DYNAMIC LOAD FLOW STUDIES OF DISTRIBUTION FEEDS IN THE SAN JOAQUIN VALLEY REGION

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PHASE I, II AND III

Navigant is supporting the Energy Commission's ongoing assessment of distributed energy resources (DER). This discussion covers Phase III.

DG Integration Cost Study

Phase I

SCE **System-Level** Study:

- Develop analytical framework to study costs of high penetration DG; leverage **steady-state** tools
- Cost to integrate 4,800 MW of DG are approximately:
  - $1B if strategically located;
  - $6B otherwise
- High cost case primarily due to transmission concerns

San Joaquin Valley Region DER Study

Phase II

SJV **Region-Level** DER Study:

- Utilize Phase I framework to study SJV
- Study value of DER to meet SJV region forecasted load growth and reliability needs
- Potential net ratepayer value of over $300M
- Value primarily due to deferral of transmission

Phase III

SJV **Feeder-Level** Study:

- Assess advanced inverter functionality with **dynamic** tools of feeders representative of the SJV Region
- Compare and validate results generated by steady state analysis in Phase II to dynamics analysis

Each phase has increased the level of granularity: System-level to feeder-level; and robustness of simulation modeling techniques, steady-state to dynamic.

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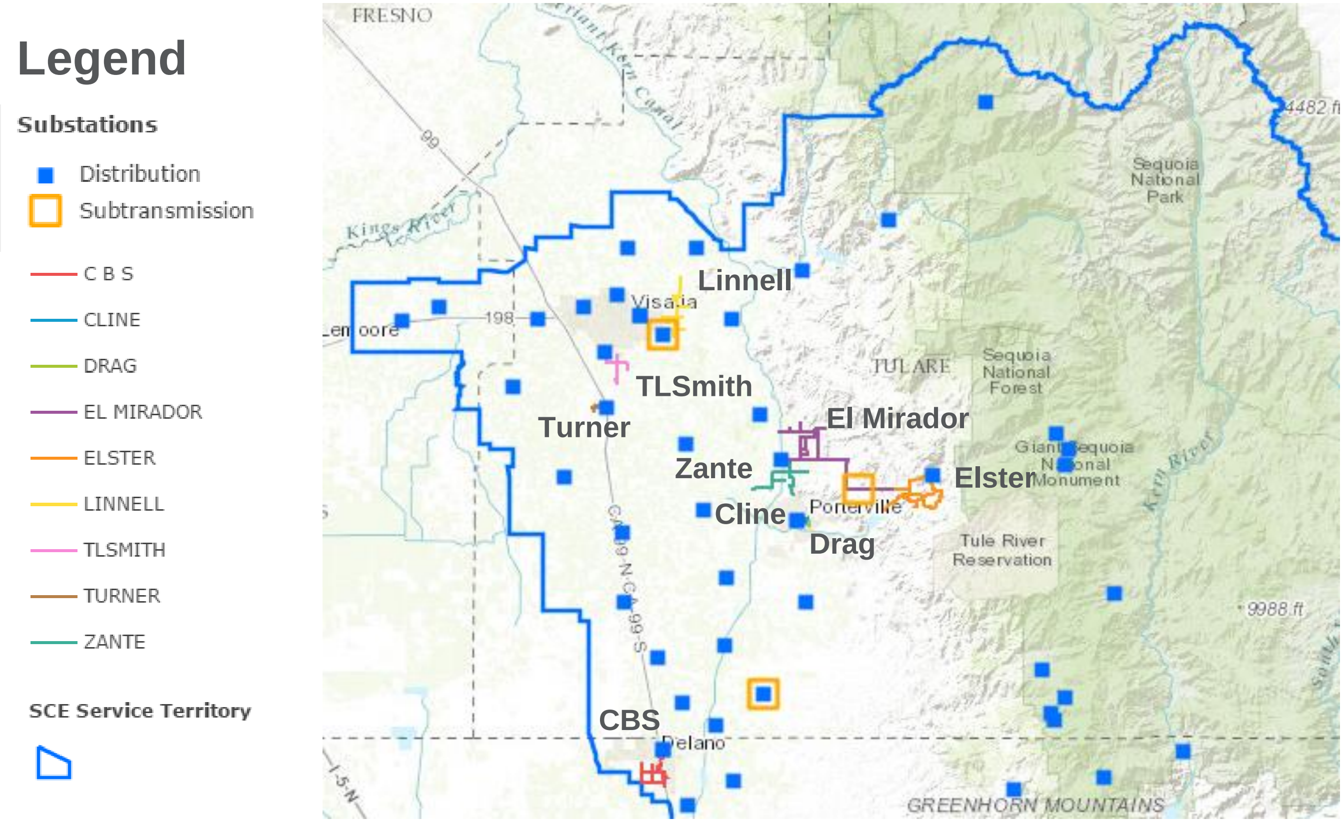
SAN JOAQUIN VALLEY REGION

This phase of the project further assesses DER integration costs for representative feeders in the San Joaquin region evaluated in prior phases.



Feeder Name	# of Feeders Represented
CBS	20
Cline	22
Drag	34
El Mirador	15
Elster	11
Linnell	35
TLSmith	33
Turner	46
Zante	23

The representative feeders were selected via statistical clustering performed in Phase 2. Feeder properties appear on slide 31 of the Appendix.

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MODELING APPROACHES

Four modeling approaches were applied in Phase II & III by varying inverter type and modeling technique. Results for each phase are compared as follows.

Phase	Inverter	Modeling Technique
Phase II	Standard	Steady-state
	Advanced	Steady-state
Phase III	Standard	Dynamic
	Advanced	Dynamic

The methodology and costs of implementing system upgrades for these scenarios appear in slides 32-34 of the Appendix.

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SIWG PHASE 1 FUNCTIONS

The Smart Inverter Working Group (SIWG) has recommended that seven advanced inverter functionalities should be mandatory by mid-2016.

SIWG Recommendations for Phase 1 Functions	Modeled in CYME?	Reason
Support anti-islanding to trip under anomalous conditions	No	Emergency functionality, cannot be modeled in CYME
Provide ride-through of low/high voltage excursions	No	Emergency functionality, cannot be modeled in CYME
Provide ride-through of low/high frequency excursions	No	Emergency functionality, cannot be modeled in CYME
Provide volt-var control autonomously (*Volt-Var*)	Yes	Controls feeder voltage during normal operation
Define default and emergency ramp rates	No	Emergency functionality
Provide reactive power by a fixed power factor (*Watt-power factor*)	Yes	Controls feeder voltage during normal operation
Reconnect by “soft-start” methods	No	Cannot be modeled in CYME

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ADVANCED INVERTER APPROACH

MODELED FUNCTIONS

Three functions were selected based on ability to regulate voltage during normal operations (i.e., non-emergency situations) and could be modeled in CYME.

Functionality	Capability to Regulate Voltage
Volt-Var	The utility sets the curves for volt-var control for the DER system to provide dynamic reactive power injection through autonomous responses to local voltage measurements (volt-var control is a Phase 1 function; updating the volt-var curves is a Phase 3 capability).
Watt-power factor	The utility sets a fixed power factor parameter for the DER system (having a fixed power factor is a Phase 1 capability; updating the power factor is a Phase 3 capability)
Voltage-Watt*	The utility sets the voltage-watt parameters for the DER system to modify its real power output autonomously in response to local voltage variations.

* Note: Voltage-Watt is a SIWG-proposed Phase 3 function. It was included as it can potentially control voltage/loading and can be modeled using CYME.

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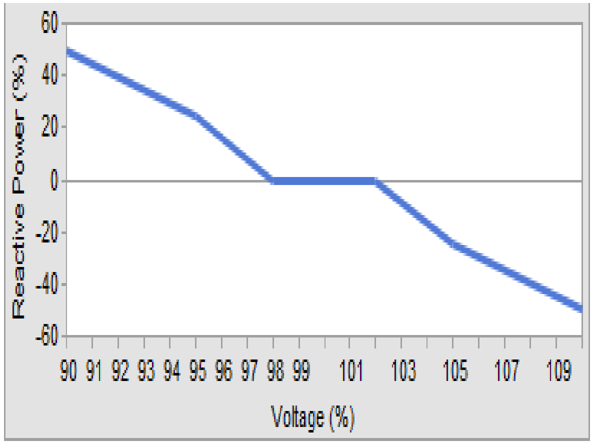
MODELED FUNCTIONS

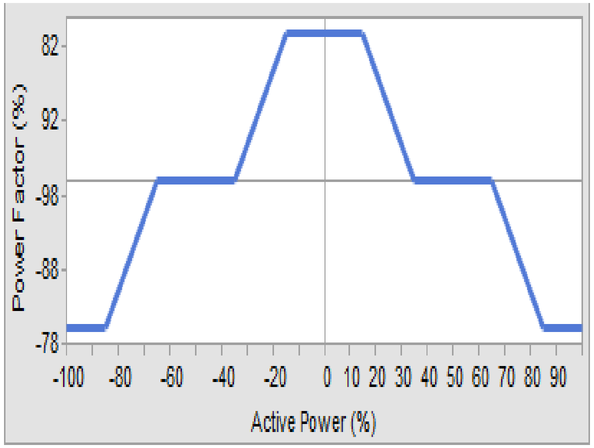
CYME simulates functions and response of advanced inverters through pre-set directions. The pre-sets for each function are depicted graphically, below.

