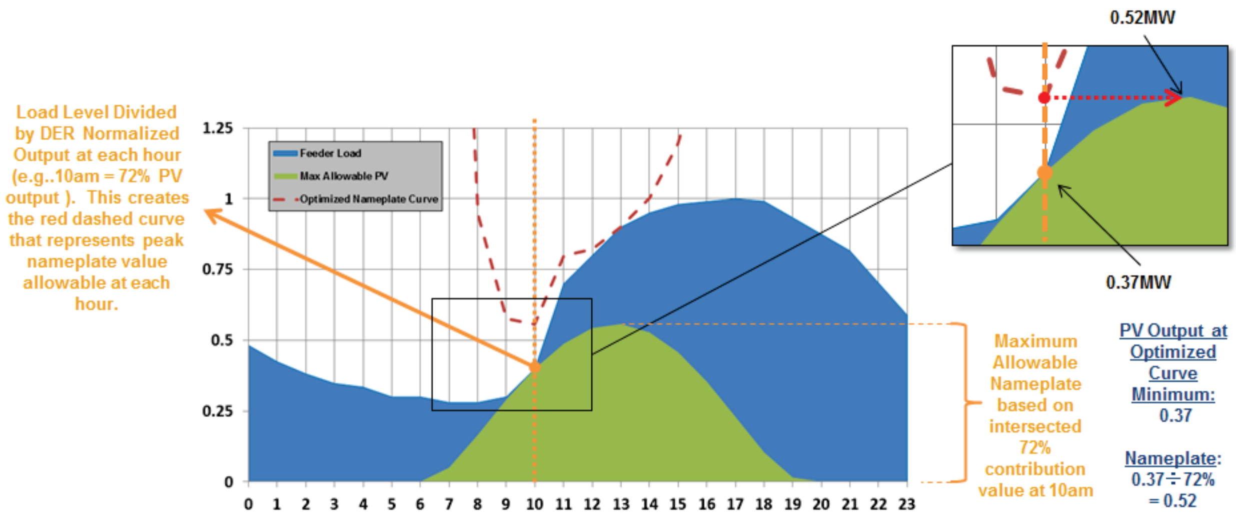



Figure 13: DER Profile Normalization and Optimization

This figure depicts that given an ICA profile, there exists a PV power profile with values smaller than the ICA for the entire observed time interval except for one specific time where the profiles intersect. This specific PV curve has the highest nameplate capacity possible while satisfying the criterion of not surpassing the ICA limit at any time.

The DER specific limit needs to be related to nameplate. Given a normalized DER profile and hourly capacity limits, an optimized curve can be created by relating the ICA profile to the normalized DER profile. This method is similar to how PG&E established DER specific capacities for the 2015 DRP filing. The method can be expressed in mathematical terms as follows:

$$Nameplate\ Capacity\ Curve = F = \frac{ICA[t]}{DER_{pu}[t]}$$

$$Limiting\ Capacity\ for\ Specific\ DER = \min_{t \in \mathbb{R}}(F)$$

Figure 14 depicts how this can be applied to various DER profiles given one ICA profile.

