An EPRI White Paper

Utility Ownership of the Solar PV Inverter

An alternative business model for distributed solar PV generation

May 2015

White Paper

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INTRODUCTION

This paper looks at the opportunities and challenges of utility ownership of the DC-to-AC inverter portion of distributed solar PV systems as one possible way to lower total system costs and improve the reliability of this variable generation resource. The utility-owned inverter may also provide a sustainable business model that works for both the electric utility and their customers.

The rapid growth of customer-owned solar power generation in the United States is creating operational and business-related challenges for electric utilities. Under the present system of net metering, the loss of retail sales is arguably putting upward pressure on rates as utilities move to recover their fixed costs over fewer kWh sales. Because the generating equipment is on the customer's side of the utility meter, electric utilities also have limited control over this variable resource that must be supplemented by other generating sources, which puts additional pressure on rates.

The customer's meter is normally considered to be the boundary between what is considered to be under the utility's control and what is governed by the National Electric Code. Under the present system, electric utilities' main method of controlling the operation of distributed solar power generation or batteries is through time-of-use pricing. Utility ownership of the inverter would give the utility greater control over how to integrate this resource into their distribution system and best serve their customers. Electric utilities would handle all the grid interconnection issues, freeing the customer to only be concerned with the DC portion of the solar power system. Many utilities may welcome this change because they would then have control over the inverter's communication and control for safety, power quality and reliability.

After installing the DC portion of the solar array, the customer would contact the electric utility to connect their solar power to the utility's grid. The utility would install the DC-to-AC inverter, along with a solar power production meter to connect the solar generation to the utility's side of the consumption meter. Utilities would not lose retail sales because the generation would not be net metered.

In exchange for selling all their solar energy to the electric utility, customers would be paid by the electric utility for 100% of the solar energy that they generate. For their solar installation to be cost effective for both the utility and the customer, the rate would need to cover the customer's cost of the DC portion of the solar array, plus repay the utility's cost of purchasing, installing and maintaining the inverter.

The challenges will be gaining customers' trust and providing them a business case that is equal to, or better than, net metering. Utilities will need to simplify their interconnection processes, reduce grid management costs, and show dramatic reductions in installation time, labor, permitting and inspection requirements.

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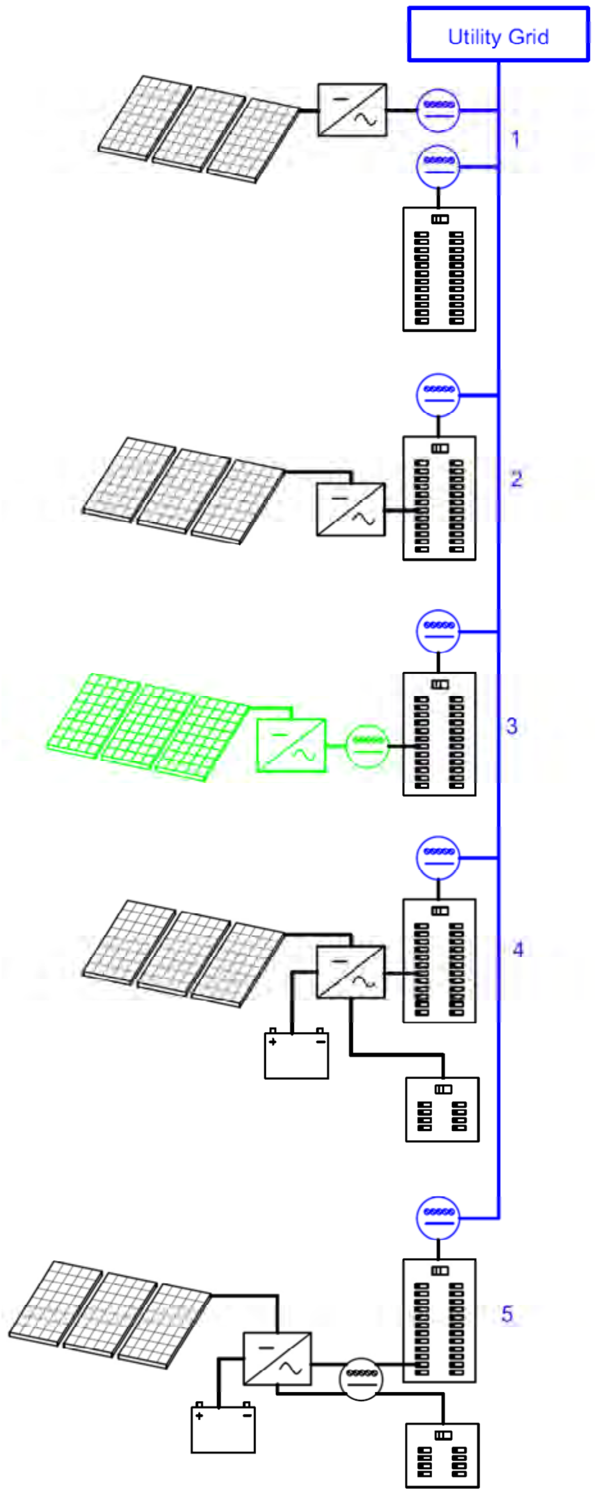


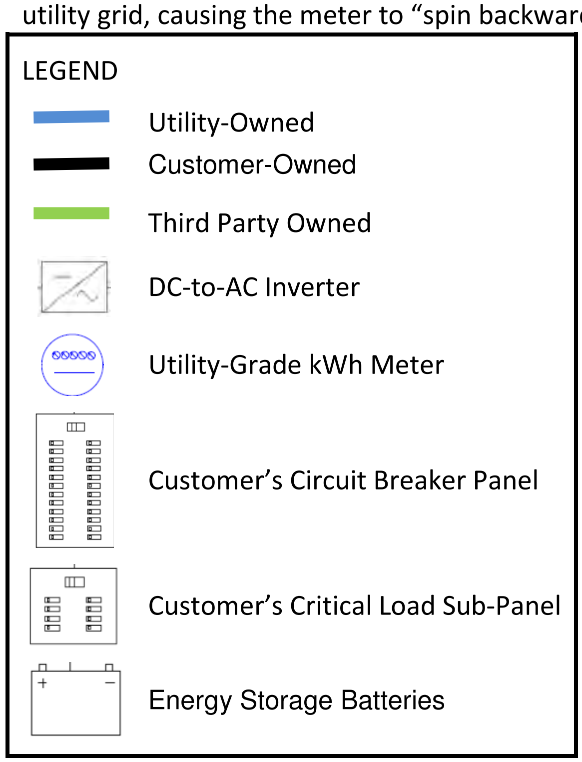
Figure 1. Conventional inverter ownership arrangements

THE STATUS QUO

Figure 1 on the left shows the different inverter arrangements for most conventional solar installations.

