Energy Research and Development Division

PROJECT TASK REPORT

Networked DER Value Proposition Report

California Energy Commission

Gavin Newsom, Governor

March 2019 | CEC-XXX-2018-XXX

PREPARED BY: SunSpec Alliance and Strategen Consulting

Primary Author(s):
Tom Tansy
Kevin Moy
Ron Nelson
Suzanne Martinez
Glenna Wiseman

SunSpec Alliance
4040 Moorpark Ave., Suite 110
San Jose, CA 95117
Phone: (831) 227-1073

Contract Number: EPC-14-036

PREPARED FOR:
California Energy Commission

Hassan Mohammed
Commission Agreement Manager

Sandra Raymos
Commission Agreement Officer

Laurie Ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

The SunSpec Alliance would like to thank the following Smart Inverter manufacturers for participating in this project: ABB Group, Advanced Energy, Enphase Energy, Fronius International, Ideal Power, KACO New Energy, Pika Energy, Outback Power, SMA America, and Tabuchi Electric. We would also like to thank our project partners: University of California, San Diego; Southern California Edison, Kitu Systems, California Independent System Operator (CAISO) and Strategen Consulting. The impact these companies have had on the advancement of the Distributed Energy Resource (DER) industry is immeasurable.

We would also like to thank Jay Johnson, the Smart Inverter research team at Sandia National Laboratories, the Smart Grid International Research Facility Network (SIRFN), San Jose State University, OSIsoft LLC, and Sacramento Municipal Utility District members for their contributions to the development of the Smart Inverter test protocols and test scripts used in this project and for their service on the technical advisory committee. These fundamental technologies are a major catalyst for the transformation of global electrical grid into an intelligent resource. In addition, we would like to thank GridSME and EPRI for their outreach and content support.

SunSpec would also like to acknowledge the expert counsel provided by Byron Washom of the University of California San Diego. Byron's insights and words of encouragement were essential as we brought this project from concept to fruition.

Finally, we would like to thank the California Energy Commission for both having the vision to invest in research of this type and for their guidance in executing programs of this magnitude.

PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solution, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities – Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company – were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increased safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Networked DER Value Proposition Report is the final report for the Smart Inverter Interoperability Standards and Open Testing Framework to Support High-Penetration Distributed Photovoltaics and Storage project (EPC-14-036) conducted by the SunSpec Alliance. The information from this project contributes to Energy Research and Development Division's EPIC Program.

All figures and tables are the work of the author(s) for this project unless otherwise cited or credited.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

Distributed Energy Resources (DERs), typically consisting of solar PV and energy storage systems on homes and commercial buildings, are a growing source of power on the electric grid. Paired with Smart Inverters, DERs have vast potential as a controllable resource for the grid. This project successfully demonstrated that Smart Inverters compliant with CA Rule 21 Phase 1 requirements can be installed safely at penetration levels of 100% or higher while eliminating the reverse energy flow and thermal problems associated with non-Smart Inverters.

The resulting Smart Inverter Value Proposition Analysis shows that DER penetration of 100% yields an annual value of $640 million to $1.4 billion due to the benefits of Smart Inverters. These benefits come in the form of grid reliability, power quality, energy delivery efficiency, dispatchable energy resources, and deferred or avoided transmission and distribution upgrades.

Keywords: *Distributed Energy Resources, DER, smart grid, wholesale market, retail market, CSIP, Rule 21, tariff, grid economics, California ISO, IEEE 2030.5, IEEE 1547-2018*

Please use the following citation for this report:

Tansy, Tom, Bob Fox, Suzanne Martinez, Glenna Wiseman. SunSpec Alliance. 2019. *Networked DER Value Proposition Report*. California Energy Commission. Publication Number: CEC-XXX-2019-XXX.