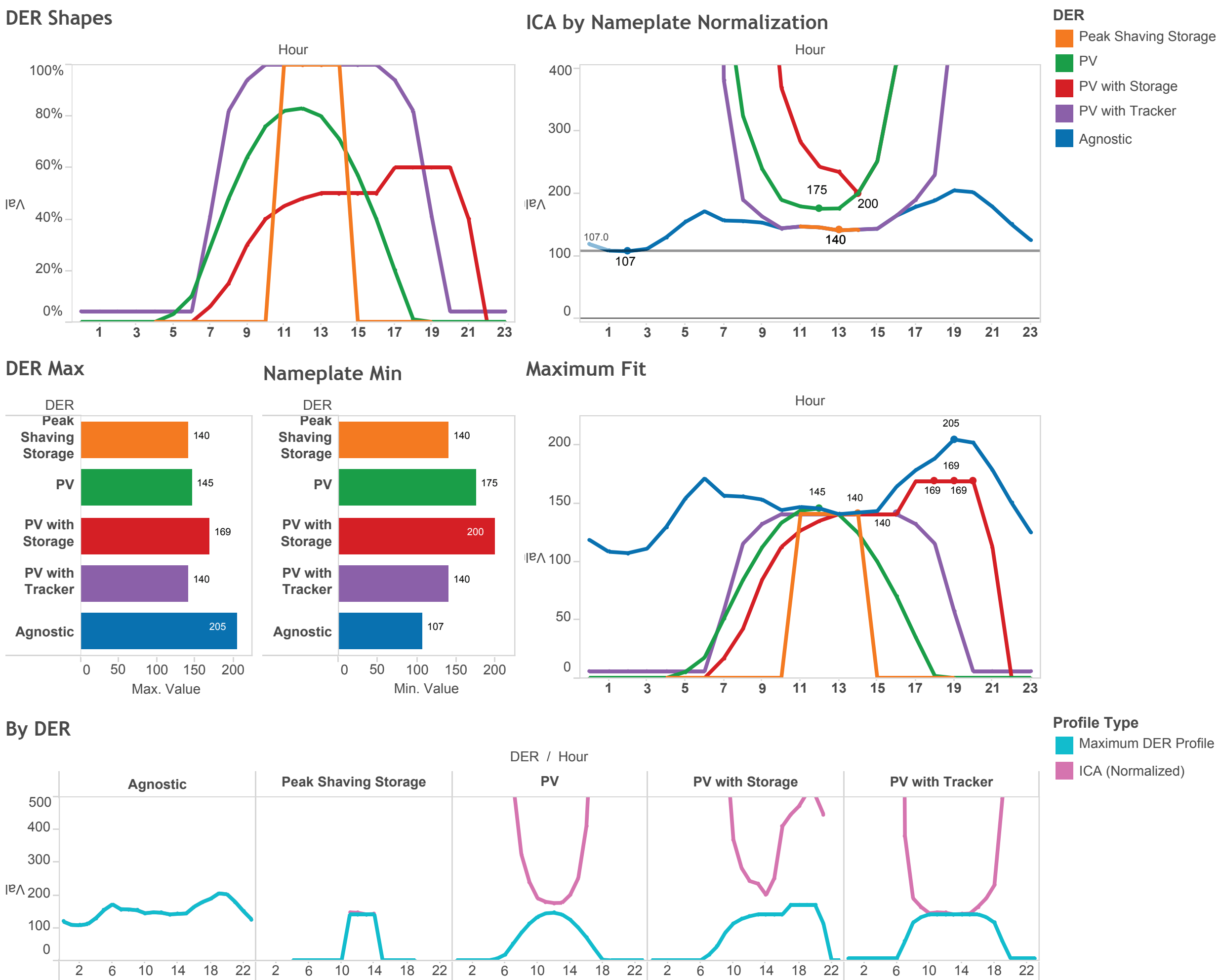



**Figure 14: DER Specific Results from Hourly ICA Profile**

### *3.b.ii Processing and Size of Data*

Current map data already shows lag in performance with 40 values per 100,000 line sections. The new data would require 576 x 2,000,000 nodes. This is why proposal focused on reducing the mapped data to the most limiting values while allowing for full result set to be downloadable.

Evaluating some of the initial indicative outputs of the shows that there may be data size issues with downloading the full result set. Given the temporal and locational increases in granularity the result sets are averaging about 1GB per feeder. For all of the PG&E's feeders this would be about 3TBs. It will be good to have discussions with the ICA working group about data sharing protocols given the size of this data. Given the project is ongoing, the project team will explore possible reductions in the sizes without reducing the granularity of information.

### *3.b.iii Comparative Assessment*

Some challenges were realized as the IOUs progressed towards creating a comparative analysis given specific reference circuits. Assessment began with the IEEE 123 feeder in order to ensure general alignment with an easy to review small data set. Two main topics of challenges were found in the process. The first was making sure the models were identical. The second was ensuring all the starting points and power flow settings were the same.

Challenges in model alignment were first with ensuring the base dataset was properly coded in the dataset required by the specific tools. PG&E and SCE were able to align on an already established circuit model from CYME, but Synergi had no such model which had to be created. Once created some differences in how the tools handle some components provided some variation. For power flows the main component of this was the regulator. While variation has been reduced to a minimal amount, it is still being evaluated why CYME and Synergi assume different impedances for the regulator.

The other side to the differences was around the starting assumption and parameters that can be used for the power flow tools. The utilities collaborated to align on many of these values which are:

- Power Flow Calculation Method
- Convergence Parameters
- Line Transposition and Charging
- Voltage Sensitivity Load Models
- Regulator Tap Operation Models
- Starting Voltages
- Pre-Fault Voltages

Another component of this is the various amounts of electrical values that can be retrieved from the tool to analyze such as:

- A/B/C Voltages
- Min/Max/Avg Voltages
- Real and Apparent Power

The tools allow for the vast amounts of settings and parameters in order for models to simulate the specific conditions necessary for evaluation. Provided that availability of assumptions the IOUs have learned many aspects in which to drive better alignment in the technical assumptions that go into the power flow.

### *3.b.iv Locational Load Shapes*

PG&E has been using locational load shapes in LoadSEER since 2010. Smart Meter history has penetrated enough of PG&E territory and has about three years of history which has provided new opportunities to enhance the load shapes. EPIC 2.23 analyzed all this history to update and enhance the locational load shapes. With this new dataset, load shapes can be built and analyzed at the customer premise or aggregated all the way up to whatever level desired.

In this process a few things have been realized. One of the most important learnings is that Smart Meter information cannot be used on its own to assume specific conditions on the grid at much higher levels. There are four main contributors to this issue:

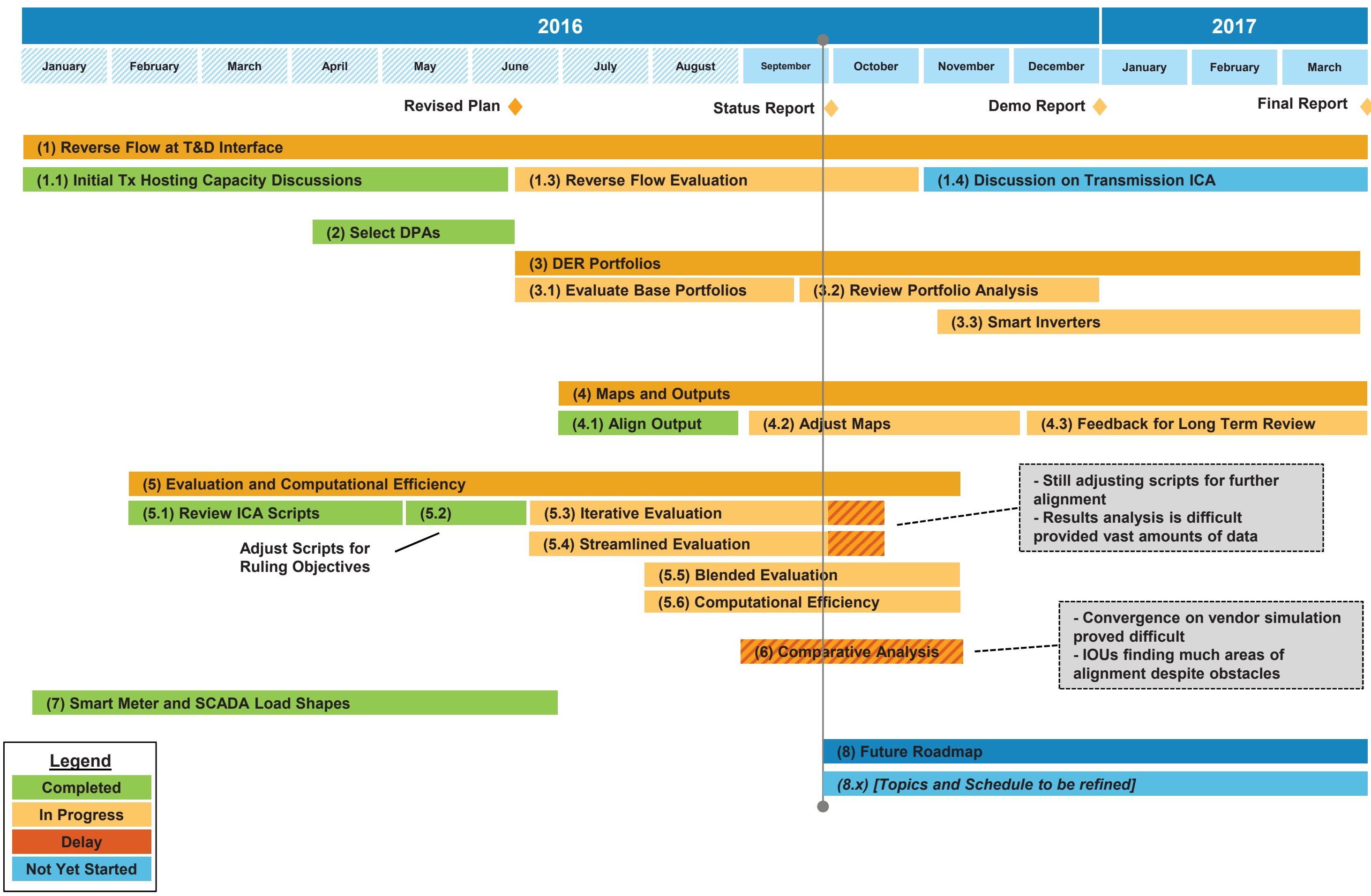
1. Not all customers may have Smart Meters
2. Smart Meter data is not precisely aligned temporally
3. Most customers are hourly consumptions (kW-h) and not demands (kW)
4. Other components to the grid impact power such as losses and capacitors

