Achieving High Performance with Solar Photovoltaic (PV) Integration
Contents

Introduction 4

Accenture’s study on impact of high penetration of solar PV 7

Section I. Trends, opportunities and challenges of solar PV 8
• The solar PV trajectory is for continued growth, with new emerging ownership models on the rise
• Technology innovation is the lead factor driving long-term viability for solar PV
• Increased penetration of PV is posing significant operational challenges for utilities

Section II. Actions and new business models to manage high-penetration solar PV 16
1. Utilities should facilitate solar PV deployment and new ownership models, by providing infrastructure, systems and processes
2. Regulatory and government support should continue to make solar PV a viable renewable energy option
3. Accelerate smart grid initiatives in transmission and distribution to sustain high-penetration solar in the grid
4. Managed services can become a viable alternative business model

Conclusion 24
Introduction

Over the past decade, the intensifying focus on renewable energy among governments and utilities worldwide has driven dramatic growth in renewable power capacity. According to the May 2011 World Economic Forum report, Developing Renewable Energy Capacity, 2009 saw more than $150 billion invested in renewable-based generation globally, rising to over $240 billion in 2010, with the United States and Europe adding more renewable than conventional power capacity.1

Within this overall rebalancing toward renewable generation, solar energy using photovoltaic (PV) technology is emerging as an increasingly important segment. From 2004 to 2009, grid-connected solar PV capacity expanded at an average of 60 percent a year to some 21 gigawatts (GW).2 Solar PV has some key advantages. Its modular design and ability to fit on existing real estate makes it attractive for both the residential and commercial segments. Also, solar PV in either segment does not require stringent environmental clearances, and the energy generated can be used to achieve goals around self-sufficiency and corporate social responsibility.

Solar PV is now being used to generate electricity in more than 100 countries. And while solar PV still accounts for a relatively small proportion of total global capacity, it is now the world’s fastest growing power generation technology.3 This rapid expansion is being driven by a combination of the abundant availability of the solar resource, ongoing reductions in solar technology costs, government policy and regulatory support and the ability to utilize existing real estate—all of which make it simpler, easier and cheaper for small and medium-size utilities, developers and utility customers to establish solar power installations at a fast pace.

In the United States, continuous government and regulatory support has helped the rapid growth of solar, and barriers to ownership of PV systems are being alleviated by reductions in the upfront costs due to technology advances and various incentives. For example, the current levelized cost of energy (LCoE) for subsidized PV systems falls within the general range of 10 to 20 cents/kilowatt-hour (kWh). Government initiatives such as SunShot4 are aiming for grid parity. This support, coupled with other financial incentives such as tax credits, loan guarantees and direct funding through grants, have made ownership of PV systems more attractive.

Renewable energy sources clearly hold out the promise of clean and abundant supply—but issues around their cost, availability and reliability may impose major constraints on the emergence of renewable energy sources in general, and solar PV in particular, as a significant player in the energy supply mix. Indeed, while the growth of solar PV has much support from various technology, regulatory and policy initiatives, as PV penetration increases, utilities will find themselves facing increasing challenges in managing their grid, maintaining reliability and sustaining the quality of supply.
The North American solar PV market is poised for very strong growth in 2011, with a range of 2.3 to 2.7 gigawatts (GW) expected in 2011. North American installations still pale in comparison to those in Europe but represent very strong growth for the region.

While subsidies undeniably underpin much of this growth, the young solar PV industry has been rapidly innovating in ways that make systems more cost effective, easier to install (from both an economic and an installation labor perspective) and easier to maintain. Subsidies appear to have been set at the right level—high enough to promote strong growth in the industry, but not so high that innovation becomes unnecessary.

Even so, uncertainty about the future levels of subsidies, in the United States and in Europe, contributes to industry volatility and adds uncertainty to long-range planning. Key factors to watch in the industry include:

• Further cost reductions for solar PV modules, inverters and other balance of system components, and installation labor will be driven by increasing volumes and continuing innovation.

• Attractive feed-in tariffs in Ontario, Canada, and solar carve-outs in state-level renewable portfolio standards (RPS) in the United States drive new installations, but uncertainty over the future of US federal-level incentives remains.

• Companies that provide solar leasing and power purchase agreements (PPAs) to residential and commercial property owners are expected to continue to thrive as they increase participation in the solar PV market.