Arrangement 1 shows generation that is metered independent of consumption. This configuration is not net metered, meaning the solar generation does not affect the consumption meter. It is not necessary that a consumption meter even be present. Examples of this configuration include independent power producers, utility-owned generators, and nearly all customer-owned generators installed under feed-in tariff programs outside the United States.

Inverter arrangements 2 through 5 are all net metered. This means that the generation from the solar power systems reduces the amount of energy that the customer purchases from the electric utility. Solar power generated by each of these systems is fed into the customer's circuit breaker panel and displaces energy that would otherwise come from the electric utility. If the solar power is greater than the power needs within the facility, the excess energy flows back to the electric utility grid, causing the meter to "spin backwards".



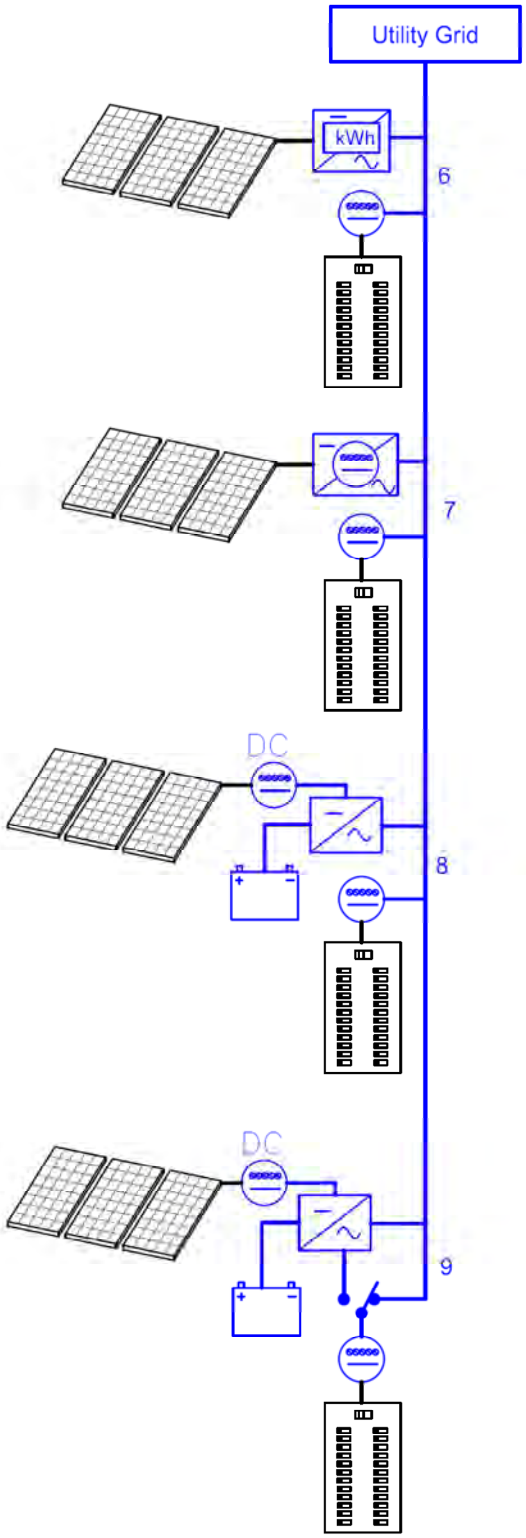


Figure 2. Utility-owned inverter configurations

UTILITY OWNED INVERTER CONFIGURATIONS

Figure 2 shows a range of possible configurations for utility ownership of the inverter. Because electric utilities typically do not allow customers to have unmetered access to the power grid, the location of the kWh production or consumption meter typically defines the line of responsibility between the customer and the electric utility. By taking over responsibility of the inverter, electric utilities have the ability to modify the inverter's characteristics to maintain grid stability during power quality disturbances, while still protecting line workers and property from damage. Electric utilities could also choose to wait before making any changes until a national standard, such as IEEE 1547.8 is finalized and/or changes to IEEE 1547 are adopted.

The AC output of each of the solar power systems shown in Figure 2 connects directly to the utility grid. The solar power generated by all of these systems does not affect the customer's consumption meter and are not net metered.

Configuration 6 utilizes a kWh production meter that is built into the inverter.

Configuration 7 is a DC-to-AC inverter with a built-in meter socket that fits a standard utility-grade kWh production meter and locking ring.

Configuration 8 uses a utility-grade DC meter to measure the DC power generated by the solar array. After leaving the DC meter the DC power is either diverted to utility-owned batteries or to the DC-to-AC inverter. Off-peak power from the grid can also be used by the utility to charge the batteries to shift loads on the power grid.

Configuration 9 is similar to 8, except it includes a transfer switch to provide emergency back-up power to the customer during an outage.

OPPORTUNITIES & CHALLENGES OF UTILITY INVERTER OWNERSHIP

Potential benefits:	*Potential challenges:*
1. Since utility workers are the only ones that can install a meter socket adapter beneath an existing utility revenue meter, the total on-site time required to install an inverter and connect to the grid could be reduced to less than one hour of a utility worker's time.	a) Utility crews or contractors would need training on solar power generation and interconnecting the inverter to the grid. Alternatively, utilities could choose to partner or contract with third parties to handle installation and/or operation and maintenance. b) Additional grid interconnection options need to be identified, simplified and designed. c) Grounding and lightning protection issues would need to be resolved. d) There may be potential regulatory restrictions to utility workers attaching equipment to a customer's home or business.
2. Customers' upfront costs would be reduced because they would only be responsible for purchasing and installing the DC portion of the solar power system, which tends to be the longest lasting and most reliable portion of the system.	a) Customers would still need to repay the utility's cost of providing the inverter through one of three ways: i. Pay all costs up front ii. Monthly fee iii. Cost is paid by the utility and spread out to other rate payers.
3. Control over battery storage could be used by the utility to shift when the solar power is added to the grid and to provide spinning reserve. By metering at the DC level and making these components utility assets, round-trip energy losses are not an issue.	a) DC delivery voltage and capacity limits would need to be standardized. b) Some configurations require a utility-grade DC kWh meter, which is not readily available.
4. Utility-owned battery and inverter can be used to provide emergency back-up power to the customer premise(s) without having to modify the interior wiring of the premise(s).	a) Jurisdictional issues may need to be resolved if the utility-owned inverters are attached to customers' homes. b) Issues regarding liability (e.g. electrical shock, fire) would need to be resolved. c) Agreements with customers would be required for any smart inverter functions that might reduce the peak power output of the customer's solar array.