SCADA helps for reconciling actual conditions and adjusting the shapes to observed conditions. Having the shapes known by specific customer types also helps assign shapes to customers that don't have Smart Meters.

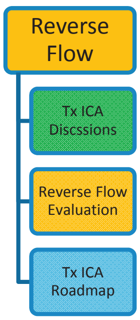
PG&E has valued the experience with load shapes versus just using raw data given this provides a better understanding of variability and causation. Raw SCADA and Smart Meter data needs to be scrubbed for anomalies as well (i.e. bad communication, transfers, outages, etc.). Much of the work with Integral Analytics and the EPIC 2.23 team has provided a rich understanding of this locational Smart Meter data and how it can increase accuracy within the power flow models.

# Attachment A -
# Summary Slides of Demo A
# Objective Status

# Demo A Gantt Chart (updated 09/22/16)



# Objective 1: Reverse Flow at T&D Interface




| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | DER Capacity with and without limiting reverse power beyond substation bus bar. PG&E also wishes to include discussion/consideration of Transmission hosting capacity limitations where possible in the ICA Working Group. This is important as to not overestimate locational transmission reverse flow capabilities without explicitly analyzing within ICA. |
| **Status:** | **In Progress** |
| **Key Points:** | • Capabilities being built to turn limits based on reverse flow on and off in order to comply with this objective<br>• Discussions need to occur to ensure understanding from commission and stakeholders that the results of these analyses can't guarantee no impacts on Transmission system |

**Interim Learnings**

- **TBD**

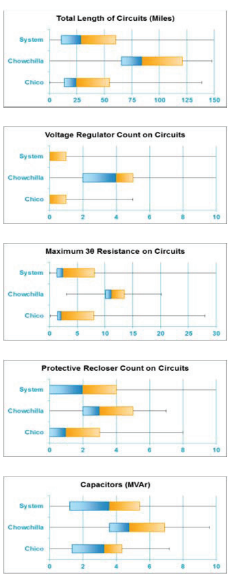
# Objective 2:  Diverse Locations

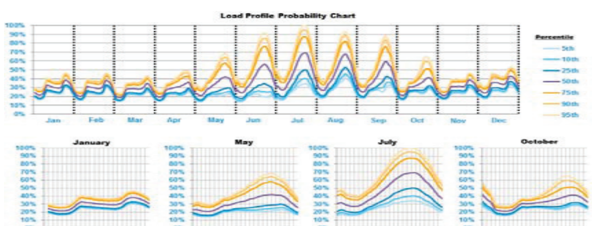
Select DPAs

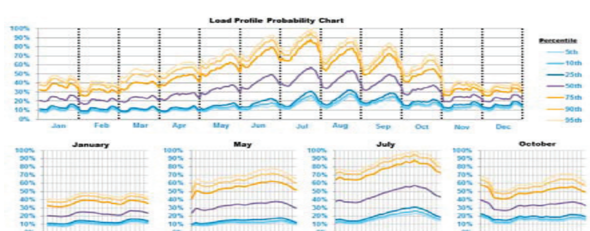
**DRP Demonstration A – Enhanced Integration Capacity Analysis**

| | |
|---|---|
| **Objective:** | Evaluate two Distribution Planning Areas (DPAs) covering broad range of electrical characteristics and load profiles. PG&E proposes to analyze its Chico and Chowchilla DPAs.  These areas range from shorter urban circuits with small amounts of devices and residential loading to longer rural circuits with many devices and industrial/agricultural loading. |
| **Status:** | **COMPLETE** |
| **Key Points:** | • Objective is complete as to finding diverse locations<br>• Other objectives will highlight any interesting differences in results |

## Interim Learnings



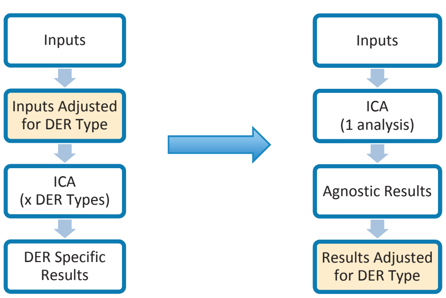

# Objective 3: Incorporate Portfolios and New Technology

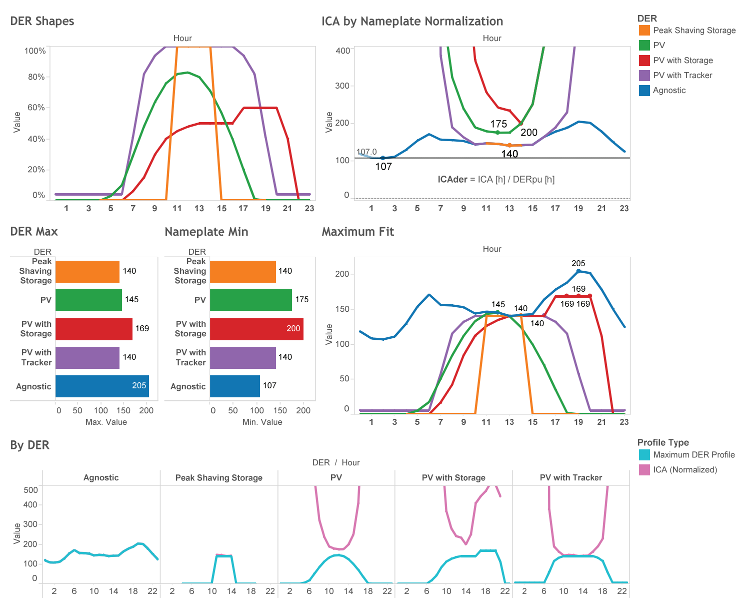
- DER Portfolios
  - Evaluate Portfolios
  - Review Portfolio Analysis
  - Smart Inverter Example

| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | Methods for evaluating different DER portfolios and the impact of Smart Inverters. PG&E will evaluate the DER and portfolios listed in the May 2nd Ruling as well as additional DER agreed upon by the ICA Working Group as important to DER development. |
| **Status:** | **In Progress (adjusted due to learnings from hourly results new Smart Inverter Plans)** |
| **Key Points:** | • Evaluated new approach to DER specific analysis with post processing on hourly results. This is in contrast to having specific DER profiles as inputs to be evaluated.<br>• New proposal is to perform post process analysis to determine DER specific values<br>• Smart Inverter analysis adjusted to be performed on a single circuit (preferably with low voltage ICA) after base analysis is complete. The example will help inform long term discussions on Smart Inverters |

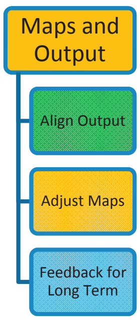
## Interim Learnings

- DER specific results can be obtained using agnostic profile ICA versus assuming specific DER profiles. This allows for ICA to be run only once.
- Main DER difference that has to be explicitly modeled separately is load versus generation
- Allows for users to have more flexibility in using data versus constraining to specific DERs used at beginning



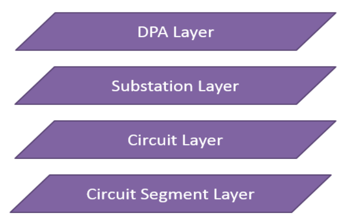
# Objective 4: Consistent Maps and Outputs



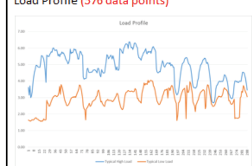

| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | Consistent and readable maps to the public with similar data and visual aspects. PG&E will work with the other IOUs and the ICA Working Group to develop an interface that is consistent as well as easy to interpret, based on guidance from the working group as to the needs of the DER community. |
| **Status:** | **In Progress** |
| **Key Points:** | • IOUs to be consistent with proposed data mapping proposal<br>• Agreement that map is to display substation load profiles and only worst case ICA for generation and load due to data size issues on maps.<br>• Full ICA profiles are to be available for download<br>• Initial data set shows that the data files are quite large |

**<u>Interim Learnings</u>**

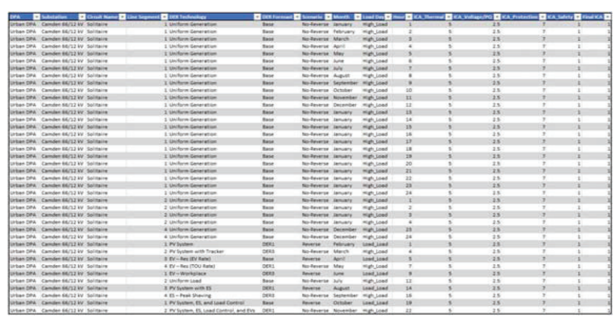
- Current map data already shows lag in performance with 40 values per 100,000 line sections
  - New data will expand to values for every node which could bring down performance
  - Will monitor performance issues as data is increased
- Feedback from users also mention that current information is too much and needs to be simplified (while still providing as much info)
  - Isolating ICA to map just worst case will reduce confusion for majority of users
  - Access to downloading enhanced profile information will enable super users
- Initial data runs have results per feeder at about 1GB




Substation Name Camden 66/12 kV
Load Profile (576 data points)