• The movement of intelligence from central inverters to PV modules will accelerate, even as central inverters add functionality to enable high penetration of distributed PV systems on the grid.
Accenture's study on impact of high penetration of solar PV
Objectives
To help utilities navigate the challenges and opportunities of solar PV integration, Accenture commissioned a study by IDC Energy Insights to understand the challenges and opportunities utilities and sector players are seeing today—and expect to face in the future—as a result of the increased penetration of solar power in their grids.

This study blends qualitative and quantitative research to provide clear insights into market trends and utilities’ priorities, strategies, challenges and opportunities around solar PV in North America.

While the study was focused specifically on North American utilities, the findings on the approaches being adopted by the utilities in North America may be very valuable to other utilities around the world, as they embark on their journeys to deliver clean and sustainable energy supplies from solar PV.

Through this study, Accenture set out to investigate:

* What are the likely models for solar PV ownership?
* When does solar PV penetration become an issue to grid operations?
* What problems does high penetration of solar PV cause?
* What are the potential solutions?
* What are the opportunities and challenges with high penetration of solar PV for the utility?
* What services might be outsourced to specialist third-party providers?

The research yields key insights into the impacts of high-penetration solar PV generation, each of which brings significant implications for the future strategies of all participants in the PV value chain.

Methodology and sample
The quantitative research is based on a survey conducted online between March and June 2011 with 50 respondents from 31 utilities in North America. In addition, 12 in-depth interviews were conducted. Investor-owned utilities (IOUs) made up 72 percent of the utilities in our sample, with the remainder consisting of cooperative utilities, authorities and municipal utilities.

IOUs tend to be large, and this is reflected by the fact that 72 percent of our respondent companies had more than 250,000 customers. Data collection and fieldwork was completed for Accenture by IDC Energy Insights.

Of the respondents, 56 percent held senior executive roles focused on high-level goals and strategy, including chief information officers (CIOs), chief financial officers (CFOs), vice presidents (VPs), directors and general managers, while 44 percent were managers and engineers more familiar with technical challenges of solar PV integration. All interviewees were integrally involved in decision making, managing or supporting the addition and/or integration of renewable generation sources to the grid, with around 70 percent having a decision-making or influencer role.
Section I.
Trends, opportunities and challenges of solar PV
The solar PV trajectory is for continued growth, with new emerging ownership models on the rise.

The momentum behind the growth in PV installations remains strong in the United States, and is continuing to increase. As Figure 1 illustrates, annual additions to grid-tied solar PV capacity in the United States have risen year-on-year throughout the past decade.

To date, California has been a leader in PV penetration, with approximately 258 megawatts (MW) of PV capacity installed in 2010. However, now other US states are emerging as significant PV players, led by New Jersey, which has the second-largest solar capacity, with approximately 137 MW. Other states with substantial PV installations include Florida, New Jersey, Colorado, Arizona, North Carolina, New Mexico, Nevada, Pennsylvania and Texas.

There are three main ownership models for solar PV installations. The most commonly used model in North America, customer-owned PV systems, involves installations purchased directly by the customers (residential/commercial), and may be financed with loans. The customer can use electricity from the system, thereby reducing the electricity purchased from their utility through a “net metering” program, if one exists where they live. The customer can also sign a power purchase agreement (PPA) with their utility and sell the output from the PV system.

The other ownership models are utility-owned and third-party owned. Utility-owned PV systems are owned directly by a utility, and the power produced is sold by the utility in the same way as any other power it produces. When the utility sells the power, it gets the environmental credits associated with the system output.

In contrast, third-party/developer-owned PV systems are installed either on the property of a utility customer or on the third party's own (or leased) property. The third party may be a developer selling the output of a large PV system to a utility either through a PPA or on the wholesale market as a merchant generator. In cases where the third party owns the PV installation on a utility customer’s property, the third-party developer may sell the output of the system to the utility customer through a PPA, or lease the system to the utility customer.
As Figure 2 illustrates, our research finds that the most common ownership model for solar PV systems is ownership by utility customers, followed by utility-owned and then a relatively small number of third-party/developer-owned systems.

Figure 2. How does ownership of distributed solar PV currently break down?