Potential benefits:	Potential challenges:
5. Customers' soft costs for permitting and interconnection would be reduced because the customers would not have to deal with utility grid interconnection details.	a) Utility would be responsible for converting the DC power to AC including making the grid interconnection, providing system protection, setting power quality standards and managing distribution system impacts. b) Utility will have to come up with processes and procedures to ensure that DC voltage and amperage supplied by customers are within prescribed limits.
6. Utilities could get full cost recovery for the inverter's installation and maintenance.	a) There could be claims of unfair utility monopoly practice.
7. As a utility asset, utilities could use their existing authority and higher bond rating to finance the purchase and lower the total costs of the inverter.	
8. Reliability could be improved by purchasing inverters with the lowest lifecycle costs instead of the common practice of buying the inverter that has the lowest upfront cost.	
9. Reduce costs through economies of scale by purchasing inverters in bulk, streamlining the supply chain and establishing uniform connection procedures.	a) There may be potential grid code issues
10. Customers would be paid for 100% of their solar power generation. A. Receiving a production payment rather than a kWh credit for production might make it easier for customers to finance their solar power installation. B. Similar to third-party financed systems, utilities could use this production payment as a means of financing the customer's cost of the solar array.	a) Building customer trust and establishing arrangements to ensure customers are fully compensated for their generation in the event of inverter problems or generation curtailment by the utility. b) Utilities will need to determine their business case for providing the inverter and/or financing the cost of the solar array.
11. The inverter asset stays with the premises, which makes it easier to transfer payments to the new owner if the existing customer moves. If the inverter is no longer needed, it could be easily relocated to a different premise.	a) Billing and compensation structures would need to be worked out.

Potential benefits:	Potential challenges:
12. Utilities would not lose retail sales from the solar power generation like they do under net metering because the generation and consumption would be metered separately and not be comingled.	a) The utility would see the production payment as an expense.
13. Total renewable energy generation will be known because the solar generation will be metered separately from the retail consumption.	
14. As a generating asset, electric utilities could employ inverters with grid-supportive functionality and communication capabilities as they determine appropriate. For example, an inverter asset could be used to provide volt/VAR management, low-voltage ride through (LVRT) or localized power during a major outage. Utilities also may want to install internal fault protection relay controls to turn off the generation if a fault has been detected on the line feeding the inverter.	

Grid/Code Issues

The customer's meter is normally considered to be the boundary between what is considered to be under the utility's control and what is governed by the National Electric Code. All of the utility-owned inverter options identified in this paper refer to solar power generation that is on the utility's side of the meter and does not pass through the customer's consumption meter. Generation is connected directly to the utility grid and is not net metered.

Under the National Electric Code, Article 90.2 Scope,
"(B) Not Covered. This *Code* does not cover the following:
(5) Installations under the exclusive control of an electric utility where such installations

a. Consist of service drops or service laterals, and associated metering, or
b. Are located in legally established easements, rights of-way, or by other agreements either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations, or
c. Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy."

Although utility generators and utility-owned distribution equipment are generally not governed by the National Electric Code or subject to inspections by the local or state electric code official, they are subject to federal reliability standards. Electric utilities also have to meet industry safety standards for generation and distribution equipment.

This should allow the electric utility greater flexibility in designing and modifying characteristics within the inverter. For example, electric utilities may want to change the characteristics within the inverter to stay on briefly during a momentary power outage to maintain grid stability.

Metering Issues

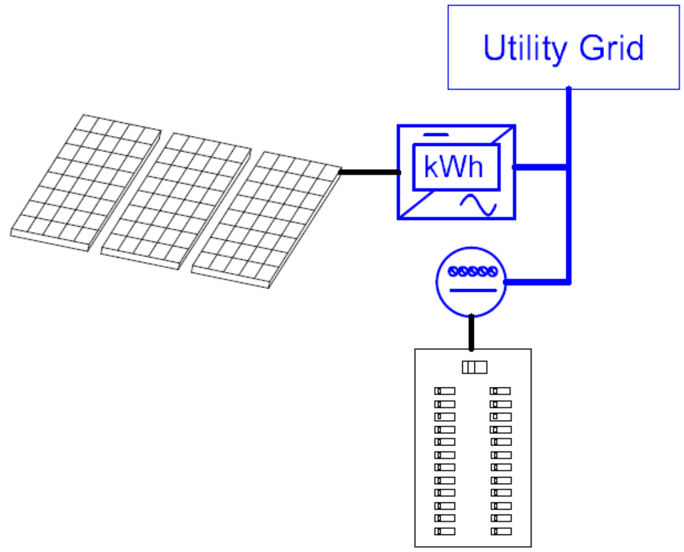


Figure 3. Utility-inverter using internal meter

Figure 3 illustrates a utility-owned inverter that utilizes a standard off-the-shelf inverter. The cover of the inverter would likely be locked and have a utility seal to deter tampering. This option would utilize an internal kWh meter supplied by the inverter manufacturer. Although readily available today, internal meters are not typically "utility grade" and electric utilities cannot read the meter using their existing meter reading equipment due to lack of compatible communication technologies. There are also questions regarding meter accuracy and security.

Many inverter manufacturers have monitoring and metering capabilities that might allow the utility to track the performance and troubleshoot their inverter systems remotely. Unfortunately, these systems are different from one inverter manufacturer to the other and often require internet or cloud connectivity in order to function.

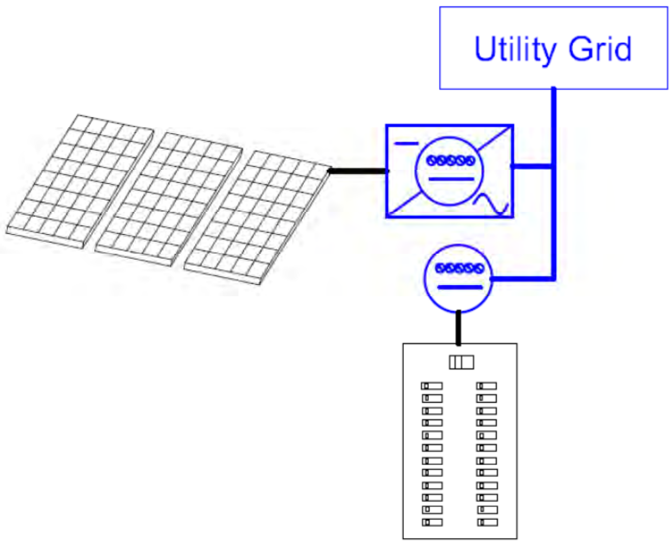


Figure 4. Utility- inverter with built-in meter socket

Figure 4 illustrates an inverter that has a lockable cover with a built-in meter socket on the front that would accept a standard AC electric utility meter. The advantage of this approach is that the meter could be consistent with other utility meters from a procurement, accuracy and management perspective and could be read using the utility's existing meter-reading infrastructure. It also insures that the meter has met all of the calibration, accuracy and display characteristics. Although not available today, adding a meter socket and locking cover could be done relatively easily to most commercially available inverters. Many large commercial inverters already come with built-in meter socket.