Note:
Download Complete Demo A Dataset

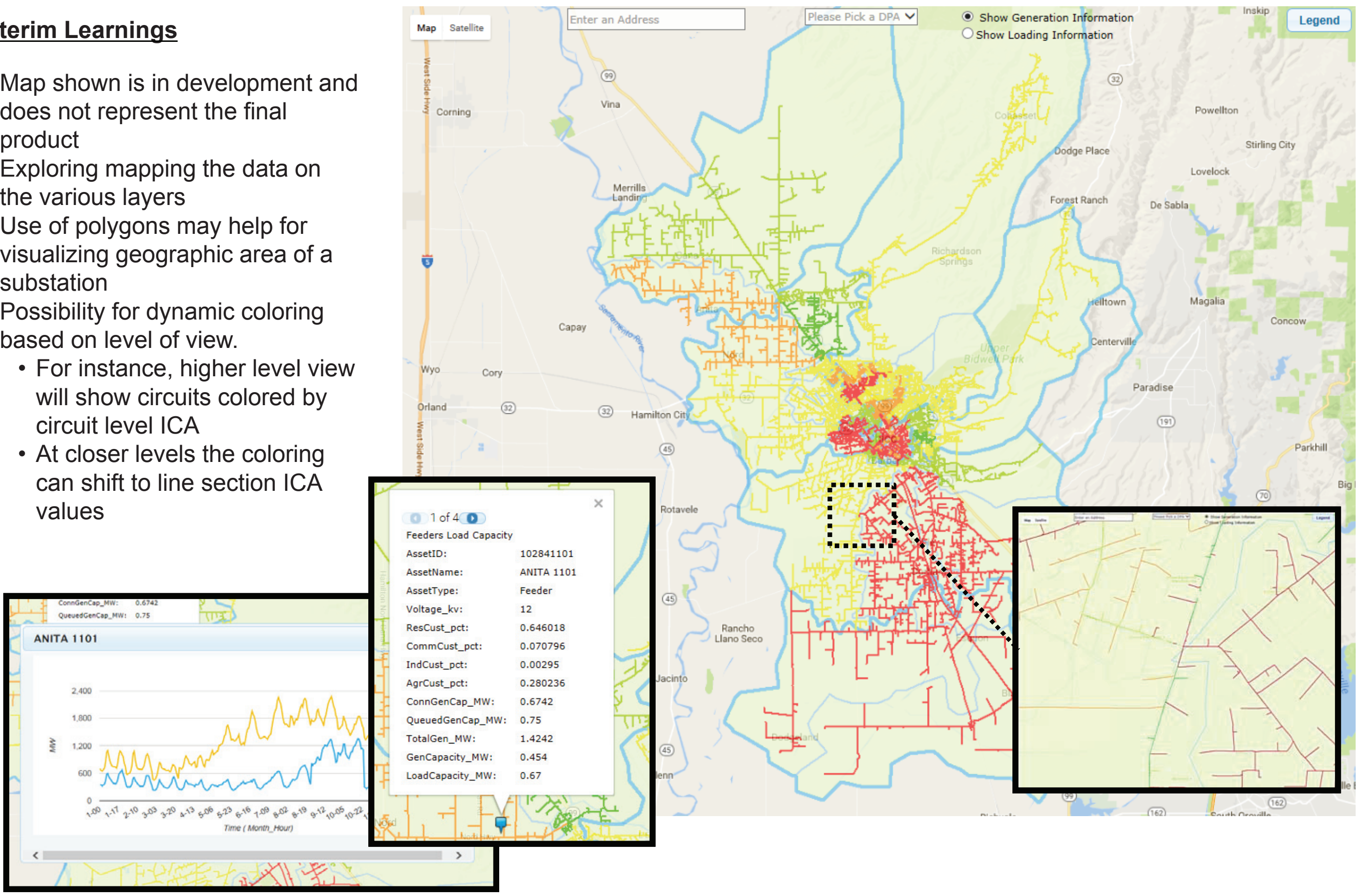


| DPA | Substation | Circuit Name | Line Segment | DER Technology | DER Forecast | Scenario | Month | Load Day | Hour | ICA_Thermal | ICA_Voltage/PQ | ICA_Protection | ICA_Safety | Final ICA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 1 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | February | High_Load | 2 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | March | High_Load | 3 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | April | High_Load | 4 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | May | High_Load | 5 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | June | High_Load | 6 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | July | High_Load | 7 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | August | High_Load | 8 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | September | High_Load | 9 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | October | High_Load | 10 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | November | High_Load | 11 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | December | High_Load | 12 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 13 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 14 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 15 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 16 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 17 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 18 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 19 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 20 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 21 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 22 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 23 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | Uniform Generation | Base | No-Reverse | January | High_Load | 24 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | Uniform Generation | Base | No-Reverse | January | High_Load | 1 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | Uniform Generation | Base | No-Reverse | January | High_Load | 2 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | Uniform Generation | Base | No-Reverse | January | High_Load | 3 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | Uniform Generation | Base | No-Reverse | January | High_Load | 4 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 4 | Uniform Generation | Base | No-Reverse | December | High_Load | 23 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 4 | Uniform Generation | Base | No-Reverse | December | High_Load | 24 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | PV System | DER1 | Reverse | February | Load_Load | 1 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | PV System with Tracker | DER3 | No-Reverse | March | High_Load | 4 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 3 | EV – Res (EV Rate) | Base | Reverse | April | Load_Load | 5 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 4 | EV – Res (TOU Rate) | DER1 | No-Reverse | May | High_Load | 7 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | EV – Workplace | DER3 | Reverse | June | Load_Load | 9 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | Uniform Load | Base | No-Reverse | July | High_Load | 12 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 3 | PV System with ES | DER1 | Reverse | August | Load_Load | 14 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 4 | ES – Peak Shaving | DER3 | No-Reverse | September | High_Load | 16 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 1 | PV System, ES, and Load Control | Base | Reverse | October | Load_Load | 19 | 5 | 2.5 | 7 | 1 | 1 |
| Urban DPA | Camden 66/12 kV | Solitaire | 2 | PV System, ES, Load Control, and EVs | DER1 | No-Reverse | November | High_Load | 22 | 5 | 2.5 | 7 | 1 | 1 |

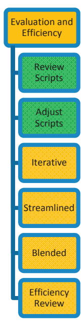
# Objective 4: Consistent Maps and Outputs

**Interim Learnings**

- Map shown is in development and does not represent the final product
- Exploring mapping the data on the various layers
- Use of polygons may help for visualizing geographic area of a substation
- Possibility for dynamic coloring based on level of view.
  - For instance, higher level view will show circuits colored by circuit level ICA
  - At closer levels the coloring can shift to line section ICA values



# Objective 5: Evaluation and Computational Efficiency




| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | Evaluate methods for faster and more accurate update process that works for entire service territory. PG&E will assess computational requirements for desired spatial granularity, single phase inclusion, and DER scenario analysis. |
| **Status:** | **In Progress** |
| **Key Points:** | • Use of CYME Server and Cloud computing help improve computational times<br>• CYME Server does not have full capabilities of desktop tool. In development with CYME to upgrade CYME Server.<br>• Streamlined methods are more helpful for some criteria where iterative are more helpful for others<br>• Streamlined methods can be used to provide a starting point for iterative methods in order to reduce iterations |