While growth is expected to continue across all ownership types, third-party ownership models are increasing particularly rapidly. The key drivers for the growth in third-party ownership include:

- Rapid reductions in the costs of PV systems, lowering the barriers to ownership. Solar PV module retail prices per watt have declined by more than 40 percent since 2008.8
- Government policy incentives and regulatory support. The SunShot initiative aims to bring cost of solar PV-generated power to 6 cents per kWh.9
- Emerging options to manage risks more effectively, including risk-sharing mechanisms, together with services such as monitoring, insurance and performance guarantees and extended warranties on solar panels and critical equipment.

This rising third-party ownership is a very encouraging sign for the industry. Private sector involvement will bring innovation, capital and efficient risk management. For example, solar technology and performance risks can be managed more effectively by solar developers that have better control over technology providers and panel manufacturers.
Technology innovation is the lead factor driving long-term viability for solar PV

The initial driver of growth in PV capacity was provided by regulation, combined with policy incentives. "Carve-outs" in state-level renewable portfolio standards (RPS) in the United States have been a major factor in new installations.

RPS and goals at the state level ensure that clean energy fuels an increasing proportion of a state’s electricity demands, either directly through renewable generation, or indirectly through the renewable energy certificate (REC) market. A solar carve-out requires a certain percentage of the RPS goal to be met with solar resources. This mechanism has been used in RPS and goals in 16 states and Washington, DC, out of a total of 37 programs (see Figure 3). The regulations influencing PV also include those for distributed generation.

Further regulatory drivers for PV include the American Reinvestment and Recovery Act (ARRA) financial incentives and feed-in tariffs, which provide financial incentives for PV installation. However, a popular financing program—the Property Assessed Clean Energy (PACE)—for the residential market has been discontinued. ARRA loan guarantees, tax credits and direct funding through grants are the financial incentives that were appropriated in 2009 by this major spending program and, in many cases, are just now being awarded to get projects off the ground. ARRA funds have driven the US PV market by funding both manufacturing facilities and installations.

Feed-in tariffs guarantee growth in renewable energy by mandating utilities to purchase energy from renewable generators at a set price.

In many cases, feed-in tariffs also promote the local manufacturing industry by including domestic content requirements. Hawaii enacted the first statewide feed-in tariff in the United States, and there are several small—mainly pilot—programs elsewhere in the United States. In Canada, Ontario has established a popular feed-in tariff program that is effectively leading the country’s efforts to promote renewable energy at the provincial level, targeting a complete phase out of coal-fired energy from the province by 2014. Supported by the program, the Ontario PV market is projected to reach 2.5 GW by 2015.¹¹

Figure 3. Location of state-level PV carve-outs in the United States.

**Sixteen states and the District of Columbia have an RPS with solar/distributed generation (DG) provisions.**

- WA: Double credit for DG
- OR: 20 MW solar PV by 2020; double credit for PV
- NV: 1.5% solar by 2025; 2.4 – 2.45 multiplier for PV
- CO: 3.0% DG by 2020; 1.5% customer-sited by 2020
- UT: 2.4 multiplier for solar-electric
- NM: 4% solar-electric by 2020; 0.6% DG by 2020
- AZ: 4.5% DG by 2025
- TX: Double credit for non-wind (non-wind goal: 500MW)
- MI: Triple credit for solar-electric
- OH: 0.5% solar-electric by 2025
- NY: 0.4788% customer-sited by 2020
- NH: 0.3% solar-electric by 2014
- MA: 400 MW PV by 2020
- NJ: 5,316 GWh solar-electric by 2026
- PA: 0.5% PV by 2021
- DE: 3.5% PV by 2026; triple credit for PV
- MD: 2% solar by 2022
- DC: 0.4% solar by 2020
- NC: 0.2% solar by 2018
- WV: Various multipliers
- IL: 1.5% PV by 2025
- MO: 0.3% solar-electric by 2025
- NC: 0.2% solar by 2018
- WV: Various multipliers
- IL: 1.5% PV by 2025
- MO: 0.3% solar-electric by 2021

While growth in US PV installations has initially been driven by regulations and subsidies, other emerging trends are making PV more sustainable as a resource. In particular, ongoing development of PV technologies is helping to lower the cost, thereby increasing its long-term attractiveness to both providers and consumers.

Solar PV technology continues to evolve rapidly at every level, ranging from the technologies used to manufacture silicon ingots to the racking systems used to support PV modules. Recent developments have focused on lowering upfront capital and project development costs, increasing PV system output and lowering operational and maintenance costs. All of these improvements are aimed at reducing the LCoE from solar PV systems.