Volt – Var Control



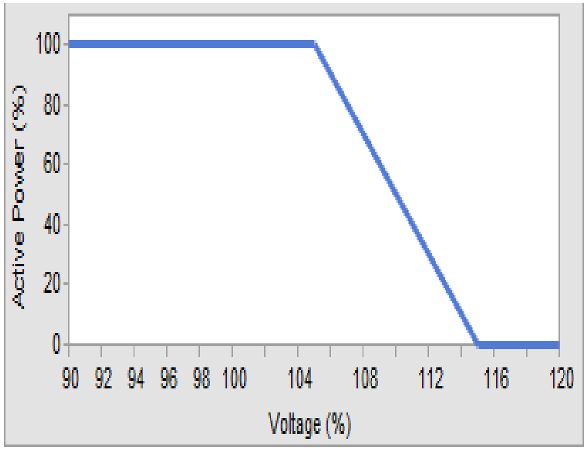
- The volt-var control curve was adjusted from the default provided in CYME
- In order to maintain voltage stability, reactive power output of the inverter was made continuous

Watt – Power Factor Control



- The watt-power factor curve shown is the default curve provided in CYME
- At certain active power outputs, the DER with W-pf control enabled adjusts its power factor, effectively providing or absorbing vars to adjust system voltage

Volt – Watt Control



- The volt-watt curve shown is the default curve provided in CYME
- At voltage levels greater than 1.05 p.u, the output of the unit with V-W control enabled drops to 0 rapidly

Note: For volt-var control, reactive power flow was prioritized. That is, the inverter would supply or absorb reactive power if capable, even if a reduction in real power output was to occur. This assumes suitable compensation or utility imposed rules surrounding this artificial curtailment.

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FUNCTIONALITY WITH INCREASING PENETRATION

A process was developed to enable different control functionalities as the number of inverters modeled in CYME increases (DER penetration: 0% to 100%).

0% Penetration

Advanced inverter functionality deployed for all DER, but not necessarily utilized

↓

50% Penetration (or first violations)

Enable **volt-var** control on those inverters connected downstream of >75% of the feeder length

↓

75% Penetration

Enable **watt-power factor** control on the inverter with the highest rated power. This functionality continues to be applied if a larger unit connects

↓

100% Penetration

Enable **volt-watt** control on all inverters that did not have functionalities enabled at lower penetration levels, as well any new inverters connecting.

- As implementation techniques were tested, we determined that DER distance from the substation increases the effectiveness of volt-var control
- In addition, adjusting power factor proved effective in controlling feeder voltage only when applied to larger DER units
- Functionalities are mutually exclusive; that is, each inverter only has one functionality enabled at a time.

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REPRESENTATIVE FEEDER COST COMPONENTS

Three cost components were evaluated for both the traditional and advanced inverter deployment strategies.

1. **Feeder level system upgrades** (i.e. reconductoring, installing line regulators) determined to be required as a result of load flow modeling.

2. **Protection upgrades** determined to be required to maintain integrity of schemes currently in place.

3. **Allocated costs for system communication and control technologies** to enable advanced inverter functionalities.

The cost of most feeder level system upgrades are included the system upgrade cost curves depicted in the following slides.

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COMPARISON OF STEADY STATE VS. DYNAMIC MODELING

Steady state simulation included use of discrete load and generation levels, whereas dynamics simulation required continuously varying profiles.

Attributes for Steady State vs. Dynamic Modeling

	Steady State	Dynamic
Load and Generation	Discrete load and generation levels	Continuously varying load and generation levels based on input profiles
Capacitor banks	Uses discrete load/generation level to determine capacitor bank production	Outputs the changing level of cap bank production at different times during the simulated period
Voltage regulators	Uses discrete load/generation level to determine voltage regulator response	Outputs the tap changes of voltage regulators at different times during the simulated period
System response	Cannot model system response to fast local changes in load/generation	Can model system response to fast local changes in load/generation
Inverter functionality	Must approximate the effects of advanced inverter functionalities through fixing inverter power factor	Can control inverter behavior with a variety of control curves to represent different functionalities

Dynamic modeling was performed for summer and winter load/irradiance profiles. The irradiance and load profiles are provided in the Appendix, slides 36-41.

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SYSTEMATIC APPROACH

Navigant followed a systematic approach to complete the dynamic modeling analysis of representative feeders located in the San Joaquin Valley.

Dynamic Model Preparation

- Determine the amount of DER capacity to simulate
- Determine which of the SIWG functionalities to model
- Select points of connection for inverter based DER
- Input hourly loading and weather/irradiance data

Dynamic Model Simulation

- Simulate models for different levels of DER penetration
- Assess dynamic impacts without advanced inverter functionality
- Assess dynamic impacts with advanced inverter functionality
- Compare system upgrade costs

This process is similar to the approach applied to examine steady state impacts in Phase 2.

SELECTING POINTS OF CONNECTION FOR DER

DER feed-in points were identified for each representative feeder based on the loads and conductor type. A similar number of points were used for each feeder.

Determine the ratio of aggregated residential / C&I / agricultural load on each feeder

↓

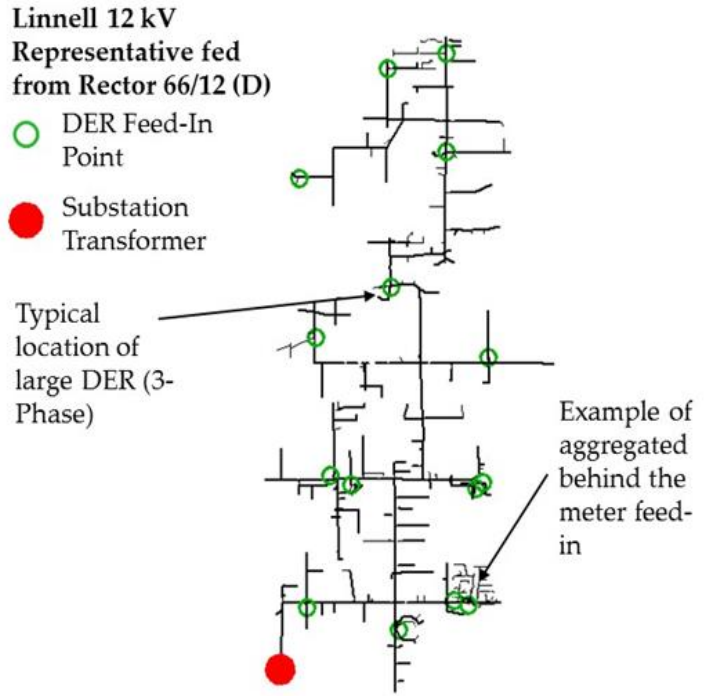
Calculate aggregated DER capacity for NEM and non-NEM proportional to ratios by customer class

↓

Identify large load centers on feeder. Classify as residential / C&I / agricultural

↓

Divide aggregated capacity by generator type into individual DERs. DER size scales with local load.



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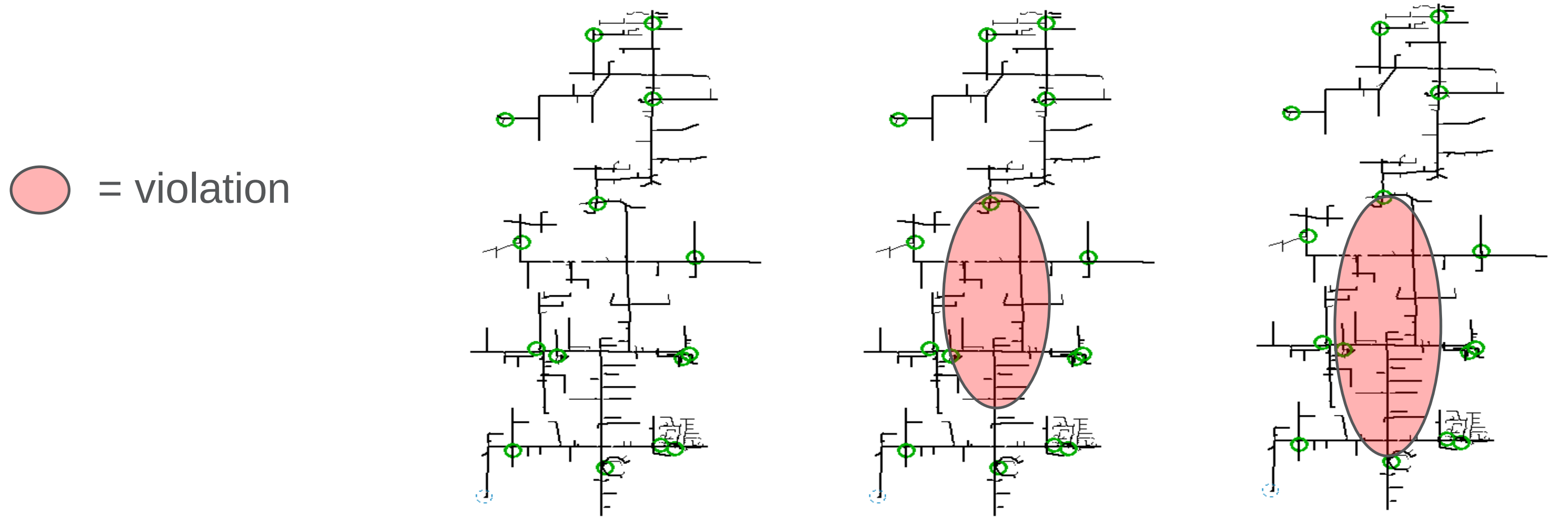
SIMULATION FOR DIFFERENT LEVELS OF DER

The degree and extent of violations typically increase as DER penetration level increases.



Penetration Level	0%	50%	100%
Violation	None	Overvoltage 9 mi	Overvoltage 10 mi
NEM Capacity	0 MW	4 MW	8 MW
Non-NEM Capacity	0 MW	2 MW	4 MW

Note: Penetration level is defined as the amount of DER divided by the feeder thermal rating. DER penetration was also assessed at 25% and 75%, but not included in this illustration.