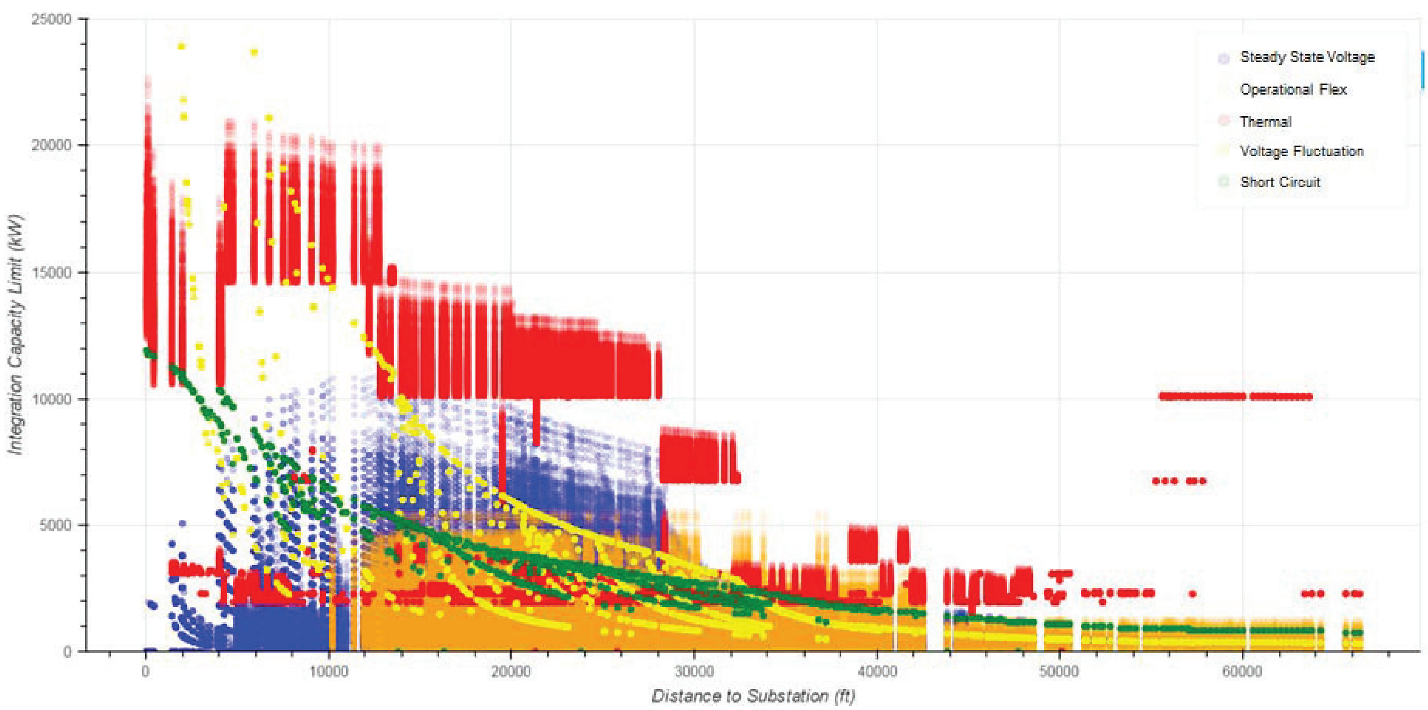
**Interim Learnings**

- Iterative helps provide more confidence on steady state voltage limits, but still need to do comparison of iterative and streamlined once results are complete
- Iterative requires the asset / specific issue to be in the circuit model
  - i.e. Can only evaluate substation transformer thermal limit if in model
- Streamlined allows for evaluation outside of model and/or without running a specific new simulation based on that issue
  - i.e. Voltage Fluctuation requires and additional simulation with regulators locked
  - i.e. Operational Flexibility would require simulated numerous amounts of switching scenarios
- Protection criteria requires specific fault flow simulations that are different from power flow simulations which adds complexity and processing
- Areas of exploration to have both methods provide a faster and more robust methodology together

# Objective 5: Evaluation and Computational Efficiency

**Interim Learnings**

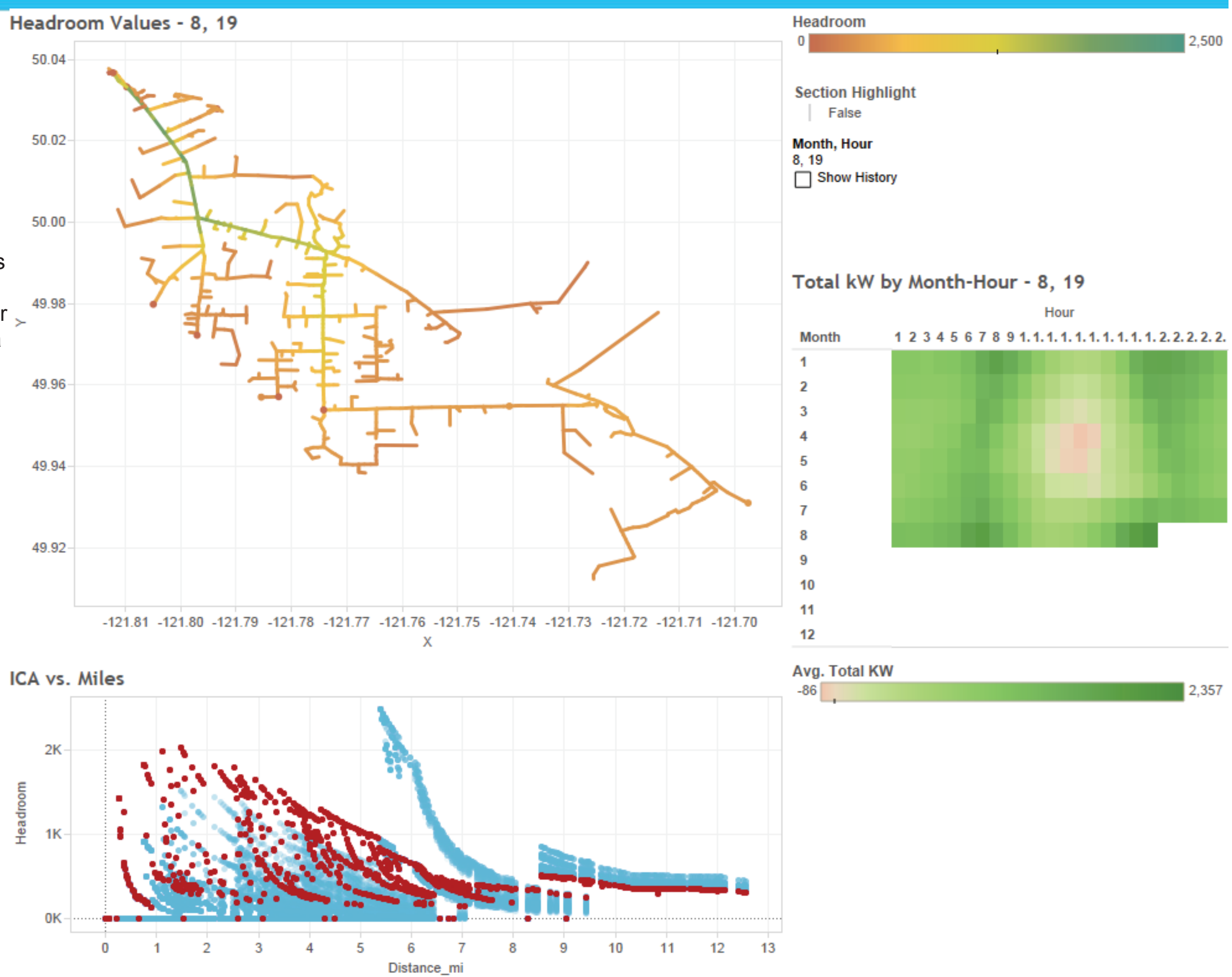
- Results shown are indicative and not final
- Exploring ways of visualizing and analyzing results along with sanity checking code during development
- Review shows how ICA significantly reduces with electrical distances from substation
- Voltage limits have a wide range of values and are quite limiting at the end of the circuit
- Thermal limits can restrictive near substation (likely tap lines) depending on equipment size