TABLE OF CONTENTS

GLOSSARY

Term	Definition
AHJ	Authority Having Jurisdiction: An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.
AMI	Advanced Metering Infrastructure typically refers to the full measurement and collection system that includes meters at the customer site, as well as communication networks between the customer and a service provider.
API	Application Programming Interface in this document refers to a web API, which allows sharing of content between different stakeholders via a defined set of protocols and definitions.
California Rule 21	Rule 21 is a tariff that describes the interconnection, operating and metering requirements for generation facilities to be connected to a utility's distribution system. Each investor-owned utility is responsible for administration of Rule 21 in its service territory and maintains its own version of the rule.
CSIP (California Smart Inverter Profile)	The California Smart Inverter Profile describes configuration requirements for how an IEEE 2030.5 interface can be implemented to satisfy the California Rule 21 requirements.
DER	Distributed Energy Resource
DSO	Distribution System Operator
EPIC	Electric Program Investment Charge, established by the CPUC in 2011, funds clean energy research and projects that support the state's climate and energy goals while also promoting greater reliability, lower costs, and increased safety.
FERC	The Federal Energy Regulatory Commission, or FERC, is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil.
IEEE	Institute of Electrical and Electronics Engineers
IEEE 1547	The technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems and distributed energy resources are the focus of this standard.
IEEE 2030.5	A communications standard which provides an interface between the smart grid and its users. It is the default communications interface in California for grid integration of DERs as described in CSIP.
IOU	Investor-Owned Utilities
ISO	Independent System Operator
Modbus	Modbus is a is a set of communications protocols used between components in process automation systems.

Penetration	Penetration refers to the amount of power capacity added to the grid by DERs. It is often reported as a percentage, which represents the ratio of peak DER output to the peak consumption of the distribution feeder on which the DERs are located.
PKI (Public Key Infrastructure)	Public key infrastructure (PKI) is a set of roles, policies, and procedures needed to manage digital certificates and public-key encryption. It is required for activities where proof is required to confirm the identity of the parties involved in the communication and to validate the information being transferred.
Smart Grid	Smart grids enable real-time data collection concerning electricity supply and demand during the transmission and distribution process, making monitoring, generation, consumption and maintenance more efficient.
Smart Inverter	As defined in Rule 21, Smart Inverters are inverters with advanced capabilities to report and manage power quality and power flow. Smart Inverters are able to perform these tasks either autonomously or by a set of commanded controls.
UL 1741 SA	UL 1741: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources" is the test standard by which inverters are certified for interconnection to the grid, with particular respect to grid voltage and grid frequency. It is intended to supplement and support IEEE 1547.

1. Executive Summary

Smart Inverters, combined with standardized communication protocols, allow for a new class of resources on the grid that are controllable and highly responsive. Increasing the number of Smart Inverters on the grid allows for grid support on both a local and regional scale, beyond what can be maintained or managed with traditional resources. These additional functions, both autonomous and controlled, will enable ratepayers and DER owners to access additional value streams.

In order to assess the value of Smart Inverters and their capabilities, a value proposition analysis model was created. Our analysis methodology is based on the prior California Energy Commission funded work on Distribution Automation (DA) impacts (Navigant, 2009).[1] We use the DA report analysis as a framework to evaluate the benefits of Smart Inverters to the utility, customers, and society at large. The high-level quantification of Smart Inverter benefits was based on a combination of published data, data from the previous Navigant report, and professional assumptions. The authors identified sensitive inputs and varied them to create a range of expected benefits.

The resulting Smart Inverter Value Proposition Analysis shows a value of $640 million to $1.4 billion per year due to the benefits of Smart Inverters and is comprised of the improvements in these areas.

SMART INVERTER VALUE PROPOSITION ANALYSIS SUMMARY

Benefit	Low Case		High Case	
Reliability	$	290,000,000	$	660,000,000
Power Quality	$	30,000,000	$	100,000,000
Energy Delivery Efficiency	$	30,000,000	$	70,000,000
Dispatchable Resources	$	270,000,000	$	530,000,000
Avoided/Deferred T&D Upgrades	$	20,000,000	$	70,000,000
Total	**$**	**640,000,000**	**$**	**1,430,000,000**

This study is published with an accompanying spreadsheet, available from SunSpec.org, to enable others to evaluate the methodology and apply it to their work.[2]

[1] https://www.energy.ca.gov/2007publications/CEC-500-2007-103/CEC-500-2007-103.PDF

[2] https://www.sunspec.org

2. Smart Inverter Value Proposition Analysis Methodology

Smart Inverters, combined with standardized communication protocols, allow for a new class of resources on the grid that are controllable and highly responsive. Increasing the number of Smart Inverters on the grid allows for grid support on both a local and regional scale, beyond what can be maintained or managed with traditional resources. Additional functions introduced by Smart Inverters, both autonomous and controlled, can enable ratepayers and DER owners to access additional value streams.