Solar module costs represent approximately 47 percent of the total cost of solar energy systems. The price of the solar module has now fallen below $2 per watt, which is about 40 percent lower than nominal 2005 prices. This rapid decline in the price of modules has focused the industry's attention on the balance of system costs, whose share had increased to around 44 percent of the total solar installed cost in 2010.12

The current LCoE for subsidized solar systems falls within the general range of 10 cents to 20 cents/kWh. However, the actual LCoE will depend on a diverse array of factors, including the financing details, system lifetime and location. Specifically, the movement of intelligence from central inverters to PV modules will accelerate, even as the central inverters add functionality to enable high penetration of distributed PV systems on the grid.
Increased penetration of PV is posing significant operational challenges for utilities

72 percent of utilities are concerned that their grids will face challenges or require upgrade even before the penetration of solar PV reaches 24 percent.

Utilities must provide power that is:

- **Reliable**: power outages must be avoided.
- **Safe**: utility employees working on power lines must always know whether those lines are “live” or not.
- **Within certain voltage limits**: voltage that is too high or too low can damage equipment or create safety hazards.
- **High-quality**: low-quality power (e.g., harmonics, voltage transients) can damage and/or shorten the life of electrical devices.
- **Low cost**: Meet regulatory obligations and key objective of supplying low cost power to its customer.

The main challenges high-penetration solar PV raises for utilities are in the areas of safety, voltage control and power quality. While solutions to these challenges exist, cost can become a factor, in terms of both equipment costs and operating costs.

In terms of **safety**, if a PV system continues to generate power during an outage, extra safety measures need to be taken to avoid harm to workers fixing the line. With very high levels of PV, the PV systems themselves may support the voltage on the line even during an outage, since the PV systems could “island,” remaining online during the outage and creating a safety hazard.

So all PV systems that interconnect to the distribution grid must have anti-islanding functionality that shuts down the inverter for a minimum of five minutes if it senses that the voltage on the line drops below a certain level, and ensures it does not come back online until the voltage level has been restored. However, the probing carried out by inverters as they check the line voltage can itself disturb the line.

In the **voltage control** arena, PV systems raise the voltage of the line, and too many of them can raise the line above its upper voltage limit. Conversely, a sudden drop in PV output, caused by clouds, could cause voltage to dip below the lower limit before the system can respond, and might cause other PV systems not impacted by clouds to trip offline. Frequent operation could shorten the life of existing voltage regulation equipment on the line, such as var cap banks and tap changers. Finally, cold load pickup raises the risk that PV systems may come back online all at once after outage, and raise the voltage above the upper limit before the system can respond.

Meanwhile, regarding **power quality**, variations in the mix of sun and clouds during the day may change the output of PV systems, and can introduce short-term voltage transients or frequency fluctuations that will negatively impact the performance of electrical devices receiving power from the grid. Also, the operation of some inverters can introduce harmonics onto the system that may have a similar effect.
These issues can begin to occur at relatively low overall PV penetration levels, because the effects can be very localized. In fact, high penetration on a single feeder can cause problems even if penetration across a utility’s entire service area is low. As Figure 4 illustrates, more than 70 percent of the respondents in our study believe their grid will face challenges or require upgrades at penetration levels below 24 percent.

Our research also shows that both commercial- and residential-scale PV systems are causes of concern for utilities, with the worries about commercial-scale systems being slightly greater. Also, the distribution grid is generally more of a concern than the transmission grid. The precise focus of such worries for a particular utility may depend on the make-up of its customer base.

Figure 5 indicates the types of undesirable impacts that our utility respondents have encountered at high frequency as a result of PV penetration. The top two conditions are the high costs required to provide reactive power support, and the additional interconnection requirements for distributed PV. Our study also confirms that utilities are investing in infrastructure to avoid such problems.
Looking forward, we also asked our utility interviewees to anticipate the challenges they believe they are likely to face once PV penetration passes 30 percent in some areas. As Figure 6 illustrates, our respondents regard additional interconnection requirements and higher costs as the most likely issues to arise.

Utilities are aware of the solutions available to address the various challenges posed by high-penetration solar PV that we have highlighted. However, the key hurdle they face is in finding the most cost-effective solution, in terms of initial capital investment and in the area of ongoing grid operations and management costs.