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DYNAMICS STANDARD INVERTER MITIGATION

Upgrades required to mitigate DER impacts are determined for each penetration level. Upgrades for the Linnell feeder appear below for increasing DER capacity.

Dynamic Modeling with Standard Inverter for the Linnell Feeder

Penetration Level	Violation or Constraint	Type of Upgrade or Mitigation	Conductor Upgrades	Quantity or Distance (miles)	Cost ($000)	Total Upgrade Cost ($000)
25%	OV	Reconductor OH	CU 4/0	4.7	$ 2,731	**$ 2,731**
50%	OV	Reconductor OH	ACSR 336	8.9	$ 5,198	**$ 5,198**
75%	OV	Reconductor OH	ACSR 336	8.9	$ 5,198	**$ 5,401**
	OV	Add line regulator		1	$ 203	
100%	OV	Reconductor OH	ACSR 336	9.4	$ 5,473	**$ 5,884**
	OV	Add line regulator		2	$ 406	
	OV	Adjust cap bank controls		1	$ 5	

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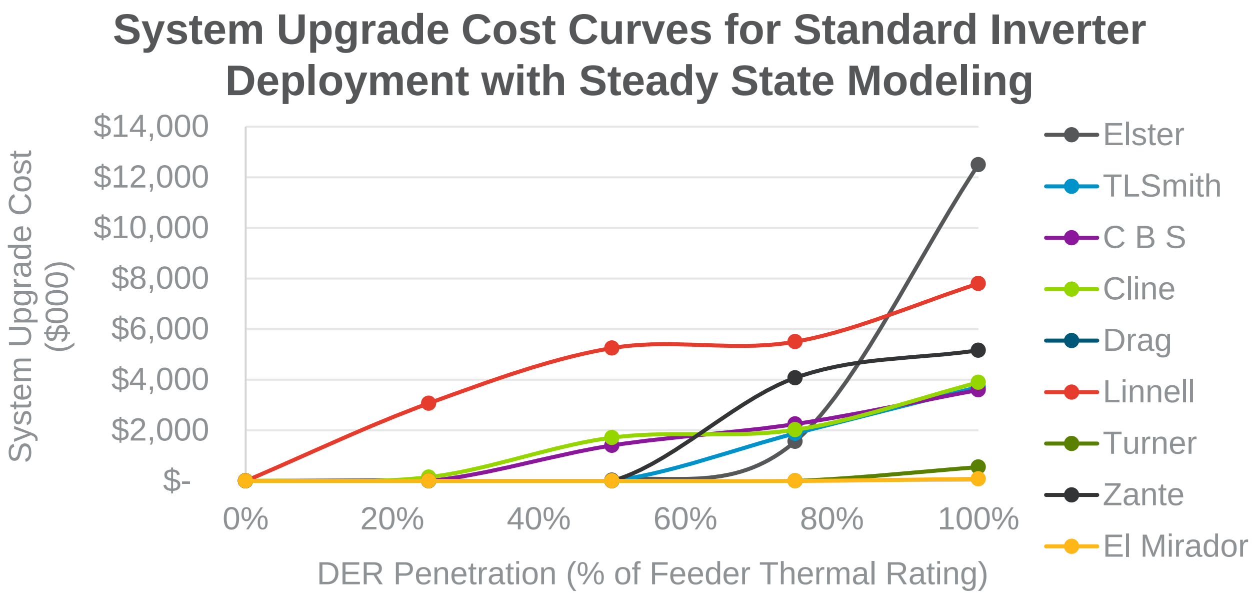
STEADY STATE MODELING OF STANDARD INVERTERS

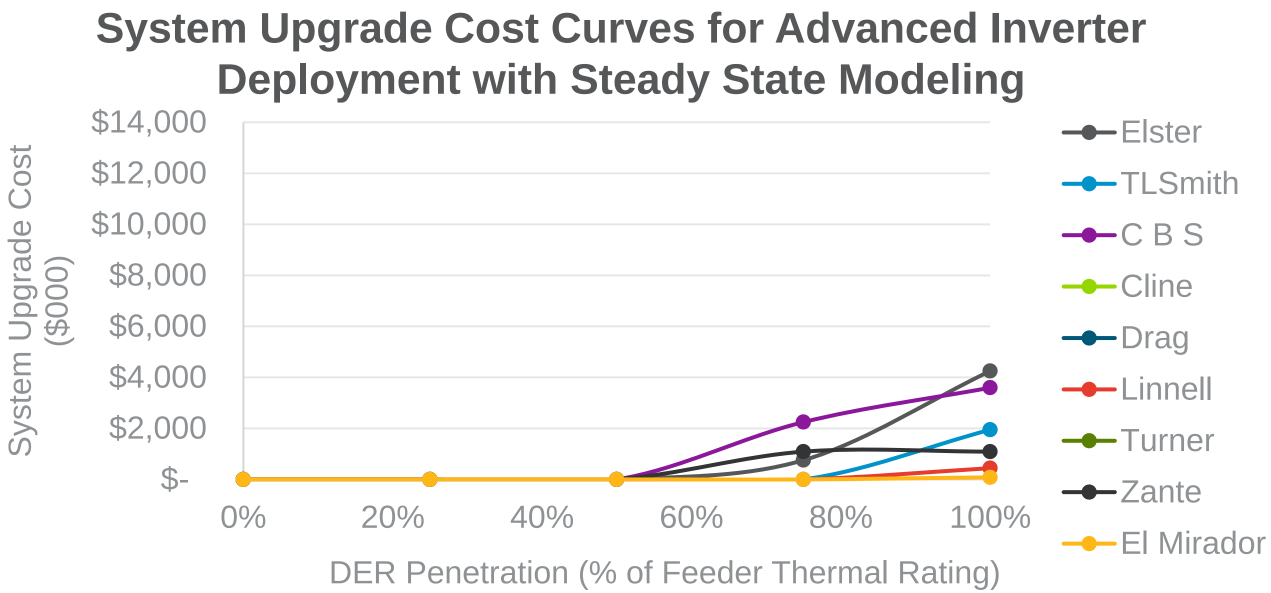
Estimated system upgrade costs for standard inverters with steady state modeling appear below.



- Cluster 5 (Drag representative) required no system upgrades, as it is comprised of shorter, highly loaded feeders; mostly high gauge conductor with few laterals
- Cluster 6 (Linnell representative) experienced high system upgrade costs due to impacts observed at low penetration levels. It is comprised of longer, lightly loaded laterals and has longer sections of smaller conductor

STEADY STATE MODELING OF ADVANCED INVERTERS

System upgrade costs decrease when advanced inverter controls are applied in CYME steady state simulations.



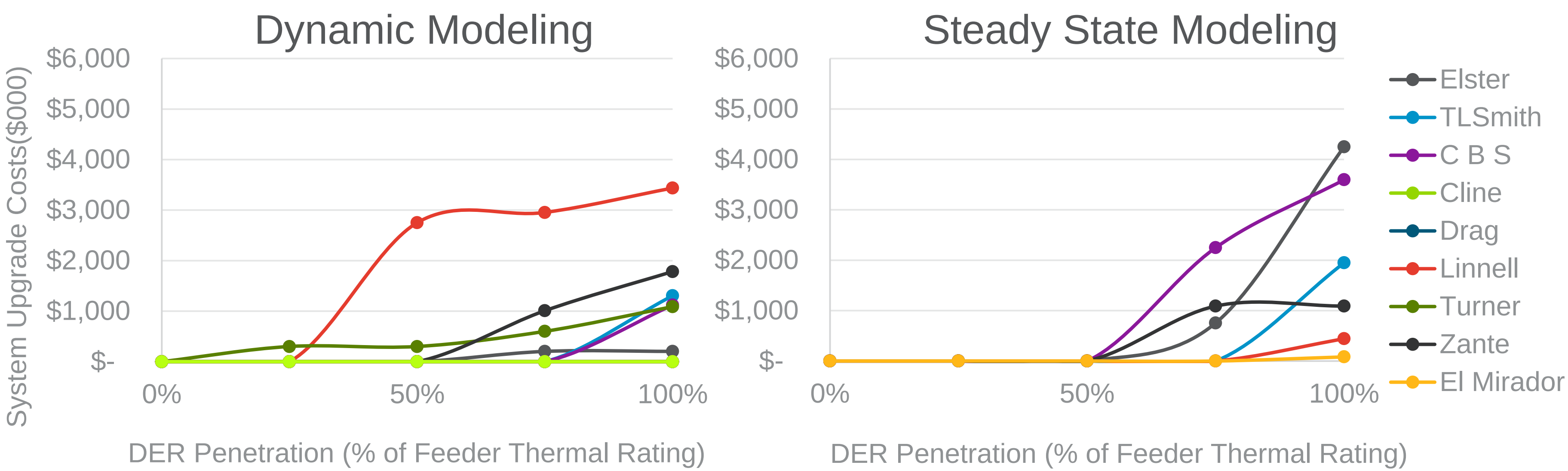
Note: cost curves do not include additional communications costs required to enable advanced functionalities.

- Cluster 4, 5, 7 (Cline, Drag, Turner) required no system upgrade costs, as Clusters 4 and 7 are shorter feeders, less susceptible to violations
- Overall, results confirm average and maximum interconnection costs are lower when advanced inverter functionalities are deployed

COMPARING MODELING TECHNIQUES WITH ADV INVERTERS

However, upgrade costs are higher when dynamic impacts are modeled in CYME (compared to steady state model for the advanced inverter scenarios).

