Screening Distribution Feeders: Alternatives to the 15% Rule

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**Project Description**

### Industry Challenge
- **Landscape is changing**
  - 155,000 US installations in 2013
  - 94% connected to distribution
  - Expected to triple by 2016
- **New Challenges for Utilities**
  - Accommodate more PV
  - Expedite interconnection process

### Project Goal
- **Improve current screening**
  - Efficiently evaluate new interconnection requests
  - Take into account existing PV and feeder-specific factors

#### Current Screening
Under and over conservative results
Approach to Develop Alternative Screening Methods

- Document current practices
- Determine the range of feeders in CA
- Collect high-res PV data for model development & screening validation
- Modeling and High-pen PV analysis
- Develop and validate new screening methods
Project Partners
Webinar Agenda

- Project Tasks
  - Current Screening Practices
  - Clustering Distribution Feeders
  - Solar Monitoring
  - Feeder Modeling and Detailed Analysis
  - Suggested and Validated Screen Modifications

- Distribution Resource Plans

- Conclusions
Task Purpose

- Investigate and document current practices for screening PV interconnection requests among California utilities and from other sources outside California

Approach

- Consider federal, state, and local interconnection procedures pertaining to CA (Rule 21, WDAT, SGIP)
- Consider non-CA and European utility screening practices as well
Review of Utility Interconnection Screens

CPUC Rule 21 Initial Review Screens

1. Not a secondary network
2. Not exporting across PCC
3. Certified equipment
4. <15% of peak load on line section
5. Starting voltage drop within limits
6. <=11 kVA nameplate rating
   If > 11 kVA rating …
7. Nameplate and short circuit contribution ratio within limits
8. Compatible transformer connection

If project passes all screens, interconnection agreement approved

Source: SCE Rule 21 – Generating Facility Interconnections, August 2004
Utility Survey of Current Practices

• Survey included input from 19 utilities operating in four regions of the United States, California (4), Southwest, Central and Northeast
General Survey Findings

Common Practices Include:

• Online applications, guidelines
• Low-cost/no-cost application
• Uniform state rules for all utilities (e.g. Rule 21)
• Standard approach to evaluating applications
• Supplemental screening options
• Standardized distribution modeling platform
• Emphasis on good communication with applicant
• Online tracking system
• Standard impact studies (when required)
Specific Survey Responses: PV Penetration

The technical screen “fast track advisory limits” are 2 MW for 12 kV circuits, and 3 MW for 21 kV circuits.

The rule of thumb within the engineering departments has been a maximum of 10 MW of DG on any feeder.

Circuits rated at 12 kV and 16 kV are allowed to have a maximum of 450 Amps of generation, which is about 10 MW on the 12 kV circuits and 13.5 MW on the 16 kV circuits.

We use 100% of minimum daytime load or 30% of the daytime peak load as a penetration parameter, rather than 15% of peak 24/7 load, for PV system screening.
Project Task: Clustering Distribution Feeders

- **Task Purpose**
  - Determine a set of representative feeders to be used for detailed analysis

- **Approach**
  - Characterize over 8,163 distribution feeders
  - Use a clustering method to group feeders by their characteristics
  - Representative feeders then chosen from the clusters
What is Clustering?

1) $K=3$ initial "means" are randomly generated within the data domain (shown in color)
2) $k$ clusters are created by associating every observation with the nearest mean
3) The centroid of each of the $k$ clusters becomes the new mean
4) Steps 2 and 3 are repeated until convergence has been reached
Purpose of Clustering

- **Purpose**
  - Determine groups of feeders with similar characteristics using K-Means Clustering to better understand how variation in feeder characteristics affects hosting capacity
  - Select representative feeders to use for development of the screening methodology and for validating the screening methodology

- **Steps**
  1. Initial Data Review and Cleanup
  2. Selecting Variables for Clustering
  3. Removing Outliers
  4. Selecting the Number of Clusters
  5. Feeder Selection
Overview of Clustering Approach

2. Selecting Variables for Clustering

- Initial variables were selected based on their potential impact on differentiating feeder types and on DG hosting capacity
- Pairs of highly correlated variables were examined using heat maps to determine if it was appropriate to remove one or more variables
Overview of Clustering Approach

4. Selecting the Number of Clusters

- K-means algorithms require the number of clusters to be specified in advance
- The optimum number of clusters can be derived from a Cubic Clustering Criterion (CCC) which is a quality metric based on minimizing the within-cluster sum of squares.
  - A local maximum that rises above 2 and drops below 2 is an indication of an optimal number of clusters
- Resulting clusters were reviewed and redundant clusters were eliminated to help minimize the number of representative feeders for each utility given the project objectives and limitations
Overview of Clustering Approach

5. Feeder Selection

- Using Principle Component Analysis (PCA), the feeder closest to the center mean of the cluster was selected, and is therefore highly representative of the cluster.