A further enhancement would be to define a new standard meter socket form that is smaller and more suitable for incorporation onto inverters. A smaller meter could still be utility-provisioned and produced competitively by any metering/AMI provider. In addition, such a meter might also have applications in electric vehicle service equipment or other end-use devices.

PERSPECTIVE OF THIRD-PARTY OWNERS

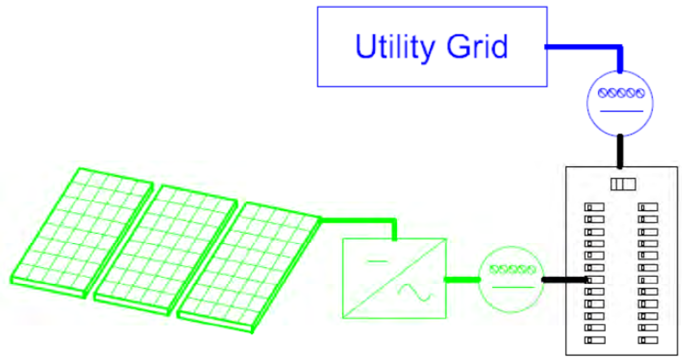


Figure 5. Net metering with production metering

Figure 5 shows a typical third-party-owned system that is becoming increasingly popular in the United States. It consists of a net metered system with a separate production meter on the solar power system.

The portion of the system shown in green is purchased, owned, installed and maintained by the third party. The solar power generated by the system is sold by the third party to the customer either as a lease payment, power purchase agreement or combination of both. The renewable energy generated by the third party system is used to reduce the energy that the customer would otherwise purchase from the electric utility.

It is possible that third-party owners could choose to participate in a solar power system that has a utility-owned inverter, but most likely the utility-owned-inverter would be viewed as competing with third party or leased solar power systems.

As solar power becomes less expensive than retail electric rates in a growing number of places throughout the United States, the question becomes, "Why would a customer or third-party choose to go with a utility-owned inverter over a net-metered system?" For the utility-owned inverter to become a viable alternative to net metering, utilities will need to find ways to lower the total systems costs and offer production payments that provide a better return than net metering.

UTILITY-OWNED BATTERY STORAGE

Battery storage is becoming an increasingly important issue as electric utilities look for ways to manage the spike in electrical demand that will occur as more and more grid-connected solar power systems are installed[1]. For example, California recently enacted that by 2020, there be at least 1.3 GW of storage capacity. If utilities owned the inverter, they could use the built-in DC-to-AC conversion capabilities to reduce the cost of adding battery storage to the grid. By owning the inverter and the batteries, utilities could use their own control and data acquisition system to specify when and where solar power gets added to the grid. Utilizing the load-shifting capability could help offset much of the additional cost of providing a transfer switch for customers who want emergency back-up power during power outages.

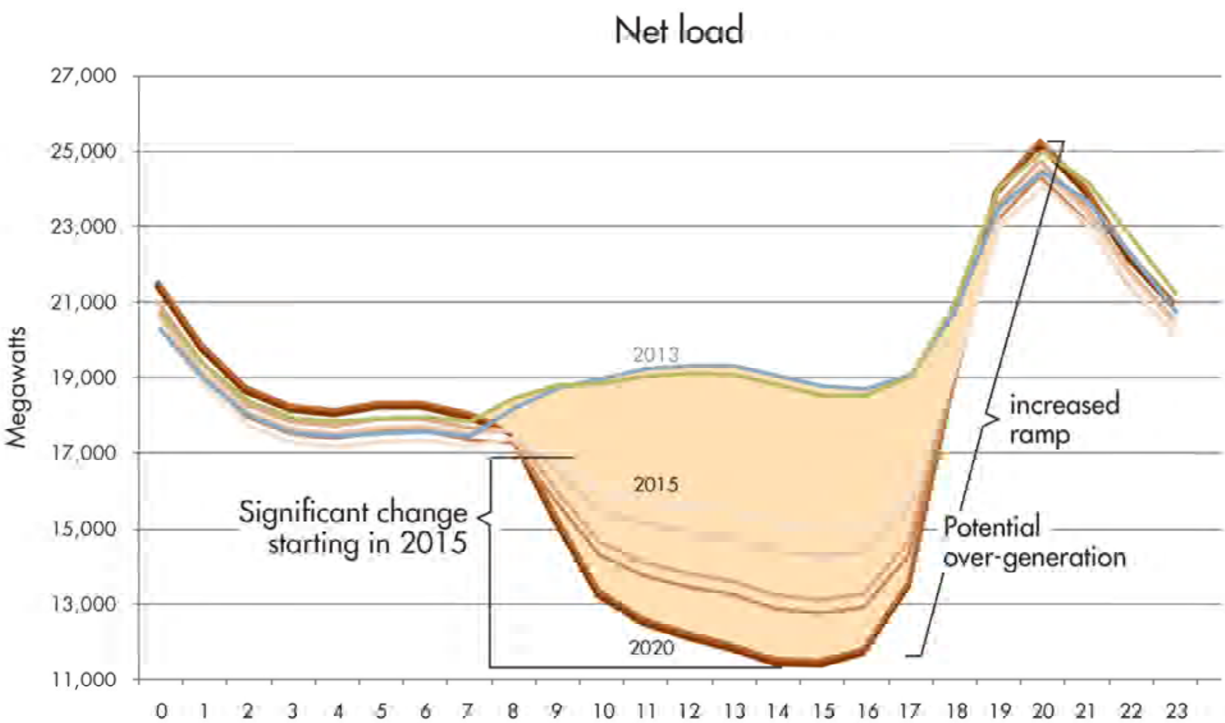


Figure 6. The "Duck Graph" showing the load spike that Cal ISO predicts will occur with increasing distributed solar PV generation

Figure 6 shows that as solar energy generation increases, solar energy stored in batteries will be needed to reduce the load spike and generation needs that will occur in the evenings. Electric utility control over customer-owned batteries is typically limited to time-of use pricing. If utilities owned and controlled the batteries and the DC-to-AC inverter, they could be assured that the stored energy will be there to meet the peak loads on the distribution system and to meet the spike in generation requirements.

[1] (Rothleder, February 26, 2013)

Utility-Owned Battery Energy Storage (cont.)

As Hurricane Sandy illustrated, there is a need for solar power systems to be able to provide emergency power (Unger, 2013). Ideally, the energy stored in the batteries could have a dual purpose of providing gird support for the electric utility, while also providing emergency power to customers when they need it most.