System Upgrade Cost Curves for Advanced Inverters



Note: cost curves do not include additional communications costs required to enable advanced functionalities.

- The assumptions applied in the steady state model did not capture the capability of advanced inverter functions beyond power factor adjustment.
- The cost curves above estimate similar upgrade costs in both steady state and dynamics simulations for advanced inverter interconnection. Exceptions include Linnell and Turner (dynamics show a higher level of cost).

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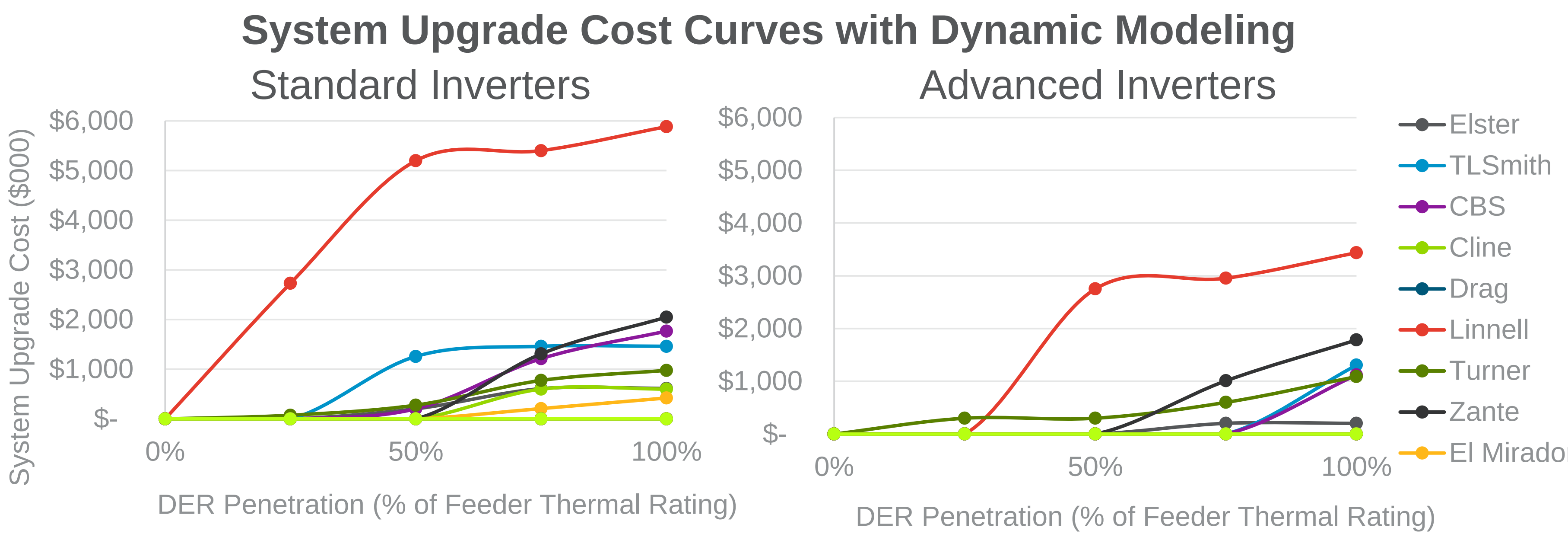
STD AND ADV INVERTERS WITH DYNAMIC MODELING

Implementation of advanced inverters reduced the extent of system upgrades necessary to mitigate DER penetration compared to standard inverters.



Note: cost curves do not include additional communications costs required to enable advanced functionalities.

- With standard inverters most feeders experienced upgrade costs in the $1-2M range when approaching 100% penetration.
- With advanced inverters few feeders required upgrades to mitigate DER interconnection at lower penetration levels as compared to standard inverters with only “conventional” upgrades

STD AND ADV INVERTERS WITH DYNAMIC MODELING

For most cases, the Advanced Inverter deployment strategy significantly reduced system upgrade costs compared to the traditional mitigation.

Comparison of System Upgrade Costs at 100% DER Penetration with Dynamic Modeling

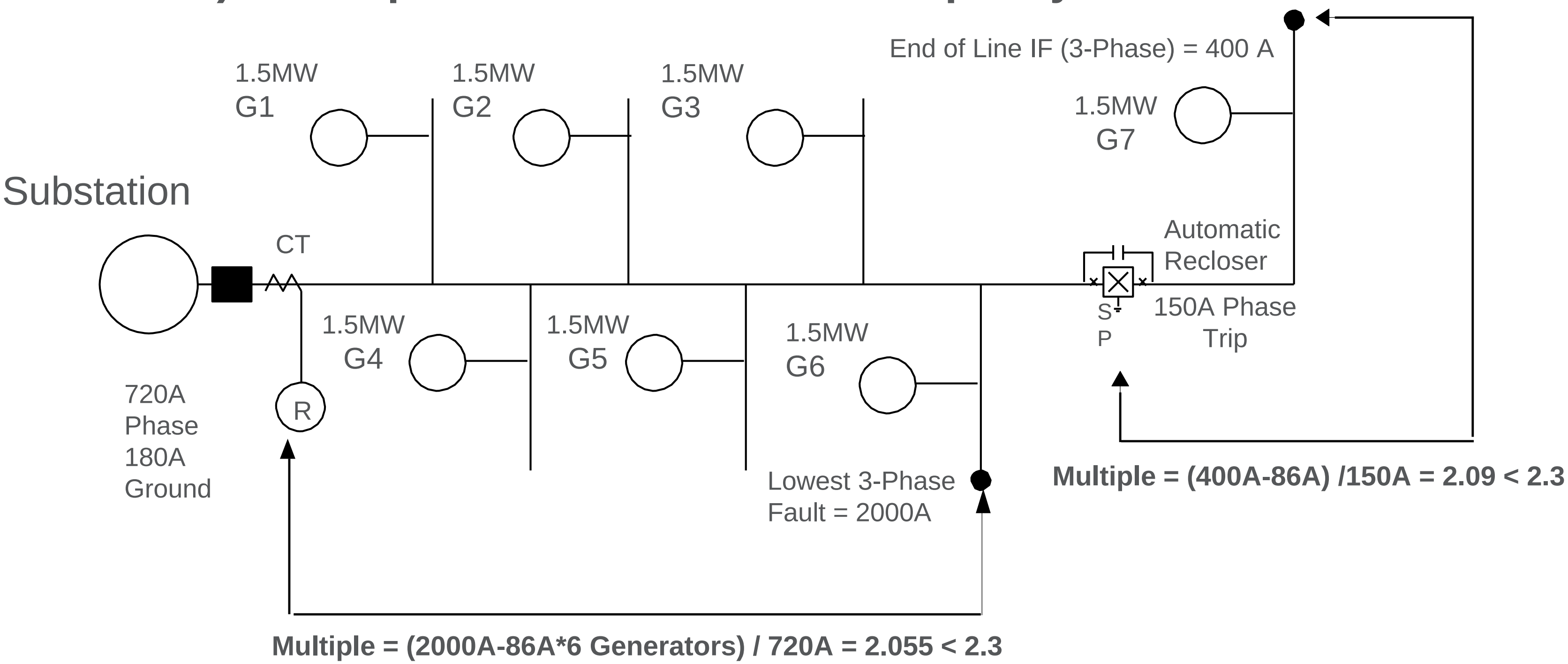
Feeder Name	Standard Inverter	Advanced Inverter	Difference
ELSTER	$ 614	$ 203	$ (411)
TLSMTH	$ 1,461	$ 1,305	$ (155)
CBS	$ 1,768	$ 1,119	$ (649)
CLINE	$ 600	$ -	$ (600)
DRAG	$ -	$ -	$ -
LINNELL	$ 5,884	$ 3,437	$ (2,447)
TURNER	$ 977	$ 1,088	$ 111
ZANTE	$ 2,048	$ 1,783	$ (265)
EL MIRADOR	$ 493	$ -	$ (493)

Note: cost curves do not include additional communications costs required to enable advanced functionalities.

- The level of system upgrade costs generally decreased when moving from standard inverters to an advanced inverter deployment strategy
- The Turner representative was a candidate for Energy Storage based mitigation in the advanced inverter case, which was more costly then conventional upgrades

EVALUATION OF PROTECTION LIMITS

The ability of reclosers to effectively isolate faults (due to reduced fault current contribution) is compromised as more DER capacity is connected to a feeder.



- A representative one line diagram at 100% DER penetration relative to the feeder rating is illustrated above.
- Each 1.5 MW generator contributes 1.2 per unit fault current (i.e. 86 A). Current trip settings of both the feeder circuit breaker (720 A phase trip) and the downstream automatic recloser (150 A phase trip) would not trigger in fault scenarios because the protective devices due not register at least 2.3x the rated fault current.
- The impedance of the circuit would need to be reduced to increase the reach of the current protection devices

PROTECTION SCREENING
RESULTS WITH INCREASING DER PENETRATION

The capacity of DER in the representative feeder's protection zones was used to screen impact on protective device coordination settings.

	Penetration Level			
Protection Zone	**25%**	**50%**	**75%**	**100%**
C B S 12KV CB	Pass	Fail	Fail	Fail
ELSTER 12KV CB	Fail	Fail	Fail	Fail
TLSMITH 12KV CB	Fail	Fail	Fail	Fail
ZANTE 12KV CB	Pass	Fail	Fail	Fail

Note: Representative feeders not included in the table did not fail the protection screen at any penetration level

	Penetration Level			
Feeder	**25%**	**50%**	**75%**	**100%**
C B S	NONE	RAR	RAR	RAR
Elster	RAR	4.7 mile - 336A	Sub Transformer Upgrade	Sub Transformer Upgrade
TLSmith	RAR	RAR	0.93 mi - 336A	2.6 mi - 336A
Zante	NONE	RAR	1.2 mi - 336A	2.4 mi - 336A

Note: RAR = Remote Automatic Recloser

- Protection screening indicated that some feeders had a capacity of DER connected that reduced the coordination of protective devices (circuit breakers/remote automatic reclosers) below acceptable levels
- These feeders were assessed to require additional upgrades, and therefore mitigation costs, as shown
- Note: protection costs could increase due to the necessity of upsizing inverter ratings when offering voltage support in the advanced inverter case. This increase was not quantified.