- Other important parameters used to make final feeder selection included significant PV system presence and the existence of feeder SCADA data.
  - These parameters are critical for developing the accurate feeder models needed for analysis.
Clustering Results

- Twenty-two feeders selected from the three utilities
  - 16 feeders for detailed analysis and development of the screening methodology
  - 6 feeders for validation of the methodology
- A relatively small number of initial clusters are needed to represent the variation in the feeder characteristics for each utility
- Characteristics that were primary drivers of cluster selection include:
  - Voltage class
  - Feeder length
  - Number of voltage regulators
Project Task: Collect Solar Measurement Data

- **Task Purpose**
  - Collect solar measurement data for modeling and to understand variability

- **Approach**
  - Pole-mount units capture time-series measurements of actual PV output
  - Accounts for the spatial relationships of measurement locations as well as the time synchronization of PV power into the grid

Variability of PV Generation
Daily Variability January ‘15 to June ‘15
Project Task: Modeling and PV Impact Analysis

- **Task Purpose**
  - Perform high-penetration PV assessment of the 16 feeders to determine each specific feeder’s hosting capacity for solar PV

- **Approach**
  - Create detailed models of the representative feeders
  - Utilize EPRI’s Distributed PV (DPV) Feeder Analysis Method for determining feeder impacts and hosting capacity
  - Simulate a wide range of PV deployment scenarios and penetration levels on each feeder

**Alternatives to the 15% Rule: Modeling and Hosting Capacity Analysis of 16 Feeders. EPRI, Palo Alto, CA: 2015. 3002005812.**
Overall Task Approach

- Detailed feeder model in OpenDSS
- Add PV at customer level
- Evaluate 1000’s of possible solar PV deployments
- Consider different load levels
- Consider small rooftop and large MW-class PV

Feeder Hosting Capacity

- Feeder Model in OpenDSS
- Add PV
- Analyze Feeder Impacts

Voltage Protection
Power Quality
Thermal
Representative Feeder’s Identified from Clustering
Convert Utility Feeder Models to OpenDSS

- The model is converted from the utilities distribution software platform into the OpenDSS platform.
- The feeder model is enhanced using additional data to provide a more detailed representation.
- The final validation is made with respect to measurement data.

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Stochastically Add PV Deployments

- Baseline – No PV
- PV Penetration 1
- PV Penetration 2
- PV Penetration 3
- Beyond…

Process is repeated 100s of times to capture many possible scenarios

Increase Penetration Levels Until Violations Occur
Detailed Feeder Analysis
What are we trying to achieve? ...Hosting Capacity

Better understanding of PV impacts to distribution feeders
- When do impacts occur
- Where is PV more problematic
- What are the limiting factors
- Why can one feeder accommodate more than another
- ...

What is Hosting Capacity?
Amount of PV that can be accommodated on a given feeder without impacting reliability or power quality
Hosting Capacity
What matters most?

- Feeder issue
- PV size and location
- Feeder design and operation

Impact
Below
Threshold
Impact
Depends
Impact
Above
Threshold

Voltage
Protection
coordination
Thermal
capacity

Feeder
Issue
PV Size and
Location
Feeder Design
and Operation
Detailed Hosting Capacity Results

Feeder Issue
1: Primary Overvoltage
2: Primary Voltage Deviation
3: Regulator Voltage Deviation
4: Element Fault Current
5: Sympathetic Breaker Tripping
6: Breaker Reduction of Reach

Vertical lines indicate 15% of peak load.
Correlations – What Characteristics Matter
**Task Purpose**
- Develop and validate a practical screening criterion for evaluating new interconnection requests in aggregate with existing PV.