Our research confirms that utilities are most interested in automated solutions that can be pre-set, rather than in applying real-time manual control. Asked to highlight the steps they are likely to take to mitigate the negative impacts of high PV penetration, more than 60 percent of respondents say they will require PV system power output to remain fixed or within predefined limits for the life of the system (see Figure 7). The requirements that impact PV systems directly will more likely apply to large systems than residential or light commercial installations.
Section II.
Actions and new business models to manage high-penetration solar PV

Following the web-based quantitative part of the study, a series of 12 qualitative one-on-one discussions has been conducted by IDC Insights with key utilities players already experiencing increased penetration of PV in their service areas, or that are preparing to introduce solar PV technologies. Their responses underline the fact that utilities are facing multiple challenges with having to adopt costly, less-reliable solar power while ensuring low-cost, reliable and quality power supplies to the customers. Four points of consensus action emerged from the discussions.
The initial adoption trends in solar PV were driven by customer-owned (residential/commercial) rooftop solar. But a combination of the decreasing cost of the solar technologies, government incentives and large-scale research funding is attracting growing interest from venture capitalists and private investors, in turn contributing to the significant growth we have highlighted earlier in third-party ownerships of solar power projects.

Solar PV power developments, however, are often restricted by infrastructure limitations. In many cases, utilities find they are unable to read the meters of customers with rooftop solar due to a lack of smart meters or an inability to configure the meters to record import/export readings. Furthermore, a lack of adequate protection and control systems can result in utilities being unable to address voltage, power factor, harmonics and transient issues, also leading to restrictions on solar penetration.

As a result, as Figure 8 illustrates, almost a quarter of the utilities in our study have imposed restrictions on PV systems joining the grid. With solar still contributing less than 1 percent of total supply in the US energy mix, the need for these restrictions highlights the inadequacy of the infrastructure.

To address these issues and facilitate solar power developments, Accenture recommends that utilities consider strengthening their infrastructure, systems and processes (see Figure 9). By looking at the areas listed in Figure 9 and determining what is presently implemented and planned in each of the three areas, a utility can chart a roadmap that will align with its renewable portfolio.

**Figure 8. Has your utility imposed restriction on PV systems coming onto the grid to avoid the grid instability, loss of power, high cost of reactive power, denial of permits?**

Don't know 16%

No 60%

Yes 24%

Base: All respondents.

**Figure 9. Key infrastructure, system and process considerations for successful integration of solar PV in the utility grid.**

**Infrastructure**
- Upgrade T&D line capacity
- Provide adequate switching capacitors
- Provide metering and communication infrastructure

**Systems**
- Implement distribution automation
- Adopt distribution management system (DMS)
- Advanced metering infrastructure (AMI) and meter data management systems (MDMS)

**Processes**
- Update distribution operations
- Specify connection requirements
- Define procedures for voltage detection and low voltage ride through
- Update billing and settlement processes

1. Utilities should facilitate solar PV deployment and new ownership models, by providing infrastructure, systems and processes
In recent years, regulatory mandates and government support have enabled solar energy to grow rapidly, while carve-outs in state-level RPS in the United States have driven new installations. Many states now have mandated solar energy targets (see Figure 10).

RPS goals ensure an increasing proportion of clean energy fuels each state's electricity demands—either directly through renewable generation, or indirectly through the REC market. A solar carve-out requires a certain percentage of the RPS goal to be met with solar resources. This mechanism has been used in RPS and goals in 16 states and Washington DC (out of 37 programs). New Jersey's carve-out has driven spot prices for solar renewable energy credits (SRECs) to very high levels, above $500/MWh. Combined with other government incentives, these spikes in renewable energy credits led New Jersey to become one of the top five US state in terms of solar MW addition in 2010.

The federal and state governments in the United States and around the world are aggressively targeting technology breakthroughs to reduce the costs of energy generation from solar sources. For example, the U.S. Department of Energy's SunShot initiative aims to reduce the total installed cost for utility-scale solar electricity to roughly 6 cents per kWh without subsidies, resulting in rapid, large-scale adoption of solar electricity across the country. Achieving the SunShot goal could enable PV penetration levels as high as 8 percent of overall energy production by 2020, 14 percent by 2030 and 18 percent by 2050.13

At the same time, the U.S. Department of Energy is continuing to support research in the area of high penetration solar PV, and is planning a technology roadmap for research to define, evaluate and test the effects of high concentrations of solar-generated power on electric power systems. Potential projects may include modeling, forecasting, technology innovations, new inverter technologies and more efficient energy storage. The Department is specifically interested in determining the level of penetration at which technical problems can be shown to occur, and to pinpoint how these impacts may vary based on distribution feeder topologies.