COMPARING SYSTEM AND PROTECTION UPGRADES

The upgrades that address protection coordination are much more significant than the system upgrade costs to mitigate DER impacts. This comparison is made below for the feeders that triggered protection upgrades.

Cost Components of selected feeders by DER penetration level ($000)

	System Upgrade Costs for Dynamic Advanced Inverter Case				Protection Upgrade Costs			
Feeder Name	**25%**	**50%**	**75%**	**100%**	**25%**	**50%**	**75%**	**100%**
CBS	$ -	$ -	$ -	$ 1,120	$ -	$ 82	$ 82	$ 82
Elster	$ -	$ -	$ 203	$ 203	$ 82	$ 2,813	$ 4,813	$ 4,813
TLSMITH	$ -	$ -	$ -	$ 1,305	$ 82	$ 82	$ 622	$ 1,593
Zante	$ -	$ -	$ 1,009	$ 1,784	$ -	$ 82	$ 779	$ 1,476

Note: Representative feeders not included in the table did not fail the screen at any penetration level

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COMPARING SYSTEM AND PROTECTION UPGRADES

Protection costs comprise a significant portion of overall costs for 3 out of 9 of representative feeders at 100% penetration

System Upgrade Costs with Advanced Inverter with Dynamic Modeling and Protection Costs

Feeder Name	System Upgrade	Protection	Total
ELSTER	$ 203	$ 4,813*	**$ 5,016**
TLSMTH	$ 1,305	$ 1,593	**$ 2,898**
CBS	$ 1,119	$ 82	**$ 1,221**
CLINE	$ -	$ -	**$ -**
DRAG	$ -	$ -	**$ -**
LINNELL	$ 3,437	$ -	**$ 3,437**
TURNER	$ 1,088	$ -	**$ 1,088**
ZANTE	$ 1,783	$ 1,476	**$ 3,259**
EL MIRADOR	$ -	$ -	**$ -**

* Includes substation transformer and feeder conductor upgrades

COST ESTIMATE

System level communications investments beyond the current SCE strategy is required to enable widespread operation of the studied functionalities.

- Incremental system level communication and control costs necessary to enable advanced inverters are being evaluated.
- Upon completion, the additional allocated cost of communication infrastructure will be associated with the advanced inverter mitigation strategy cost curves.

DESCRIPTION

Energy Storage was evaluated with dynamics simulation as a potential mitigation option when paired with advanced inverters.

- Energy storage as a mitigation option was implemented on a test feeder.
- A representative feeder was selected that experienced voltage violations that could not easily be mitigated with voltage regulation devices as well as overloading due to DER interconnection.
- The Turner representative feeder exhibited these properties – the majority of the feeder is underground cable and line voltage regulators were ineffective in reducing overvoltage conditions. Overloading was also present at points of the circuit where the predominant conductor size was ACSR#4.

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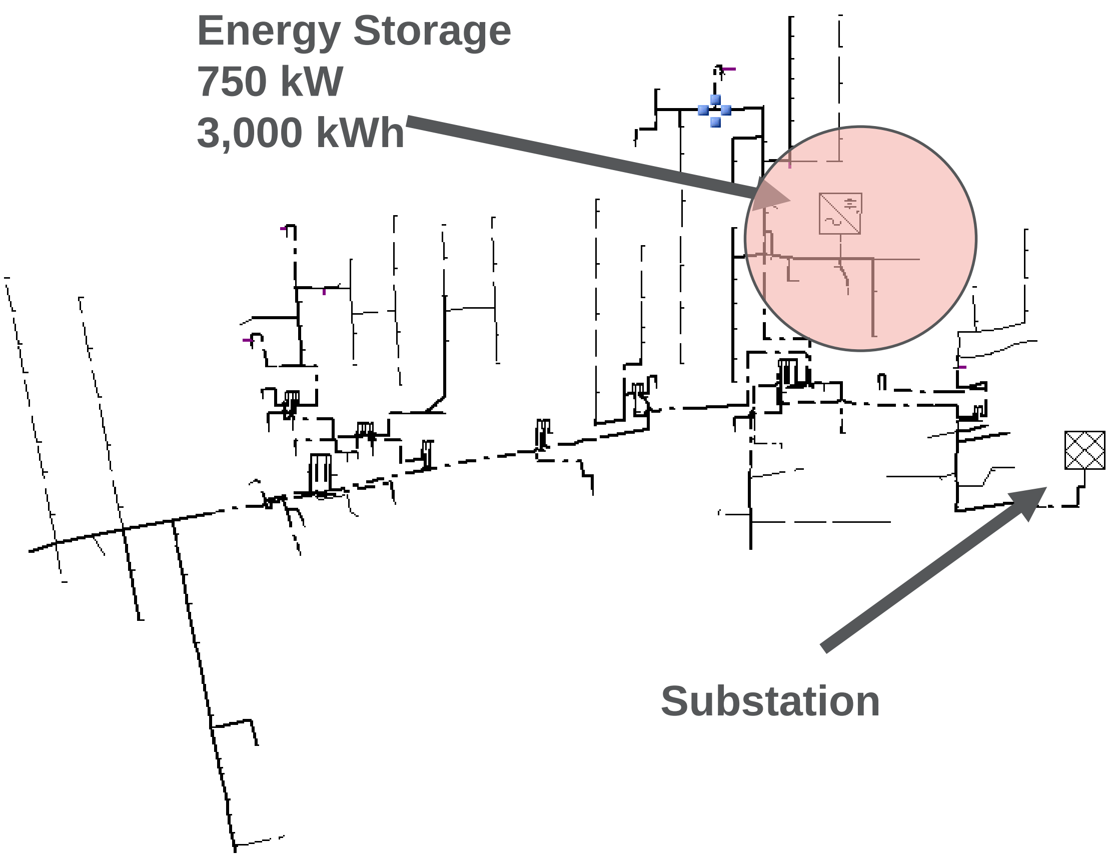
DESCRIPTION

Energy Storage was paired with the largest rated inverter. The rating of the device scaled with increasing penetration of DER simulated.



- The point of connection of the storage device relative to the substation, and approximate radius of effect (i.e. area of the feeder where violations were cleared) are represented
- In all, the cost of reconductoring required in the traditional approach was similar to the cost of storage implemented, when assuming a storage cost of $2,000/kW

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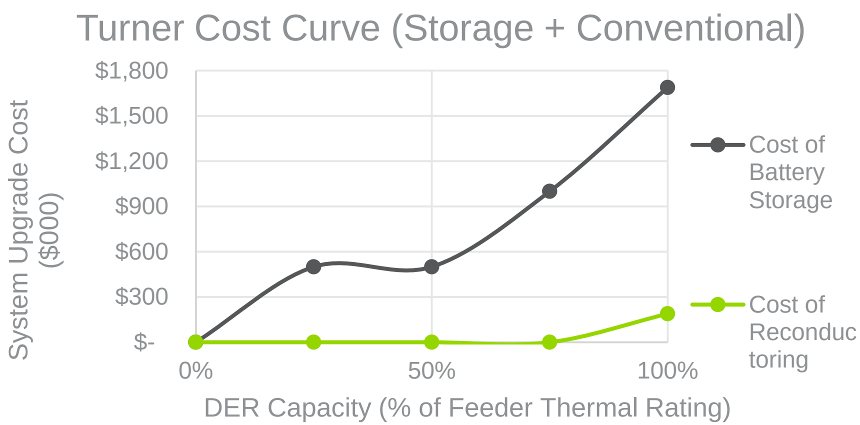
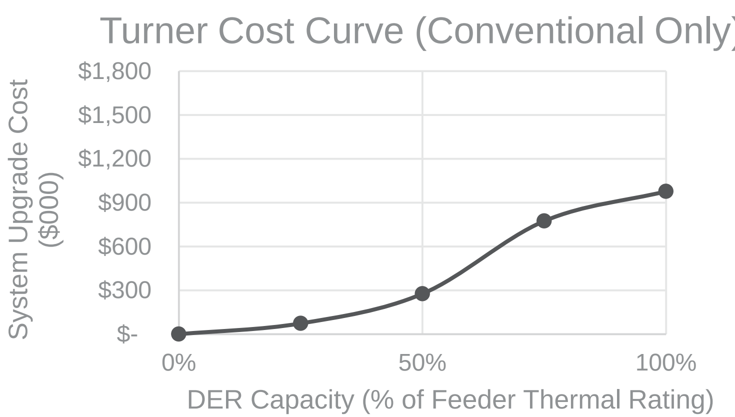
COST CURVE WITH INCREASING PENETRATION

Energy storage was implemented as a mitigation option on the Turner 12 kV feeder and was effective in mitigating overvoltages/overloading.





- The energy storage was connected in "DER-driven" mode (i.e. generator following) at the point of connection of the largest capacity DER on the feeder.
- Costs increased at higher penetration levels as higher capacity of energy storage was required to mitigate violations.
- Energy storage at the assumed cost is more expensive than reconductoring, but is a reasonable comparison given declining costs.