**Approach**
- Analyze results from PV study
- Develop improved screening methodology
- Validate method using control group of feeders

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*Alternatives to the 15% Rule: Modified Screens and Validation.*
3002005791.
Overview of CA Rule 21

Application for Interconnection

Initial Review Screening
No technical analysis necessary
Pass

Supplemental Review
Technical Analysis required
Pass
Fail

Detailed Study

Interconnection Approved

► Inclusive of all types of distributed generation while this research focused on inverter-based PV

► Adequate for the majority of single system issues

► Need to identify incorrect Pass from Initial Review and incorrect Fail from Supplemental Review
Identify Gaps and Improvement for CA Rule 21

Incorrect Pass of Initial Review
- Impact may occur well below a specific percent of load

Incorrect Failure of Supplemental Review
- Impact may not occur until much higher than a specific percent of load

► Feeder Issue
1: Primary Overvoltage
2: Primary Voltage Deviation
3: Regulator Voltage Deviation
4: Element Fault Current
5: Sympathetic Breaker Tripping
6: Breaker Reduction of Reach

► Vertical lines indicate 15% of peak load
CA Rule 21
Modified Screening Process

Initial Review Screens
• Add screen that considers if the feeder has line regulators
• Always consider aggregate generation

Supplemental Review
• Add simple equations to estimate hosting capacity

Shorthand equations

Screen Q: Does the feeder have Line Reg?

Proceed with interconnection subject to requirements determined by Initial Review or SR, if any

Go to Electrical Independence Tests and Detailed Studies
Detailed Hosting Capacity and Supplemental Review Estimates

Feeder Issue
1: Primary Overvoltage
2: Primary Voltage Deviation
3: Regulator Voltage Deviation
4: Element Fault Current
5: Sympathetic Breaker Tripping
6: Breaker Reduction of Reach

► Vertical lines indicate 15% of peak load
► Asterisks indicate supplemental review estimated hosting capacity
Validation

Initial Review

- Feeder 679 does not contain a line regulator
  - As expected, hosting capacities are above the 15% load limit
- Feeder 514 does contain a line regulator
  - As expected, hosting capacities are below the 15% load limit
  - Feeder subjected to the supplemental review process immediately as opposed to allowing PV deployment up to 15% of peak load and then implementing the supplemental review
- At some point, the aggregate generation on the feeder will cause adverse impact

Supplemental Review

- Asterisks indicate the feeders’ estimated ability to accommodate PV
- Independent of load level and better matches the detailed analysis
Long-Term Solution
Screening that’s in Coordination with Distribution Resource Plans (DRP)

Application for Interconnection

- Fast Track Screening
  - No technical analysis necessary

Supplemental Review

- Technical Analysis required
  - Pass
  - Fail

Distribution Resource Plans

- Automated technical analysis

Detailed Study

- Interconnection Approved

Alternatives to the 15% Rule:
EPRI’s DRP (Streamlined Hosting Methodology) Sample Results

System Hosting Capacity
(~ 300 distribution feeders)

Substation-level Hosting Capacity

Feeder-level Hosting Capacity

*Sample results applying EPRI’s Streamlined Hosting Method for DOE/TVA study, initial results, not finalized
Conclusions

- Current utility planning methods
  - Not consistent nationwide, but planning procedure like CA Rule 21 helps provide uniformity
- Clustering
  - Great way to identify different feeders
- Detailed modeling and analysis
  - Can accurately determine impacts from distributed generation but at the cost of time and resources
- Modified Screening
  - Add an Initial Review screen that addresses if the feeder has line regulators
  - Modify the Initial Review to always account for aggregate generation
  - Add Supplemental Review equations to address the impacts of aggregate generation for issues not solely dependent on load
- Long-term Solution
  - Coordinate screening with establishment of Distribution Resource Plans that account for the locational impact and value of all forms of DER
Together…Shaping the Future of Electricity

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References

Public Link to Reports Online


Alternatives to the 15% Rule: Modified Screens and Validation. EPRI, Palo Alto, CA: 2015. 3002005791.

Backup Slides
Utility Cluster Means

Utility 1:

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Data needed for Supplemental Review (SR) Equations

**Feeder Related**
- **Feeder Resistance**: Resistance to last three-phase node
- **Feeder Impedance**: Impedance to last three-phase node
- **Feeder Voltage Class**: Primary voltage class of the feeder
- **Regulators**:
  - Resistance to regulator
  - Bandwidth
  - Line drop compensation settings

**DER Related**
- **DER Fault Current**: Fault current contribution in PU of rated

**Analysis Thresholds**
- Voltage Headroom
- Allowable primary Voltage Deviation
- Allowable percent increase in fault current
- Allowable percent decrease in breaker sensitivity
- Allowable current rise on breaker ground relay
Validation of Proposed Modifications (proposed SR changes)

- Asterisks demark SR calculated hosting capacities

- SR1 – Primary overvoltage
- SR2 – Primary voltage deviation
- SR3 – Regulator voltage deviation
- SR4 – Element fault current
- SR5 – Sympathetic breaker tripping
- SR6 – Breaker reduction of reach