# Objective 5: Evaluation and Computational Efficiency

**Interim Learnings**

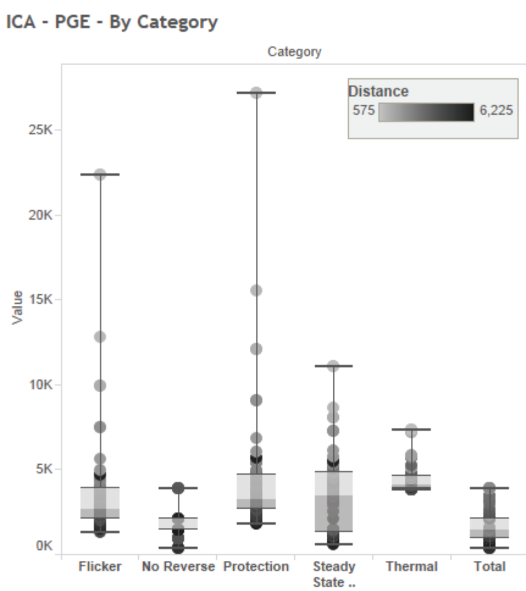
- Results shown are indicative and not final
- Exploring indicative values from initial coding to explore ways of visualizing and analyzing results
- Figure shows snapshot of circuit for a specific hour and a timeline history of steady state voltage ICA with distance
- Analyzing the large data set, visualizing, and obtaining learnings is process intensive as well

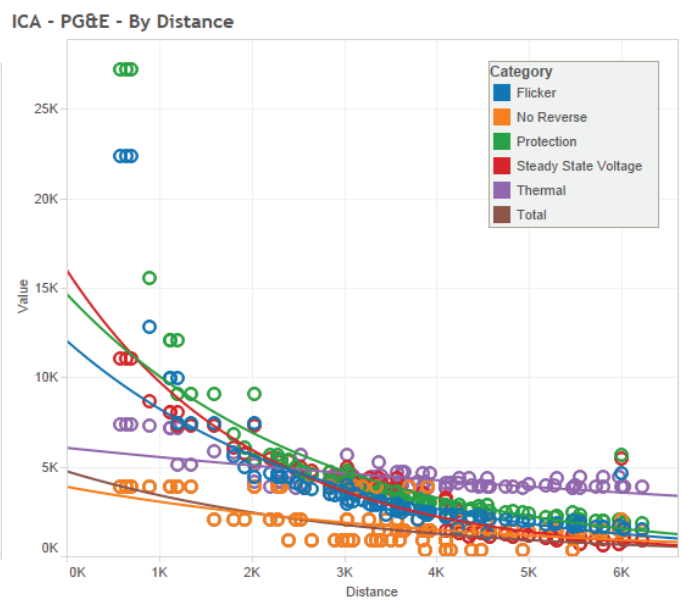


# Objective 5: Evaluation and Computational Efficiency

**Interim Learnings**

- Results shown are indicative and not final
- Exploring indicative values from initial coding to explore ways of visualizing and analyzing results
- Another way of visualizing, but this time with the IEEE Test feeder

# Objective 6: Comparative Analysis

Comparative Analysis

| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | Benchmark for consistency and validation across techniques and IOUs. As noted in the comparative analysis section, PDG&E will be running multiple analyses to compare both methodologies on its own system, as well as with the other IOUs for consistency of results. |
| **Status:** | **Multiple Circuits Delayed (proposal to isolate comparison on IEEE 123 test circuit only for demo)** |
| **Key Points:** | • Obstacles in vendor proprietary conversion of distribution circuit models across tools;<br>• There is limited time to expand on the conversion of additional feeders used for comparative analysis given the DRP Demo A timeframes.<br>• Proposal for DRP Demo A comparative analysis only consider the IEEE 123 test feeder.<br>• IOUs are open to discuss evaluating additional circuits after Demo A |

**Interim Learnings**

- IOUs started baseline comparison on IEEE 123 node test circuit.
- Outside of ICA results comparison, discrepancies in base power flow proved difficult to align. This is due to various computational methods, input assumptions, parameter configurations/setpoints, and values for comparison.
- In consultation with technical consultant, their expert opinion was that additional work for consistency on additional circuits was not necessary and that the IEEE test circuit was designed for these types of applications.
- Power flows provide many options for allowing proper solution convergence based on data available and configurations of distribution system
    - Unbalanced vs. balanced
    - Iterations and tolerance
    - Device operation modes
    - Various parameters (i.e. A/B/C phase, average voltage, min/max, balanced voltage, etc)
- Synergi and CYME handle regulators slightly different in modeling impendence of device which creates some difficulties when comparing short circuit and voltages downstream