CONCLUSIONS

1. System upgrade costs required to mitigate DER interconnection can be decreased significantly when advanced inverter functionalities for local voltage control are enabled.

2. Fault protection and coordination is a factor in interconnecting DER on some feeders, and has the potential to significantly increase the cost of feeder upgrades.

3. Energy Storage is effective in mitigating overvoltages and overloads when deployed in a "generator-following" mode, i.e. when its output can be controlled to follow generator output..

4. The level of voltage control that can be achieved by inverters through var absorption may be constrained by reactive power transfer limits provided by the transmission system in areas where var controls are enabled. Additional study is required to identify these limits.

5. Investments in communications systems are required in order to support monitoring and controls requirement for DER, particularly with advanced inverter functionalities enabled.

NEXT STEPS

- Workshop
- Final report

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DYNAMIC STUDIES PROPOSED METHODOLOGY

The 9 representatives used in the DER pilot study along with physical properties and customer/load information are listed below:

Cluster	Feeder Name	Substation	Voltage (kV)	2012 %3phase	2012 Total Length (mi)	2012 Number of Line Capacitors	2012 Load (MW)	2012 Total Customers	% Res	% C&I	% Ag
1	ELSTER	Boxwood 66/12 (D)	12	55%	61.6	8	7.3	1086	76%	13%	11%
2	TLSMITH	Liberty 66/12 (D)	12	89%	10.0	4	2.8	392	24%	13%	63%
3	C B S	Delano 66/12 (D)	12	79%	34.6	7	11.3	1409	26%	53%	21%
4	CLINE	Porterville 66/4.16 (D)	4.16	84%	4.1	1	2.4	230	61%	39%	0%
5	DRAG	Porterville 66/12 (D)	12	90%	12.2	5	4.9	805	49%	48%	4%
6	LINNELL	Rector 66/12 (D)	12	84%	32.1	4	4.5	910	65%	22%	13%
7	TURNER	Tulare 66/12 (D)	12	67%	11.0	3	9.5	1240	42%	54%	4%
8	ZANTE	Strathmore 66/12 (D)	12	92%	43.7	5	7.1	671	46%	19%	35%
9	EL MIRADOR	Strathmore 66/12 (D)	12	86%	48.4	6	5.1	607	22%	13%	65%

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MITIGATION STEPS

Navigant has taken steps to apply planning criteria and solutions used by SCE to mitigate DER impacts. The following reflects the mitigation decision tree that Navigant has applied in the DER pilot study.

For Temporary Overvoltage or Sustained Undervoltage scenarios:

1. Determine if power factor regulation at large DER point of connections (POCs) clear violations. Due to the limitation of real power injection caused by power factor restriction, the impact on customer financials should be considered as an impediment to integration. This method should only be used for large interconnecting DER.

2. Review settings of controlled capacitor banks/regulating devices in the locale of the violations. Determine if changing these settings would accommodate DER.

3. Explore the installation of shunt capacitors near the DER POC or the upgrade of fixed capacitors to controlled capacitors to provide voltage support.

4. Determine if reconductoring overvoltage/overloaded sections with larger gauge conductor can accommodate power injection at the DER site.

5. Where operational policy does not curtail DER, if violations are widespread on the circuit and are not mitigated by the above options, examine adjustment of substation bank tap changers. In extreme cases the need to construct a new feeder to accommodate DER may arise.

6. Explore the installation of a line regulating Under Load Tap Changing (ULTC) transformer on the main line of the circuit, upstream of DER feed in point, in situations where the DER is not causing reverse power flow.

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MITIGATION STEPS

Continued

For section Overloading scenarios:

1. Assess which protective devices (fuses, reclosers) or regulating devices (line regulators) require upgrading due to DER local power injection and select equipment that can maintain operability under maximum DER output.

2. Determine if adding phases and reconductoring overloaded sections with larger gauge conductor can accommodate power injection at the DER site.

3. Where operational policy does not curtail DER, if violations are widespread on the circuit and are not mitigated by the above options, examine adjustment of substation bank tap changers. In extreme cases the need to construct a new feeder to accommodate DER may arise.

Other Notes:

1. SCE does not have an anti-islanding stance which would restrict the connection of DER.

2. Most of the protection equipment in SCE substations are non-directional and will not be affected by reverse power flow.

3. Feeder transfer limits are considered when screening DER to be integrated. Adjacent feeder transfer capacities must be assessed to limit reliability/operational flexibility impacts that result from DER connection.

4. With regards to burden of the above mitigation costs, SCE will only bear the costs associated with distribution upgrades for generators connecting under the NEM agreement. The distribution upgrades associated with non-NEM generators, and the interconnection facilities costs for all generators are borne by the customer.

MITIGATION MEASURES COST TABLE

The mitigation costs for wires-type options have been identified by SCE.

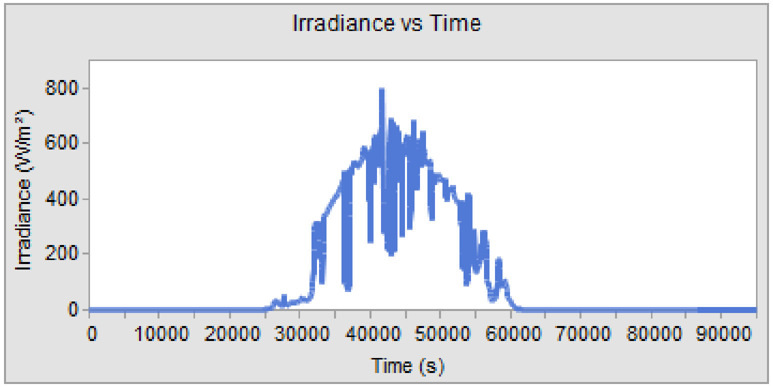
Mitigation Measures

Description	Cost ($000)	
Reconductor OH - 1 Phase (per mile)	$	481
Reconductor OH - 3 Phase rural (per mile)	$	581
Capacitor Bank Setting Adjustment	$	5
New Capacitor Bank	$	54
Inverter Power Factor Adjustment	$	-
LTC Controls	$	80
New Distribution Feeder	$	2,500
Replace Line Fuse	$	14
New Recloser	$	82
New 3 Phase Underground Cable	$	1,584
New Regulator	$	203
New Substation XFMR Bank	$	5,000
Statcom	$	200
New Substation	$	50,000

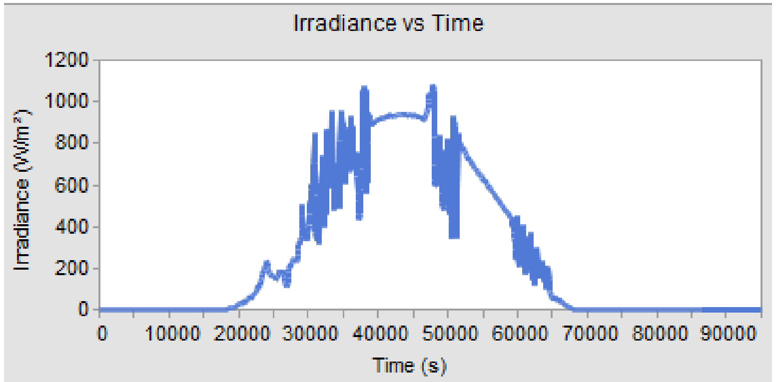
IRRADIANCE PROFILES USED

Navigant utilized the irradiance profiles listed for Los Angeles in the CYME library; a profile was provided for winter (in January) and summer (in July).

Los Angeles January



Los Angeles July

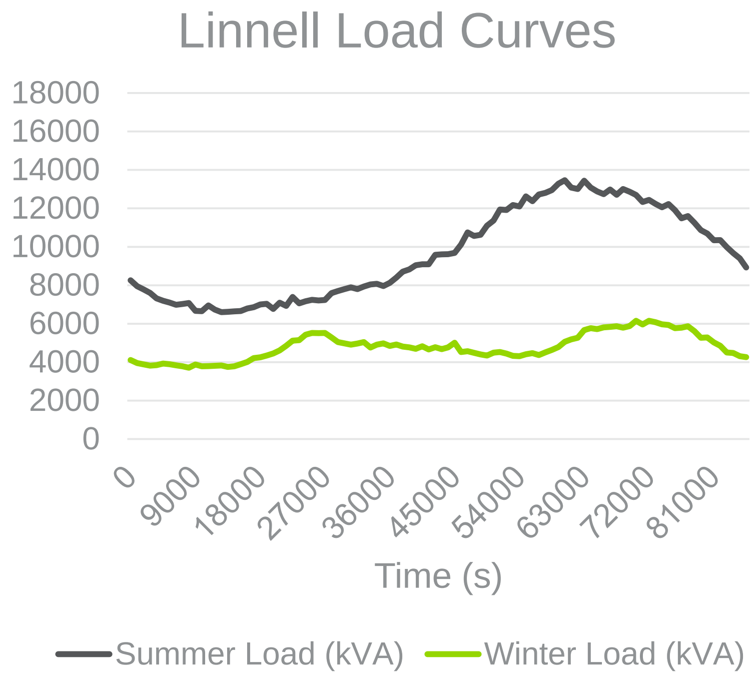


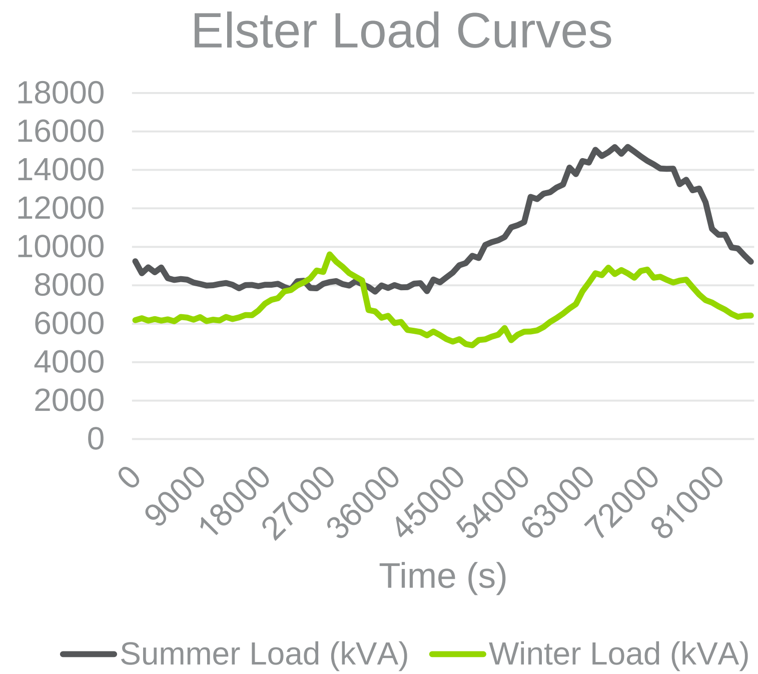
- It can be noted that the winter profile has a narrower bandwidth of irradiance and a lower peak
- There are similar amounts of variability in each profile (due to cloud cover, etc.)