Two different configurations for utility-owned inverters and batteries are shown below in Figure 7 and Figure 8. The challenge of implementing the utility ownership of the batteries along with the inverter is that a utility-grade DC kWh meter is needed to measure the DC solar energy generated by the customer. Utility-grade DC kWh meters are not readily available and would need to be reintroduced. With the exception of the utility-grade DC meter, all of the system components shown in the following figures are available today using off-the-shelf equipment. The other option is to use the DC kWh production meter inside the battery's charge controller, or use a third-party DC kWh meter. Although available today, using non-utility meters DC would require resolving accuracy, security, reliability and calibration issues.

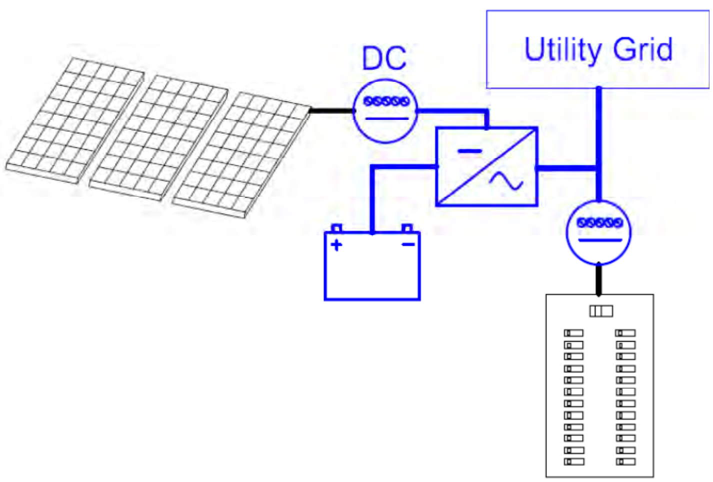


Figure 7. Utility-owned inverter with batteries

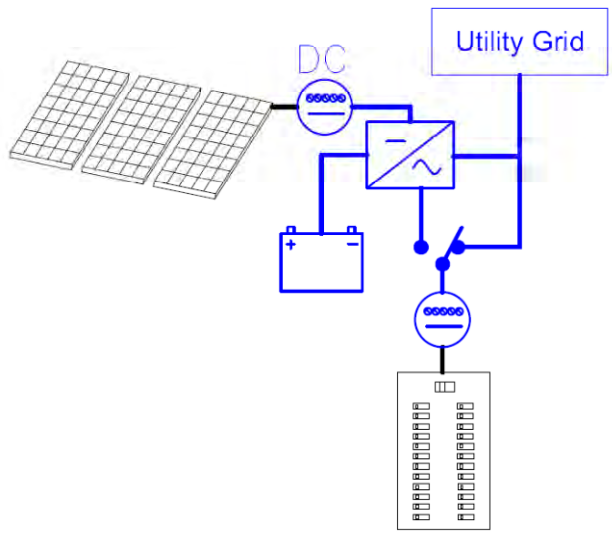


Figure 8. Utility-owned inverter with batteries & emergency back-up power capabilities

Figure 8 adds a transfer switch to provide emergency power during a power outage. The advantage of this system is that the entire home or business can receive the back-up power, without having to install a separate critical load sub-panel or perform any rewiring within the building. An advantage for electric utilities is that the storage batteries can be used by the electric utilities during non-outage periods for peak generation, shifting the time that solar is added to the grid, dampen the effects of clouds, or as potential spinning reserve.

A more detailed diagram of a utility-owned battery and inverter system is shown in Figure 9 on the following page.

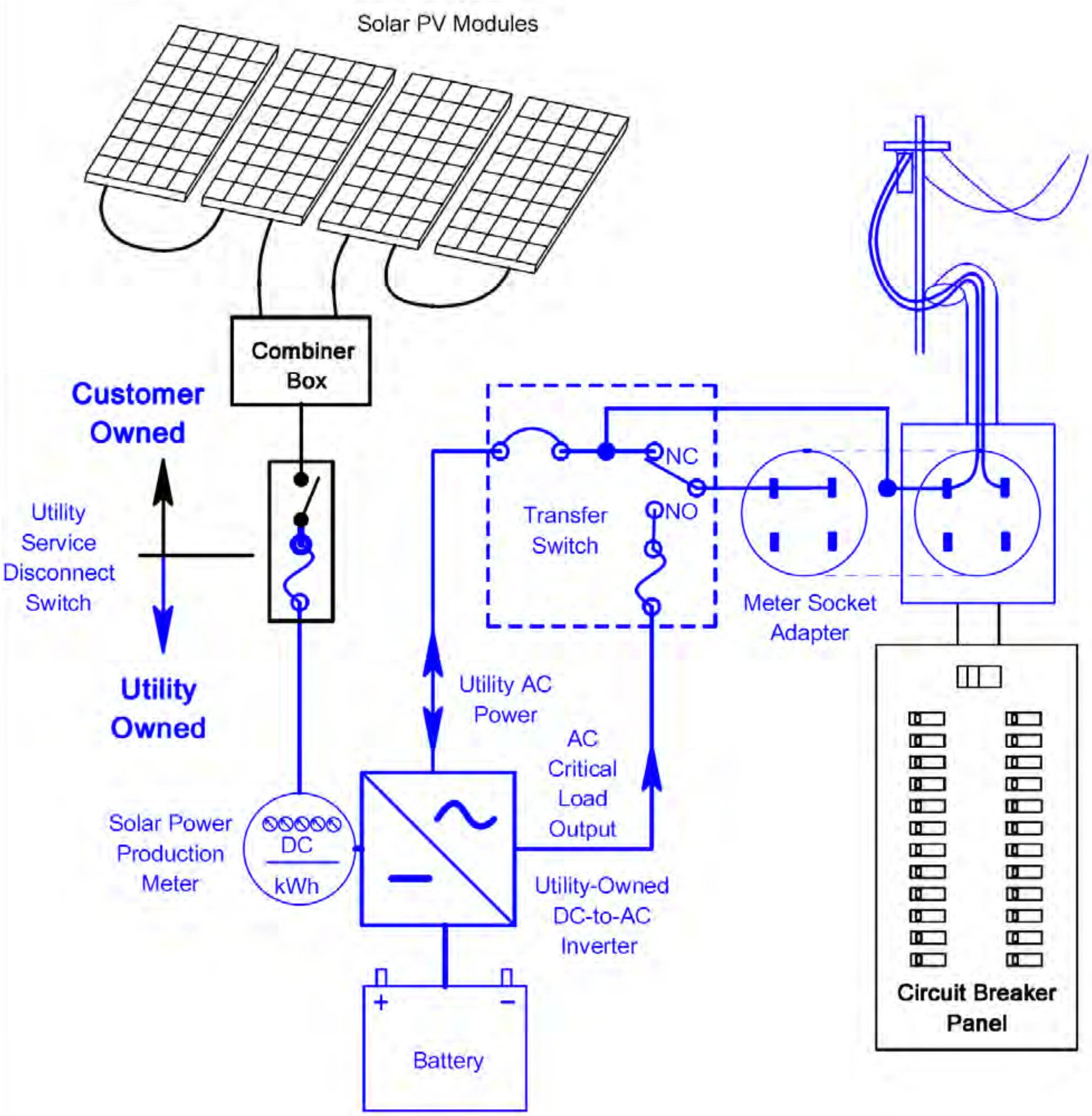


Figure 9. Detailed one-line diagram of battery-based utility-owned inverter and transfer switch providing the customer with emergency power generation.