2. Regulatory and government support should continue to make solar PV a viable renewable energy option

Figure 10. Specific solar carve-outs in the state-level RPS requirements in selected states.

<table>
<thead>
<tr>
<th>State</th>
<th>Provision</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon</td>
<td>20 MW PV (double credit for PV)</td>
<td>2020</td>
</tr>
<tr>
<td>Nevada</td>
<td>2.4 – 2.45 multiplier for PV</td>
<td>2025</td>
</tr>
<tr>
<td>Illinois</td>
<td>1.5 percent PV</td>
<td>2025</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>400 MW PV</td>
<td>2020</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>0.5 percent PV</td>
<td>2021</td>
</tr>
<tr>
<td>Delaware</td>
<td>3.5 percent PV, triple credit for PV</td>
<td>2026</td>
</tr>
</tbody>
</table>

3. Accelerate smart grid initiatives in transmission and distribution to sustain high penetration solar in the grid

The integration of solar technologies into the existing grid will require changes to be made to the traditional grid and also to PV system operations and controls. As highlighted in our survey findings and through a number of other industry research studies, distribution grids will need to be upgraded and operated in a more intelligent manner to accommodate the two-way flow of power and respond to variable generation. PV systems will need to operate interactively with grid conditions and load, and the addition of emerging technologies such as storage, electric vehicles, will further complicate the operations.

In combination, evolving integration standards, interoperability and operational requirements create complex challenges for the utilities and PV developers. Grid analytics, faster controls and more effective communications will be key in managing distributed sources of power generation. According to our survey respondents, the functional areas shown in Figure 11 are most heavily impacted by rising solar penetration in their transmission and distribution (T&D) networks.

In Accenture’s view, the areas in which utilities need to focus most attention include grid analytics, commercial operations and PV system control and management.

Figure 11. Which of the following functions that may be needed to integrate high-penetration of solar PV on the grid are you currently performing in-house?

- Grid analytics: 48%
- PV system control: 44%
- PV system management: 32%
- Commercial transactions: 32%
- Design services: 30%
- Distributed resources programs: 30%
- Solutions to integrate PV in utility systems: 28%
- Project developer services: 20%
- Solutions to integrate PV with trading systems: 18%

Base: All respondents.

**Grid analytics**

Solar PV—like other renewable technologies—requires voltage and power factor support. Reactive power control and optimization through utility operations is critical. Optimized operation requires enhanced real-time grid analytics based on data drawn from multiple field systems, and often captured through various enterprise and operational systems. As a result, utilities need an integration platform that can bring together information from various systems and present optimized grid analytics in real-time to support operational decisions.

**Commercial operations**

Solar PV systems provide a bi-directional flow of energy. This entails a paradigm shift for traditional distribution operations, in which the model was based solely on power delivery and billing to customers for consumption. In many cases, distributed PV systems need to provide their schedule on a day-ahead basis. These schedules are consolidated with other generation availability schedules to develop a dispatch schedule. Distribution utilities require systems and processes to enable them to accept schedules, and also need to be able to communicate back to the distributed generation sources on the dispatch schedule and any real-time operational changes.
Furthermore, different types of tariff structure are emerging to value and promote solar power more efficiently. The most popular of these tariff structures include net metering and feed-in tariffs, both of which require a mechanism for utilities to capture generation readings. In case of net metering, the generation needs to be settled against consumption and energy banks created. Utilities need to review their energy scheduling, dispatch, accounting and settlement processes and systems to ensure that solar PV systems are commercially integrated into their operations.

**PV system control and management**

Utilities are concerned about the reliability and stability of their grid networks due to the increased penetration of solar power. The Solar Energy Technologies Program (SETP), in the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy (EERE), held a technical workshop on high penetration of PV systems into the distribution grid. The participants at the workshop identified the following issues as the top barriers to high penetration solar:

**Grid integration**
- Smart grid characteristics, such as two-way controls and communications
- Inverter development with intelligent bundling for ancillary services (e.g., voltage support)

**Solar variability/intermittency**
- Standardized collection and analysis of data from PV sites for forecasting generation and modeling effects on grid
- Storage as a possible solution

**Modeling the integration of PV generation**
- Steady-state and dynamic models to simulate penetration levels
- To encourage acceptance of PV by electric utilities and ensure stable power supply

**Revision of standards and codes**
- To establish agreement on PV equipment capabilities
- Update Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 to address high penetration levels.