NAVIGANT

LOAD PROFILES USED

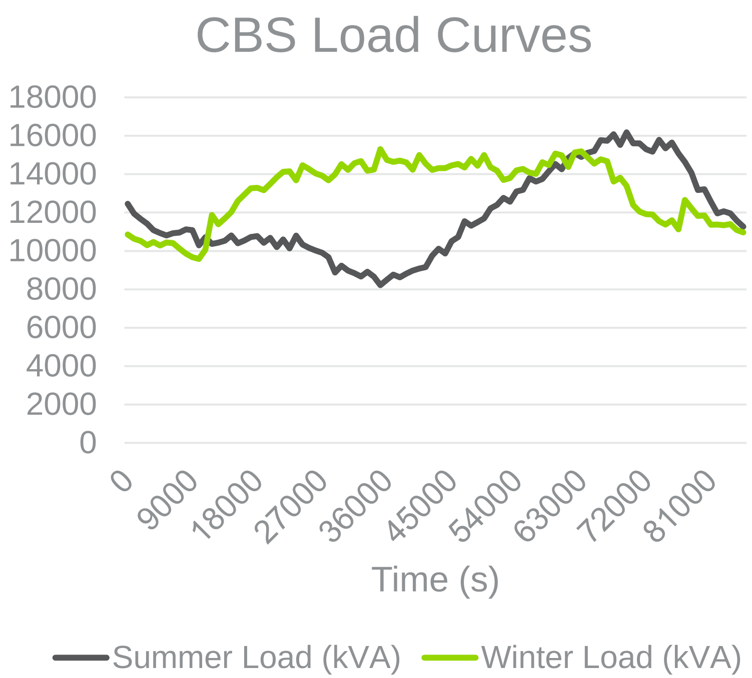
15 minute load profiles were made available by SCE for each representative feeder based on metered data.

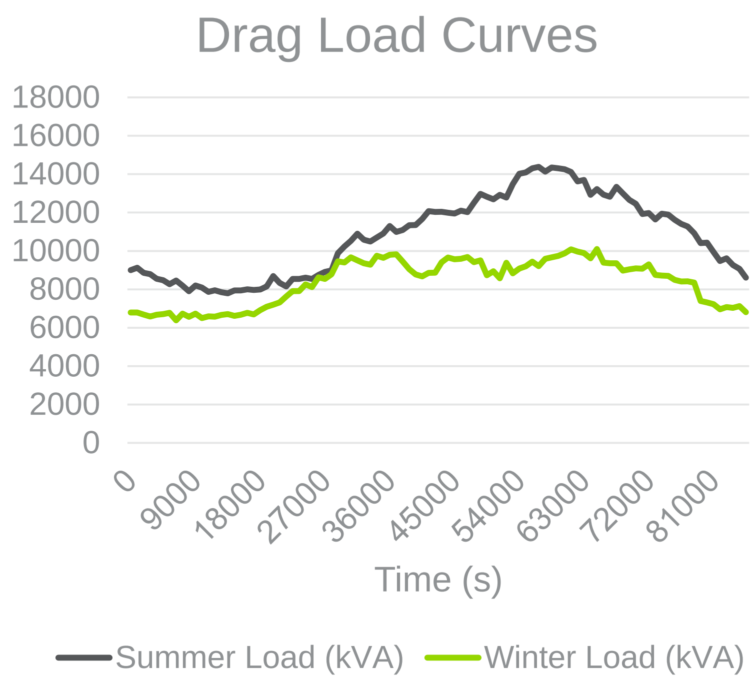




LOAD PROFILES USED

15 minute load profiles were made available by SCE for each representative feeder based on metered data.

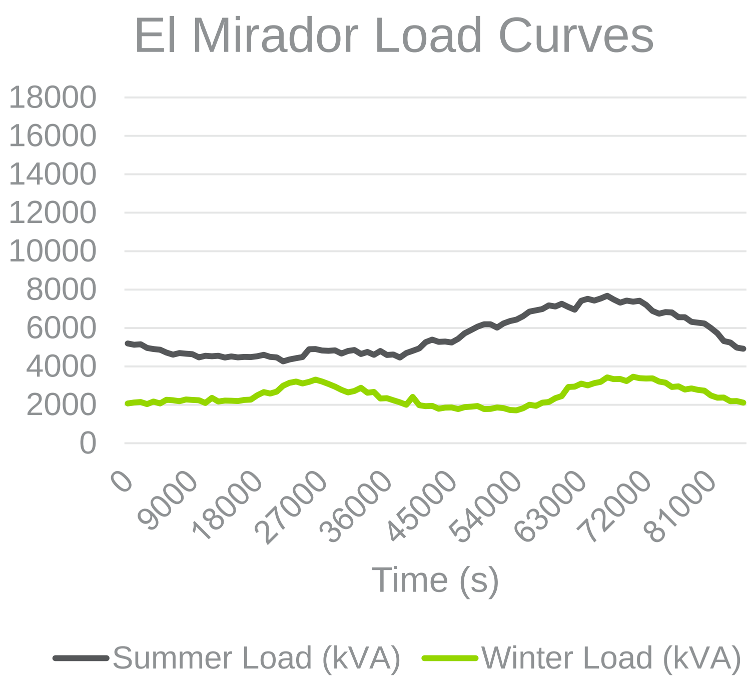


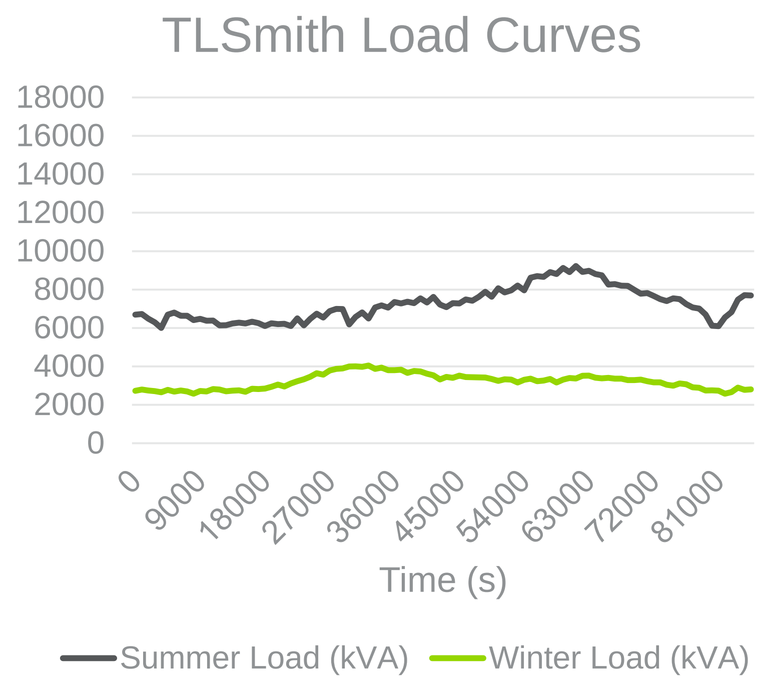


NAVIGANT

LOAD PROFILES USED

15 minute load profiles were made available by SCE for each representative feeder based on metered data.