In order to assess the value of Smart Inverters and their capabilities, a value proposition analysis model was created. Our analysis methodology is based on the prior California Energy Commission funded work on Distribution Automation (DA) impacts (Navigant, 2009).[3] We use the DA report analysis as a framework to evaluate the benefits of Smart Inverters to the utility, customers, and society at large. The high-level quantification of Smart Inverter benefits was based on a combination of published data, data from the previous Navigant report, and professional assumptions. The authors identified sensitive inputs and varied them to create a range of expected benefits.

This framework includes a suite of Application Concepts (ACs), which will be used to represent state and utility goals. Each AC requires a set of Functions to implement. In other words, ACs represent the grid operational improvements, and Functions represent the device capabilities. Each Function is further responsible for series of Benefits with discrete dollar-per-unit amounts. In short, ACs can be linked to Benefits via the Functions that are implied by both.

We narrow the focus of our benefit analysis to Smart Inverters, rather than the broader Distribution Automation concept introduced in the DA report. The analysis intends to capture the Application Concepts, Functions, and Benefits achieved solely due to the advancements in Smart Inverters achieved and demonstrated during this project.

Narrowing the focus to Smart Inverters also required two scenarios to be developed. Scenarios were necessary because Smart Inverters create benefits through their own functions, but they also unlock the potential for DERs to provide benefits. For example, increasing penetrations beyond 15% of peak load on a distribution feeder unlocks the potential to create additional services on the feeder and potentially more cost-effectively achieve policy goals. The Current and Future State of the DER Market scenarios are described at a high-level in Chapter 2 of the final report of the EPC-14-036 project. The Current State of the DER Market is used as the baseline for the model. To create the Future State of the DER Market, we incorporated known policy goals related PV and energy storage.[4] We consider this to be a conservative estimate for the benefits that DERs will provide given that these goals could be accomplished by 2024, and the state will still have a long way to go before reaching its goal of 100% clean energy.

---

[3] https://www.energy.ca.gov/2007publications/CEC-500-2007-103/CEC-500-2007-103.PDF

[4] For example, AB 2514 includes 200 MW of customer-sited storage, while AB 2868 mandates an additional 500 MW of behind-the-meter storage.

3. Application Concepts

The capabilities of Smart Inverters to autonomously manage power quality, monitor and control distributed energy resources, and act in aggregate enable the following Application Concepts:

1. Improve Grid Stability and Operations: Autonomous/controlled participation to handle abnormal voltage/frequency conditions and grid outages.
2. Enable Non-Wires Solutions for a Changing Grid: Handling increased renewable energy generating capacity and additional customer load via management of Smart Inverter DER assets.
3. Enable DER Participation in Wholesale Markets: Establishing operational and communications standards for DERs to participate in retail and wholesale demand response markets.

4. Functions

The functions of Smart Inverters are a subset of the original Distribution Automation functions defined in the Navigant report. We report the following functions in our analysis.

1. Automatic Voltage and VAr Control: Autonomous Volt-VAr[5], Freq-Watt[6], Volt-Watt operating curves; voltage ride-through (IEEE 1547 compliance)
2. DER Monitoring: Real-time status and output data from an individual DER or aggregated groups of DERs
3. DER Control by Unit: Control of an individual DER by utility or third-party operators ("Scenario 1: Direct DER Communications" under CSIP[7])
4. DER Control by Class: Control of multiple DERs by an aggregator to achieve grid-wide functions such as Conservation Voltage Reduction as a Virtual Power Plant (VPP) ("Scenario 2: Aggregator-Mediated Communications" under CSIP)
5. Automatic Islanding and Resynchronization: Autonomous handling of grid outage conditions to cease operation under unsafe conditions and resume operation only when safe
6. Real-Time Communications from the Utility to the Customer: Utility signals for market participation by Smart Inverters

5. Benefits

The original Benefit categories for Distribution Automation are well-representative of Smart Inverter benefits, with some adjustments to account for Smart Inverter capabilities. We calculate and report the following benefits in our analysis. The values calculated accrue to the general customer population at large on an annual basis.[8] While the benefits are not intended to be discrete, and therefore may be related and overlap, we did purposely omit benefits that are almost entirely duplicative, such as the benefit of bill reduction that are reflected through avoided wholesale and infrastructure costs.