The recommended steps to address these barriers included:
- Ensuring safe and reliable two-way electricity flow.
- Developing smart grid interoperability.
- Developing advanced communication and control functionalities for inverters.
- Integrating renewable systems models into power system planning and operational tools.
- Integrating with energy storage, load management and demand response to enhance system flexibility.
- Understanding high-penetration limiting conditions.
- Understanding how various climates and cloud transients affect system reliability.

Utilities need to maintain a long-term perspective while selecting their distribution grid management technologies. Distribution management system (DMS), supervisory control and data acquisition (SCADA) and energy management system (EMS) deployment decisions need to factor in the potential impacts of integrating distributed generators such as solar PV. For example, a utility with a high penetration of solar and other renewable sources in its grid network may decide to implement real-time system upgrades before moving on to advanced metering infrastructure (AMI) and smart metering programs.
4. Managed services can become a viable alternative business model

As previously discussed, the increased penetration of solar PV and other distributed technologies is presenting new challenges for utilities. In many cases, distribution operation businesses are not familiar with—or equipped for—the resulting changes. While the utilities in our survey expressed a desire to keep their core operations in-house, they also indicated that they may be willing to change this view if viable alternatives are presented. With this in mind, the key challenges utilities are facing today as they embark on the journey toward smart grid and adoption of distributed generation include:

Technology risks
Smart grid technologies are evolving—and many utilities are feeling the brunt of being at the leading edge of the technology adoption. Technologies are frequently being upgraded, leaving utilities with the huge burden of managing obsolete technologies or constantly struggling with system upgrades. These upgrades can have wide impacts on business processes and often lead to lost productivity.

Operational risks
The introduction and integration of distributed generators require sophisticated grid controls and operations. Many utilities that previously had limited numbers of control devices are seeing five- to six-fold explosions in their number of network devices. Managing these devices while maintaining the same level of network availability is a challenge. A number of utilities are worried less about the initial cost of deployment, and more about the complexities of managing these devices in the future.

People and process risks
Utilities have seen large-scale reductions in their workforces over the past few years. However, smart grid deployment is leading to the introduction of thousands of sensors, controls and intelligent devices into the network. Ultimately, these intelligent devices and sophisticated controls are expected to reduce manual processes, but the transition will be long and, in many cases, complex and will require changes to processes, as well as the skills mix in some instances. With a high proportion of their workforces approaching retirement and a constrained talent pool, utilities are compelled to think about new business models to realize the full potential benefits of the smart grid.

During the research for our survey, we raised the issue of utilities’ views on managed services. Traditionally, utilities have performed the functions of managing grid infrastructure and operations themselves. They are likely to continue doing so if they do not see any viable alternative.

However, it is significant that 14 percent of the utilities in our study are currently using a third-party service provider to support the ongoing management of solar PV connected to the distribution grid. As Figure 12 illustrates, the functions currently managed most frequently through managed services are commercial transactions, managed network services, and distributed resources programs. A further key finding of our survey is a desire among the utilities we interviewed to explore the potential for managed service more deeply, and to look for viable managed service options if some key criteria are met and concerns addressed.

Figure 12. What service(s) does the third-party provider perform to help the ongoing management of solar PV-related assets connected to your grid?

<table>
<thead>
<tr>
<th>Service</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managed network services</td>
<td>57%</td>
</tr>
<tr>
<td>Commercial transactions</td>
<td>57%</td>
</tr>
<tr>
<td>Distributed resources programs</td>
<td>43%</td>
</tr>
<tr>
<td>Managed network services to manage telecommunications</td>
<td>29%</td>
</tr>
<tr>
<td>PV system management</td>
<td>14%</td>
</tr>
<tr>
<td>PV system control</td>
<td>14%</td>
</tr>
</tbody>
</table>

Base: All respondents.
We built on these findings by exploring the key drivers that may lead utilities decide to move further toward managed services:

Cost and resources constraints
The cost-reduction agenda favors managed services that are built around operation and maintenance-related functions. Workforce skills are less of a driver overall, but utilities with a mix of utility-owned and third-party owned PV may be facing complexity issues and a need to seek external help. In our survey, we found that lowering the cost of operation and maintenance is favored by around 70 percent of the respondents, while 40 percent felt the need for expert workforce (see Figure 13).