The system shown in Figure 9 not only can provide emergency power to the home or business during a power outage, it can also be used during the majority of the time that the power is on to provide grid support for the electric utility. The batteries can shift the time the solar gets added to the grid, store generation from other renewable generating sources, shift loads from on-peak periods, or balance other generation needs of the utility.

INTERCONNECTION ISSUES

Being able to easily and simply connect the solar power system to the utility's grid is essential to reducing the installed cost of a solar power system. Meeting a utility's interconnection standards and obtaining utility approval before being able to connect to the grid may be one of the reasons why soft costs are so high in the United States. The utility-owned inverter can help remove this burden from the customer by making it the utility's responsibility to meet their own interconnection requirements. The utilities will need to develop new standards for connecting the solar power generation to the utilities' side of the customer's existing revenue meter. The main advantage of the utility ownership of the inverter is the ability to connect the solar resource directly to the grid, without having to connect to the customer's internal wiring.

There are several options for connecting the inverter to the utility's side of the distribution system.

Meter socket adapter

Figure 10 illustrates connecting to the grid by removing the consumption meter on the customer's premise, plugging the meter socket adapter into the meter socket, and reinstalling the consumption meter.

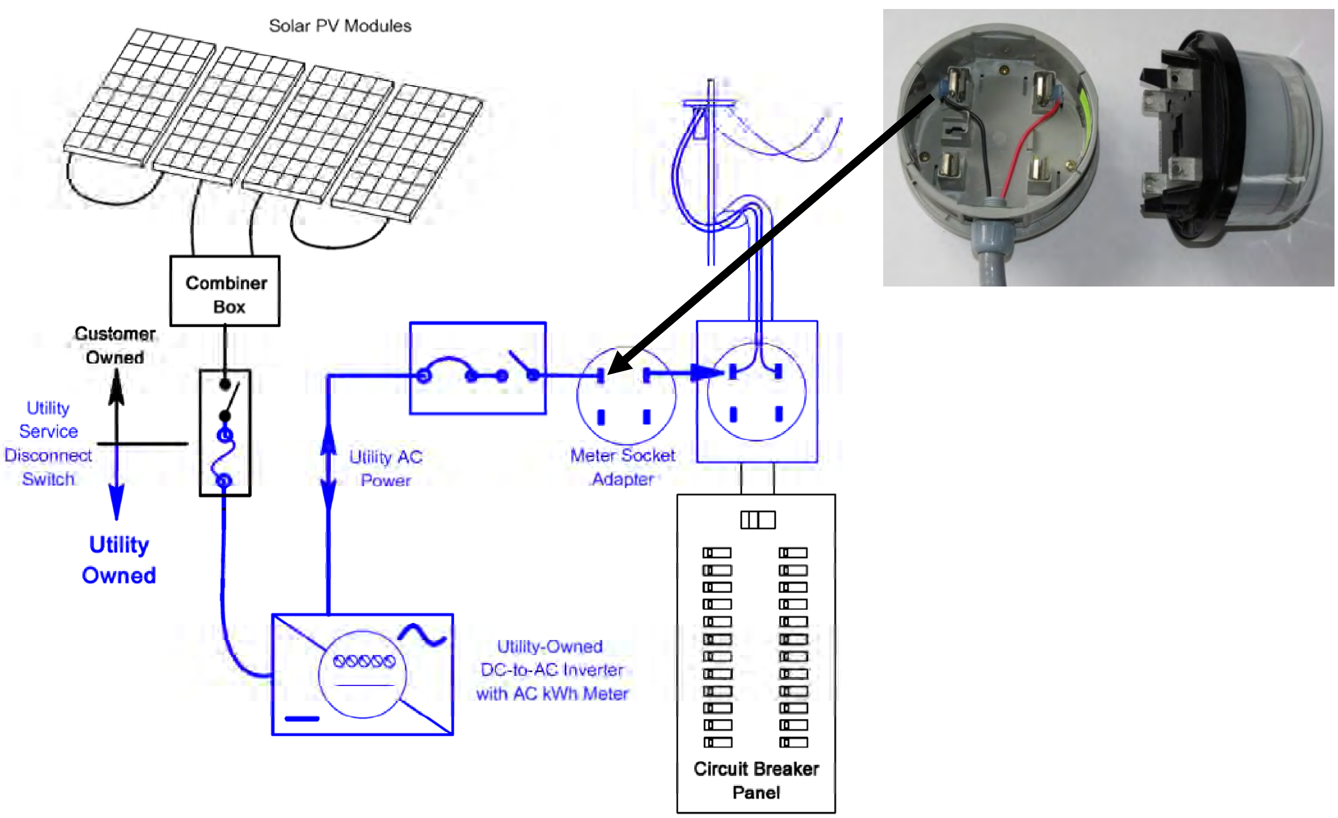


Figure 10. Meter socket adapter installed between the utility meter and the customer's meter base.

Direct connection through meter base knockouts and place under utility's meter base lugs.