[5] https://www.nrel.gov/docs/fy19osti/72298.pdf

[6] https://www.nrel.gov/docs/fy17osti/68884.pdf

[7] https://sunspec.org/download/

[8] While some benefits may first accrue to the utility, such as avoided and deferred T&D upgrades, eventually the decreased costs would flow to customers through rate case proceedings. In addition, not all values flow equally to all customers, such as reliability values that accrue in larger portions to commercial and industrial customers.

We note that there is considerable overlap between the Smart Inverter benefits described below, and those resulting from DERs in general. However, as Smart Inverters enable 100% DER penetration, and are indeed required of DER generation in current policy, these benefits cannot be decoupled from each other.

- Reliability
    - A reduction in the number and duration of sustained outages results in faster service restoration, fewer affected customers, and reduced utility costs. Smart Inverters create benefits that arise from Automatic Islanding and Resynchronization. For this reason, the proliferation of the benefits created through microgrids is reflected through this benefit calculation.[9]
- Power Quality
    - A reduction in harmonic distortion, fewer and less severe voltage sags and surges, causes less damage to equipment and lost production. This includes Volt-VAr, Freq-Watt, Volt-Watt autonomous regulation (i.e. following a Volt-VAr curve), as well as deliberate control of Smart Inverters to inject or absorb real/reactive power on the grid.
- Energy Delivery Efficiency
    - A reduction in peak demand and energy losses results from optimized control of grid-wide operation, including such methods as Volt-VAr optimization (VVO) and Conservation Voltage Reduction (CVR).[10]
- Dispatchable Resources
    - A reduction in reserve margin requirements results from higher DER penetration and the use of DERs replacing peaker plants as a dispatchable resource for capacity markets and ancillary services.[11]
- Avoided and Deferred Transmission and Distribution (T&D) Upgrades
    - A reduction in carrying costs based on avoided capital expenditures, including using inverters as their own production meters, results from higher utilization of T&D and substation capacity and extended equipment life.

[9] The benefits that microgrids may create is not entirely and solely captured within this benefit calculation.
[10] https://www.nrel.gov/docs/fy17osti/67296.pdf
[11] Cite NREL/CAISO/First Solar study: https://www.nrel.gov/esif/partnerships-caiso-first-solar.html

6. Application Concepts Matrix

The Application Concepts Matrix describes each Application Concept in terms of the Smart Inverter Functions which are associated with it. For a given Application Concept, if a Function enables it, the matrix entry is labelled, " ● ". Otherwise (i.e. if Application Concept and Function are not related), the entry is blank.

SMART INVERTER VALUE PROPOSITION ANALYSIS
APPLICATIONS CONCEPT MATRIX

Functions	Improve Grid Stability and Operations	Enable Non-Wires Solutions for a Changing Grid	Enable DER Participation in Wholesale Markets
Automatic Voltage and VAr Control	●	●	
DER Monitoring	●	●	
DER Control by Unit		●	●
DER Control by Class		●	●
Automatic Islanding and Resynchronization	●		
Real-Time Communication from Utility to Customer		●	●

7. Benefits Matrix

The Benefits Matrix is very similar to the Application Concepts Matrix, in that each Benefit is described in terms of the Functions which contribute to and enable that Benefit. The matrix is labelled in a similar manner to the Application Concepts Matrix.

SMART INVERTER VALUE PROPOSITION ANALYSIS BENEFITS MATRIX

Functions	Reliability	Power Quality	Energy Delivery Efficiency	Dispatchable Resources	Avoided and Deferred T&D Upgrades
Automatic Voltage and VAr Control		●			
DER Monitoring	●	●	●		●
DER Control by Unit		●	●	●	●
DER Control by Class		●	●	●	●
Automatic Islanding and Resynchronization	●				
Real-Time Communication from Utility to Customer				●	●