Reliability, security and integration capability
In terms of the attributes they look for in a managed services provider, utilities place the highest importance on reliability (see Figure 14). However, the relatively even distribution of their responses indicates that utilities expect their suppliers to have multiple competencies. While they regard the ability to meet service level agreements for reliability as vital for any managed service providers to even be considered for the service, they also think proven security capabilities are another key consideration, narrowly ahead of the ability to integrate closely with the utility’s own systems.

These findings reflect the fact that utilities are investing heavily in security of their infrastructure, and would expect a managed service provider to demonstrate strong security capabilities. They also believe that deep knowledge and experience of systems integration are critical for any managed service provider to be able to understand the interoperability of complex control systems, and to manage systems to achieve the desired results.

Figure 13. Please rank the following major drivers for you to consider using managed services in order of importance?
(Top two responses)

<table>
<thead>
<tr>
<th>Driver</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower ongoing maintenance cost</td>
<td>76%</td>
</tr>
<tr>
<td>Lower ongoing control cost</td>
<td>60%</td>
</tr>
<tr>
<td>Lack of experienced workforce</td>
<td>40%</td>
</tr>
<tr>
<td>Lack of subject matter expertise</td>
<td>10%</td>
</tr>
</tbody>
</table>

Base: All respondents.

Figure 14. Please rank the following primary attributes that you would look for in a managed service provider in order of importance.
(Top response only)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate security capabilities</td>
<td>34%</td>
</tr>
<tr>
<td>Ability to meet service level agreement for reliability</td>
<td>40%</td>
</tr>
<tr>
<td>Ability to closely integrate with utility systems</td>
<td>26%</td>
</tr>
</tbody>
</table>

Base: All respondents.
Conclusion

As we have described in this report, Accenture’s study reveals compelling evidence that solar PV installations will continue to grow during the next few years, as falling costs cause the key driver of their expansion to switch from regulation and policy incentives to a more sustainable commercial rationale.
However, the increasing penetration of solar PV is already posing operational challenges to the utilities. Unless technology and operational interventions are introduced, utilities are likely to respond by imposing stringent connection requirements or restricting future solar PV installations.

As utilities position for high performance in solar power developments, their long-term success hinges on their ability to develop the necessary infrastructure, systems and processes. Smart grid will play a key role in the successful introduction and integration of distributed generation and high penetration solar. To realize the full potential of solar PV, utilities need to strengthen their systems and processes, and explore new operating models to meet the technological, operational and human resource challenges that stand in the way.

Following are the key actions we believe utilities and their stakeholders should consider, to maximize successfully implementing and integrating high-penetration solar PV:

- Review existing roadmaps or develop a comprehensive roadmap for utility T&D infrastructure upgrade and smart grid implementation, with a clear focus on the impacts of an increased penetration of solar PV.
- Upgrade utility infrastructure by performing interconnection-wide system planning studies, together with design and construction of new T&D lines, reactive power capacities, switching and controls.
- Review the impacts on the utility business processes, and redesign the processes as needed for efficient integration and facilitation of solar PV in the utility system.
- Lead and manage initiatives and take advantage of the regulatory and policy incentives to adopt solar PV.
- Develop a risk management framework to assess and manage regulatory, technology and operational risks arising from high penetration of solar PV.
- Assess the organizational capability, training and change management needs for adopting new process and business models required for the integration of solar PV in the grid.
- Explore new business models based on the organizational capabilities, costs, risks and reliability considerations related to the adoption of solar PV in the utility system.
Endnotes


3. Ibid.


7. Ibid.


Contact us

Sharon Allan
sharon.s.allan@accenture.com

Navneet Trivedi
navneet.trivedi@accenture.com

About the Accenture Utilities industry group

The Accenture Utilities industry group has more than 30 years of experience working with electric, gas and water utilities worldwide. Our group includes 10,000 professionals working with approximately 275 clients in 40 countries. We work with 93 percent of the utilities on the 2010 Fortune 500 list, providing the deep industry knowledge, people and assets utilities need to develop the strategies and adopt solutions to improve performance in the dynamic energy market.

About Accenture

Accenture is a global management consulting, technology services and outsourcing company, with approximately 236,000 people serving clients in more than 120 countries. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world’s most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. The company generated net revenues of US$25.5 billion for the fiscal year ended Aug. 31, 2011. Its home page is www.accenture.com.