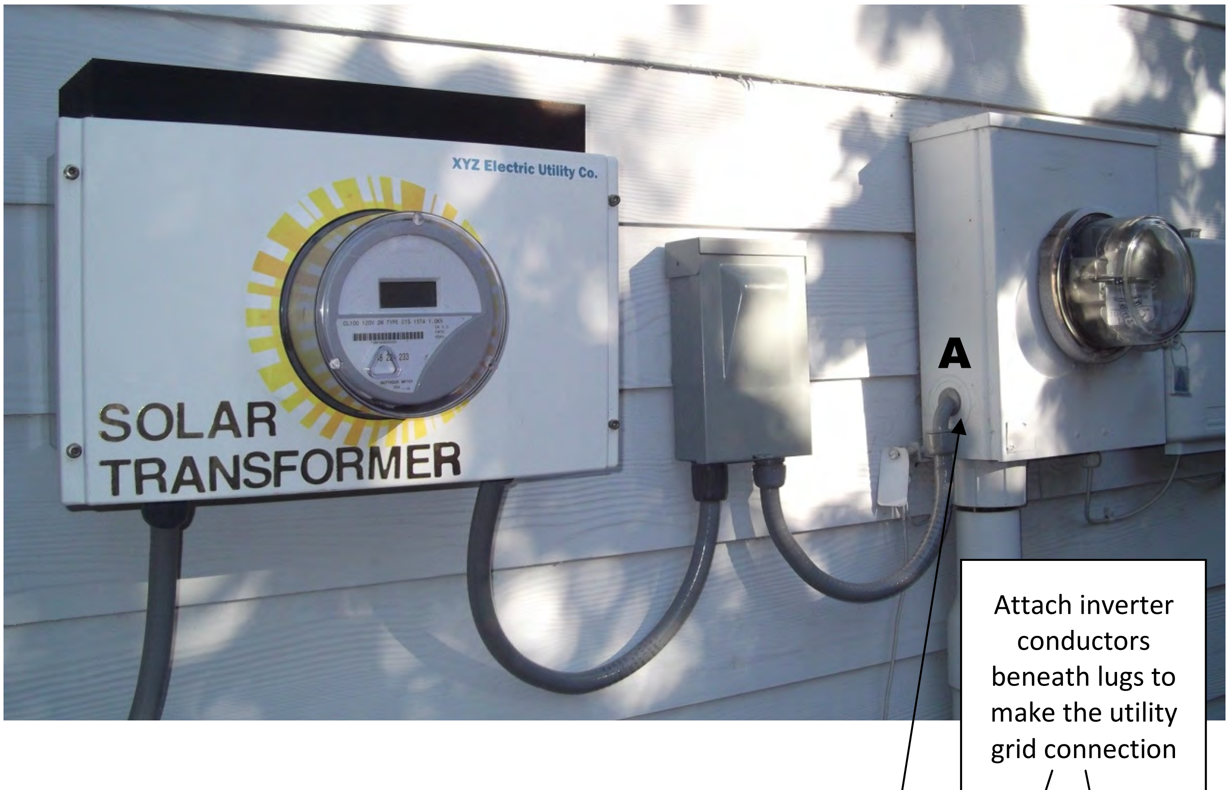
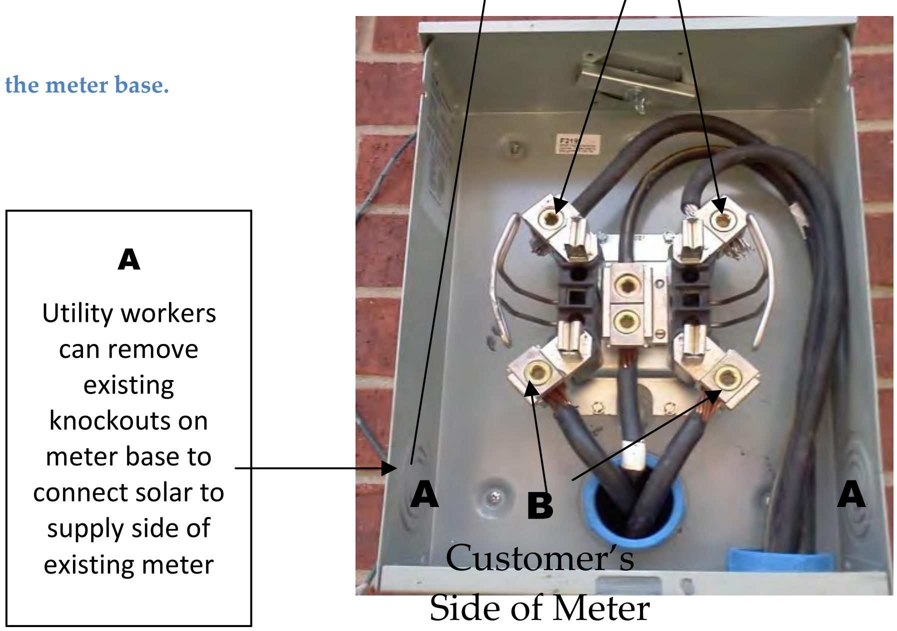


Figure 11. Direct connection to grid to the meter base.



Other grid connection options

Not every utility inverter installation can be made through the meter base or through a meter socket adapter. In those cases, it would be necessary to connect the inverter's conductors to the distribution transformer or to the conductors feeding the premise.

For inverters that have batteries that provide emergency power to a facility, it will be necessary to install a transfer switch between the distribution transformer and the facility's service connection. For larger commercial installations, it may make sense to connect the utility's inverter directly to the lugs on the utility's existing distribution transformer or handhold. Some commercial installations have metering cabinets that can be utilized for making the grid interconnection.

DC PLUG AND PLAY CONNECTION

The cost and complexity of installing a solar power system could be further reduced with the addition of a standard DC plug in the inverter to connect to the solar modules. Instead of having to install a DC disconnect switch, the conductors from the solar modules would all be plugged together and then be simply plugged into a standardized socket that is built into the DC-to-AC inverter. There is some precedence for doing this in Germany. Many German PV inverters come with DC connectors that simply plug into the DC wires coming from the modules. A non-conductive tip inside each of the connectors prevents an arc from occurring if the DC connections are unplugged under load.

Provisions would need to be made for physical protection from contacting voltage sources, grounding, lightning protection, and internal controls within the inverter to protect against over-voltage and/or over-current.

ECONOMIC CONSIDERATIONS

According to a study by Lawrence Berkeley National Laboratory (Joachim Seel, February 2013 Revision), residential solar power total installed costs were 120% higher in the United States than in Germany. In 2012, German solar power systems were $2.51 per watt, compared to $5.52 per Watt in the United States.