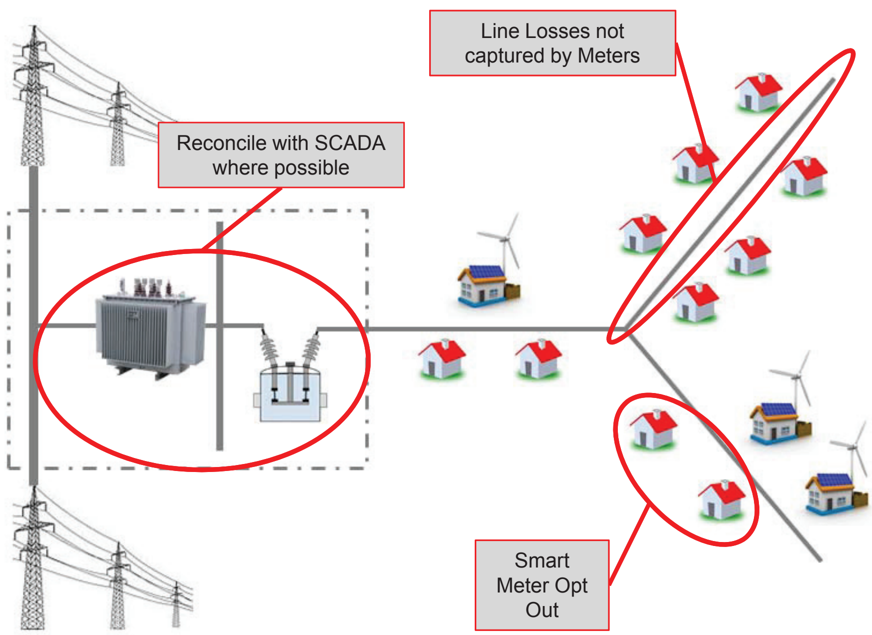
# Objective 7: Locational Load Shapes

Load Shapes

| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | Utilize Smart Meters for localized load shapes, which include at a minimum peak and minimum load shapes |
| **Status:** | **COMPLETE** |
| **Key Points:** | • PG&E has been using locational load shapes in LoadSEER for about 5 years<br>• Smart Meter history has penetrated enough of PG&E territory and has about three years of history<br>• EPIC 2.23 analyzed all this history to update and enhance the locational load shapes<br>• Load shapes can be built and analyzed at the customer premise or aggregated all the way up to system level<br>• Smart Meter information can not be used in isolation and requires SCADA for reconciling actual conditions |

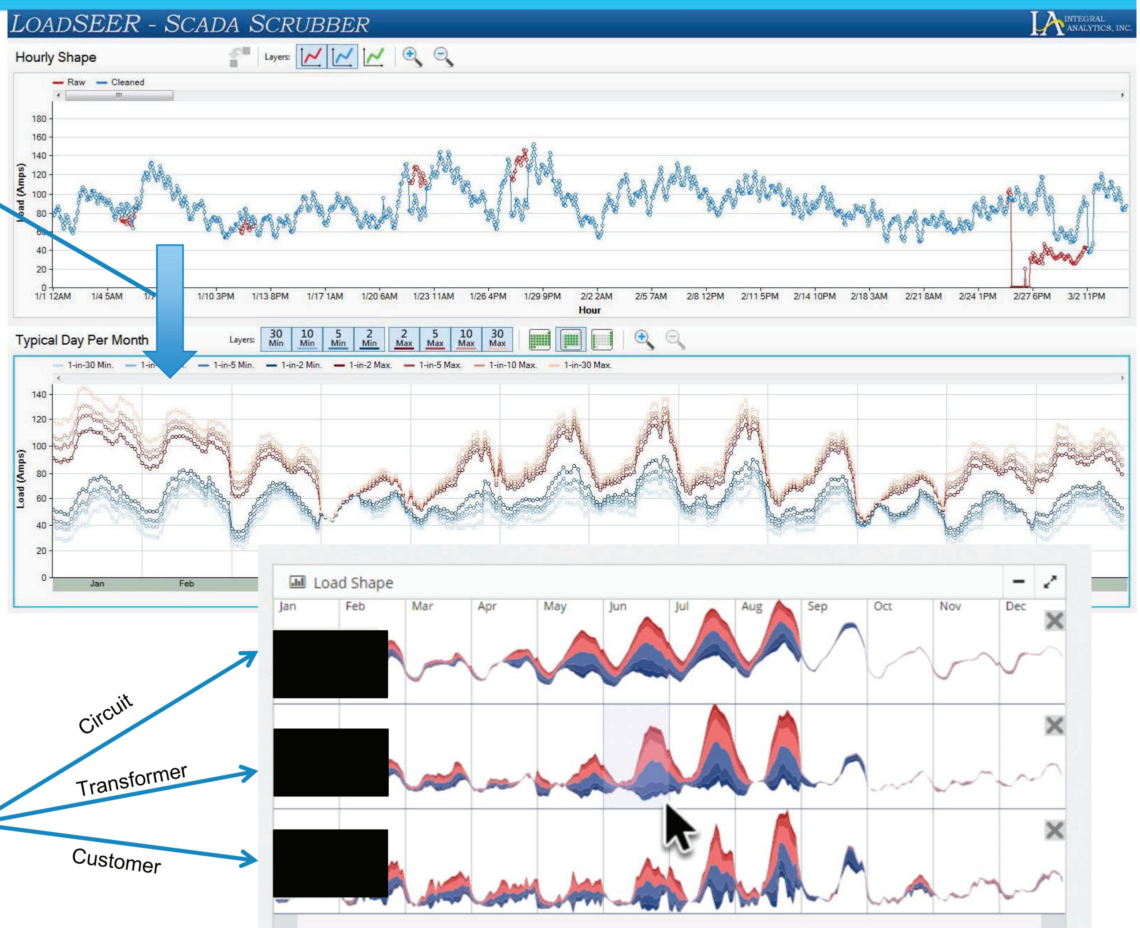
**Interim Learnings**

- PG&E has valued the experience with load shapes versus just using raw data given this provides a better understanding of variability and causation
- Raw SCADA and Smart Meter data needs to be scrubbed for anomalies (i.e. bad communication, transfers, outages, etc.)
- Smart Meter data is in kWh for non-demand customers which needs translation and reconciliation with SCADA where possible.



# Objective 7: Locational Load Shapes

Translates raw 8760 data to statistical load shapes




Circuit

Transformer

Customer

Using Smart Meters to understand shapes along with system hierarchy allow for analyzing load diversity within a circuit

# Objective 8: Future Roadmap

Load Shapes

| DRP Demonstration A – Enhanced Integration Capacity Analysis | |
|---|---|
| **Objective:** | Determine roadmap and timelines for future ICA achievements based on demonstration learnings. Through the ICA working group, PG&E will collaboratively review and develop recommendations for future ICA improvements. |
| **Status:** | **TBD** |
| **Key Points:** | • Some initial discussions have started, but core discussions may rely on learnings from Demo |

**Interim Learnings**

- **TBD**