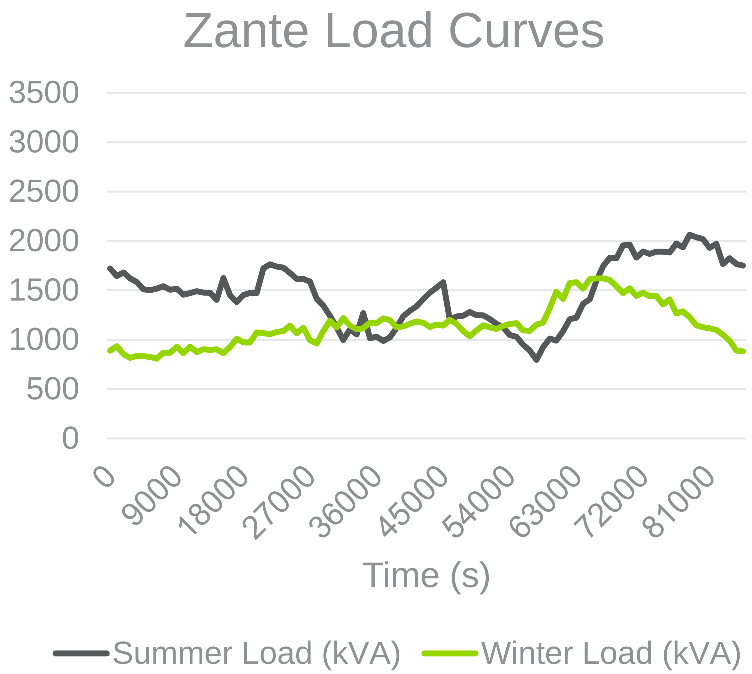


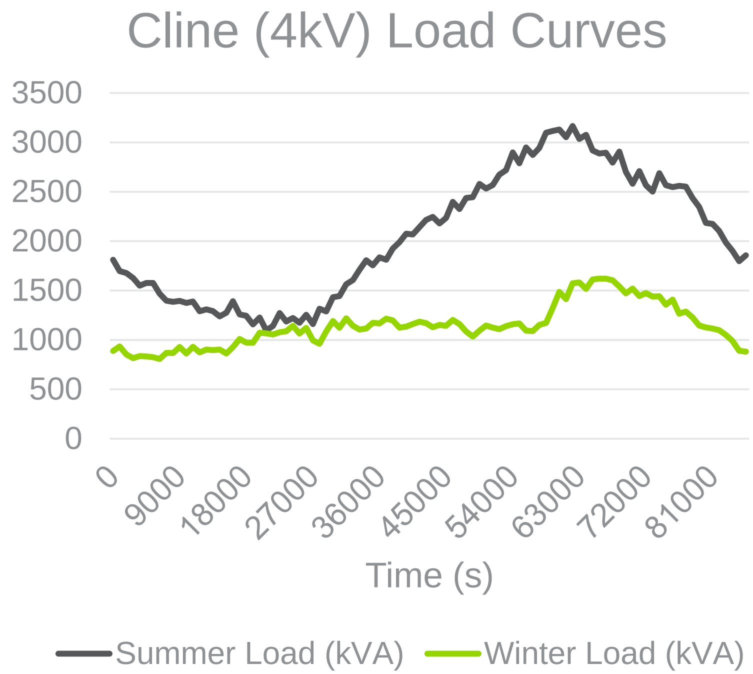


NAVIGANT

LOAD PROFILES USED

15 minute load profiles were made available by SCE for each representative feeder based on metered data.

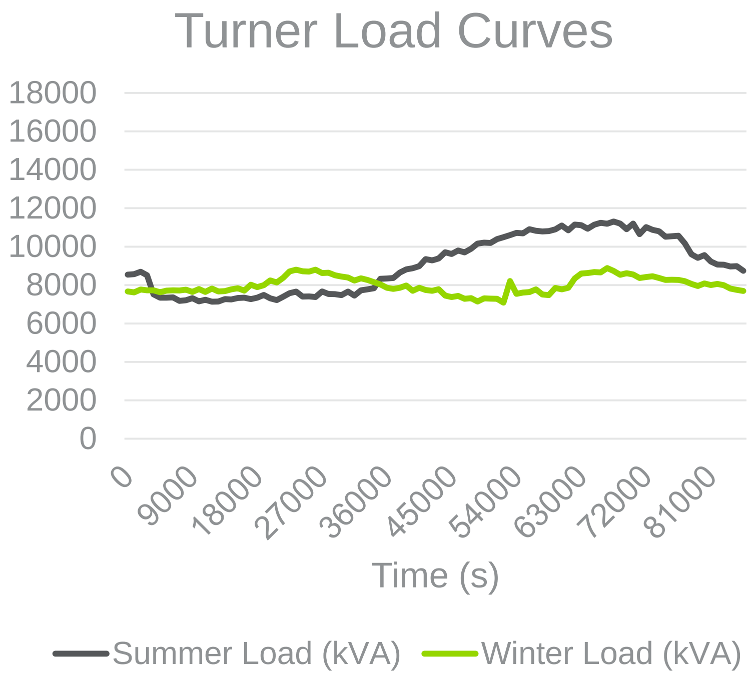




NAVIGANT

LOAD PROFILES USED

15 minute load profiles were made available by SCE for each representative feeder based on metered data.

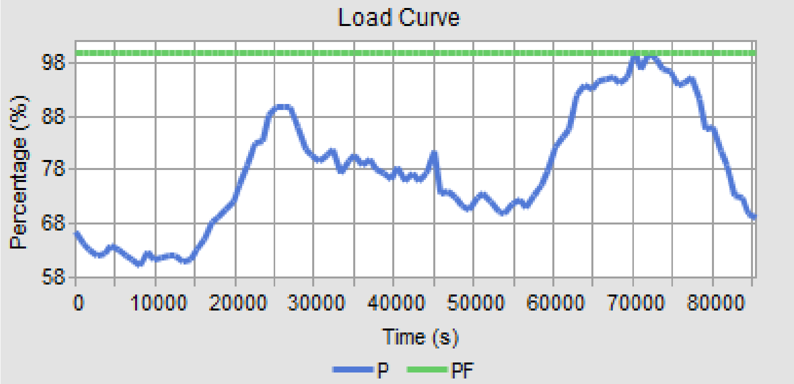


NAVIGANT

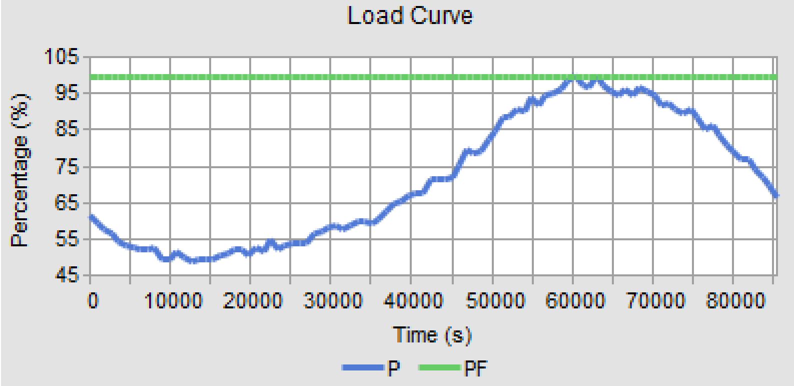
LOAD PROFILES USED

15 minute load profiles were made available by SCE for each representative feeder based on metered data.

Linnell Representative January 15th (~7 MW Peak load)



Linnell Representative July 15th (~12.5 MW peak load)

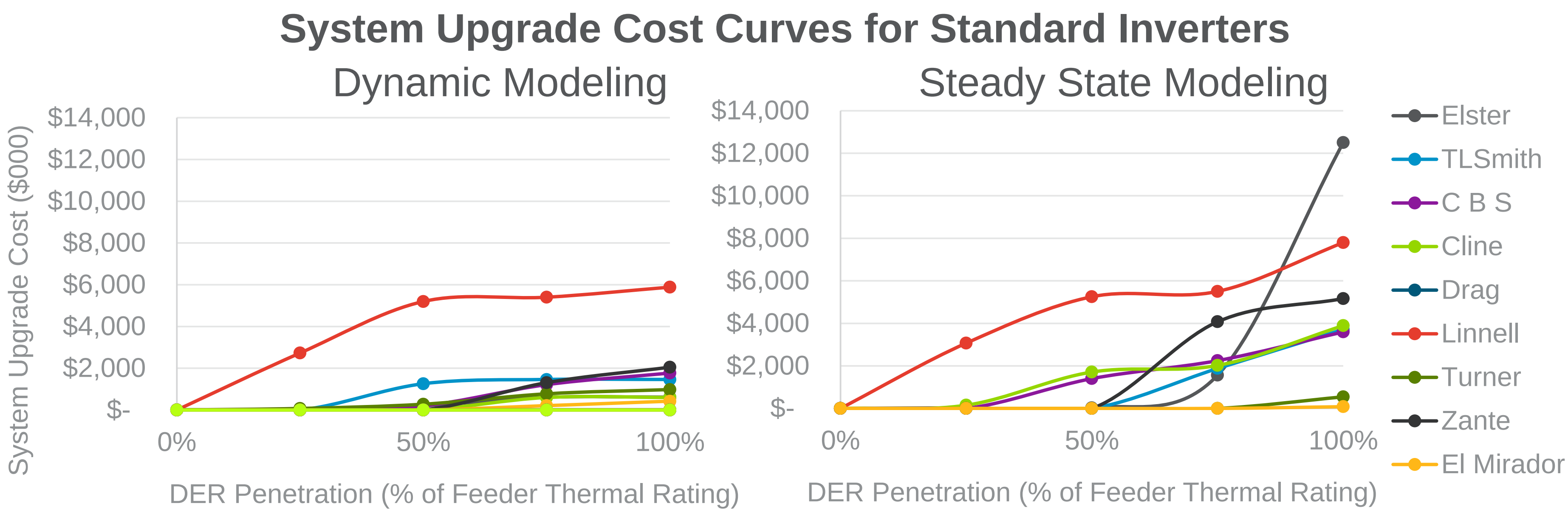


- The Linnell representative load profiles are shown here
- It can be noted that the winter profile has multiple peaks compared to the summer profile, and the winter peak load is less than 60% of the summer peak.

NAVIGANT

COMPARING MODELING TECHNIQUES WITH STD INVERTERS

Dynamic modeling indicated lower system upgrade costs as voltage regulation devices were sufficient to control feeder voltage.



- It was assumed widespread reconductoring was necessary when assessing steady state conditions. However, it was found that voltage reulation devices were sufficient to control feeder voltage given additional insight into load vs. generation levels that accompanied the dynamics studies