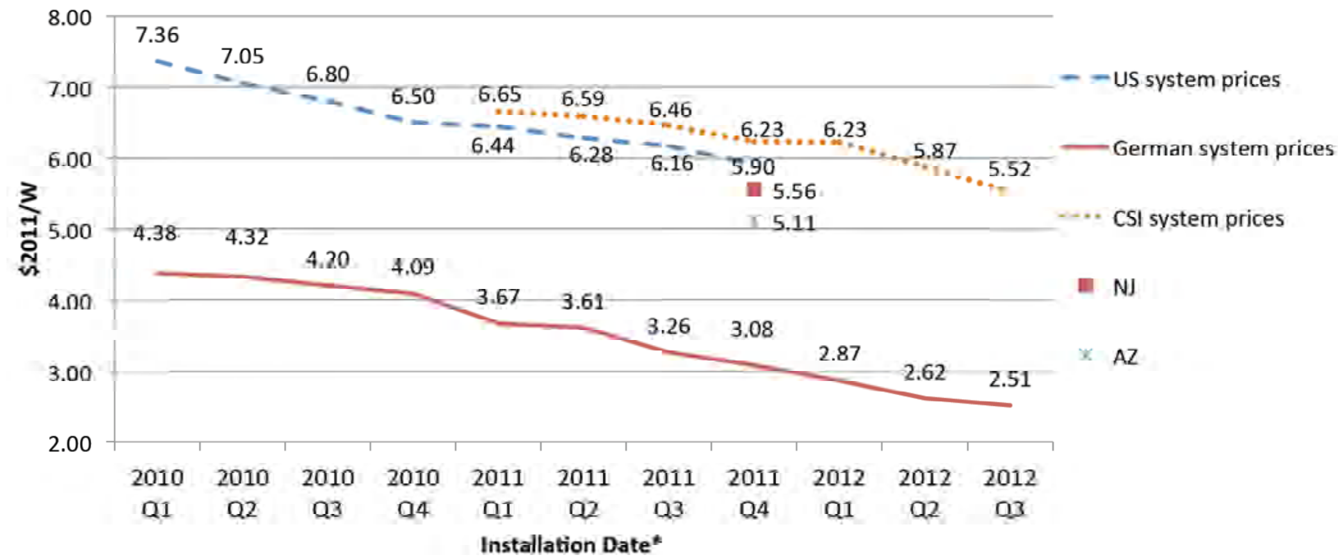


Figure 12. Historical cost differences between German and USA residential solar PV systems

Figure 13 shows that a majority of this cost difference is due to additional labor and other non-hardware costs. In Germany, licensed electricians can install a solar power system, connect it to the grid and install the production meter for the electric utility. The electrician needs to be registered with the utility and a portion of their licensing is done through the utility. This structure enables the utility to keep control and save money by not sending a serviceman.

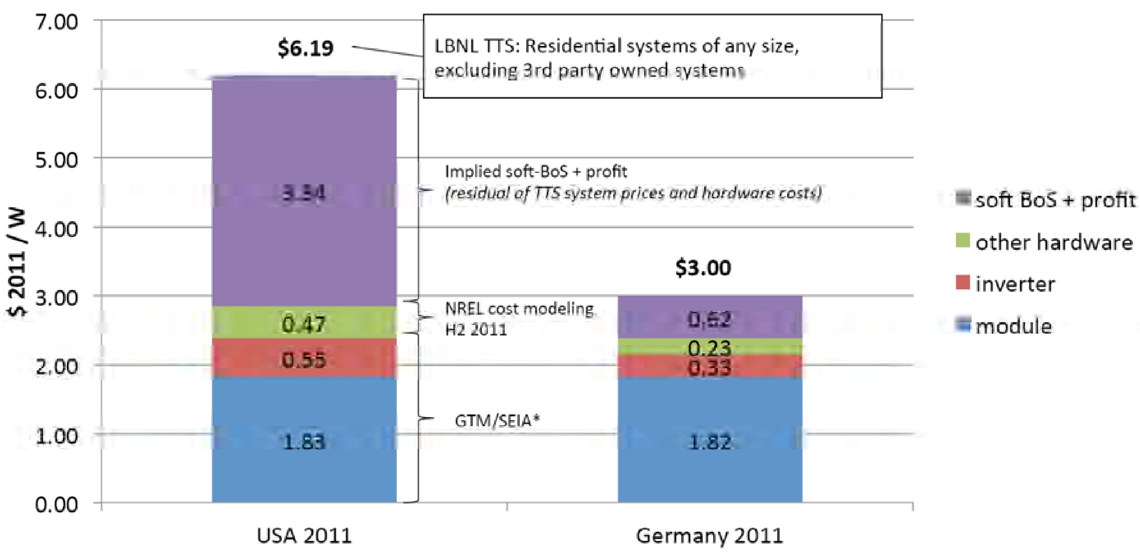


Figure 13. Breakdown of cost differences between Germany and USA in 2011

Utility ownership of the inverter could significantly reduce the balance of system (BoS) soft costs of small distributed solar power systems in the United States by:

- Simplifying interconnection requirements placed on the customer,
- Reducing installation times,
- Reducing permitting and inspection requirements, and
- Increasing economies of scale by having a business model that works for both the electric utility and the customer.

WHY STOP AT THE INVERTER?

Utility ownership of the entire asset is beyond the scope of this paper. Such a system would likely be net metered and compete directly with third-party owned systems. If it were not net metered, then the utility would essentially be leasing the customer's roof space to mount their solar power array.

Utilities already own the entire asset for larger solar installations and could install smaller ones now if they wanted to. In 1999 and 2000, Sacramento Municipal Utility District (SMUD) installed 100% utility-owned systems on customer's homes. In those systems, the customers paid a small monthly fee to have the array mounted on their home. The power generated by the system was fed into the grid on the utility's side of the meter and did not reduce the customer's consumption meter reading.

Treating the DC-to-AC inverter as just another transformer should be relatively easy for utilities to incorporate into their existing business systems, but going further and installing solar modules on customer's roofs would be an entirely different business model. It would require new worker qualifications, and there would be many more jurisdictional lines that would need to be dealt with related to building codes and permitting. There would also be an increase in potential liability.

CONCLUSION & NEXT STEPS

Utility ownership of the PV inverter provides electric utilities a new way to integrate distributed solar power into their distribution system. Electric utilities may prefer owning the inverter because there is no loss of revenues from electrical sales. Owning the inverter also provides the utilities greater control over the grid-connected variable resource, and the ability to receive full cost recovery on a new generating asset. Having control over the inverter makes it easier for the electric utility to embed technologies into the inverter that help manage the increasing amount of grid-connected variable resources.

Whether or not customers will choose to have the utility own the inverter will depend on the economic advantages that the utility can provide the customer, and achieving the right amount of regulatory alignment. The production payment to the customer will need to be sufficient to more than cover the cost of installing the solar modules and repaying the utility for the cost of owning, installing and maintaining the inverter.

The viability of this option for each electric utility will depend on the available solar resource, retail electric rates, daytime wholesale power rates, and the distribution benefits that the solar and/or storage may bring to that utility.

Next Steps

It is apparent that additional work is needed to evaluate the economics of the utility ownership of the inverter, and compare this to other customer-owned solar generation options. This may be a topic for future study by EPRI.

Electric utilities could choose to implement pilot projects of the utility-owned inverter in their service territory. A utility-owned inverter pilot program would be easiest to start at utilities that already have performance-based solar PV incentive programs. For example, City of Austin Electric Utilities, Gainesville Electric Utility in Florida, Los Angeles Water and Power, Long Island Power Authority in New York, or utilities in Washington State and Hawaii.

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