MICROGRID KNOWLEDGE

Creating a 21st Century Utility Grid with DERMS and VPPs

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Contents

Introduction

DERMS and VPPs Help Utilities Address the Many Challenges of Integrating DERs

Big changes are afoot in how electricity is produced and managed. We're seeing a shift away from centralized power plants to a new model that features distributed energy — renewable resources, combined heat and power (CHP) and battery storage.

The drivers include renewable portfolio standards requiring utilities to invest in renewable energy; "prosumers" deciding they want to produce their own energy, go green and save money; and worries about climate change.

But utilities and regulators are grappling with the challenges of integrating all this new distributed energy into the old-fashioned grid. Among the many prickly issues are outdated regulations that make it difficult to compensate producers for the energy they bring to the grid. Voltage excursions, brownouts and blackouts are also potential problems.

One way for utilities to address the distributed energy resources challenge is by taking advantage of Distributed Energy Resource Management Systems (DERMS) and Virtual Power Plants (VPPs).

This series identifies distributed energy resource (DER) challenges and explains how DERMS and VPPs address them.

Part I:
The 21st Century Power Grid: Not Your Parents' Power Grid

Our power grids are changing, and they are changing very dramatically and rapidly.

A new solar installation goes live in the U.S. every 2.5 minutes. In fact, over a 14-day period in March 2017, California had so much solar power flowing to its grid that it paid Arizona to take excess power off its hands, fearing blackouts caused by overloaded power lines.

There are now more than 1,000 utility scale wind projects representing 84,405 megawatts and over 52,000 wind turbines installed across the US, and there are some 3.4 gigawatts of energy storage in the current global pipeline.

> *As factors like lower costs, greater incentives and new corporate initiatives continue to drive growth of DERs, the opportunities continue to expand with each passing day.*

Add to that the other renewables on the rise — biomass, geothermal, hydropower — and then tack on flexible process load, fuel cells, CHP, flywheels, electric vehicles, microgrids, demand response and still other DERs that are continually being added to our evolving power grids, and you begin to get a sense of how they are changing the fundamental physical and economic landscape of the utility industry.

The potential reliability, environmental, efficiency and economic benefits offered by successful integration of DERs into the energy mix have been well-documented. And as factors like lower costs, greater incentives and new corporate initiatives continue to drive growth of DERs, the opportunities continue to expand with each passing day.

There are challenges, however, with integrating this vast and growing mix of DERs into a power grid that was not designed for two-way power flows: challenges with managing these resources in a way that keeps the power grids in a perpetual state of balance.

DERMS and VPPs act as the platforms to manage a more DER-dominated grid via needed software.

"Think of VPPs and DERMS platforms as network orchestrators that control how and when each distributed energy asset contributes to a continuously

> *"These software systems are the brains needed to bring the vision of a more sustainable energy future to life."*
> *– Eric Young, Enbala*

balanced grid," says Eric Young, vice president, industry solutions for Enbala, which, according to Navigant Research is the industry's #1 provider of VPP software. "These software systems are the brains needed to bring the vision of a more sustainable energy future to life."

Given the importance of their role and their ubiquitous inevitability, it makes sense to take a close look at the criteria for VPP and DERMS effectiveness both today and into the future as the grid — and the mix of DERs on the grid — continues to evolve. Both control and manage DERs, but there are fundamental differences that warrant exploration and which impact the ROI and evolution of these systems.

Virtual power plants

Virtual power plants perform active power control across a fleet of assets to provide grid services that are independent of the specific location of each asset, for example feeders or circuits. In general, they provide system-wide benefits associated with increased or decreased generation or load and focus more on larger territories such as cities, counties, states or areas where independent system operators or regional transmission organizations operate.

VPP usage

The grid services for which VPPs are optimally used include:

- Demand response/capacity
- Frequency regulation
- Operational reserves
- Energy arbitrage
- Peak demand management

Distributed energy resource management systems

DERMS, in contrast, provide grid services that are highly dependent on the specific location (grid connection) of each asset. DERMS-controlled grid services are delivered by manipulating power flows along individual feeders and include:

- Voltage management
- Optimal power flow
- Locational capacity relief

DERMS can manage both real power (watts) and reactive power (VAR), and can increase load on one part of a feeder while decreasing load — and increasing generation — at another part of the same feeder.

DERMS typically require more back end system integrations than a VPP due to the requirement of locational grid and asset state information. For DERMS applications, integration with the utility is required, typically through a distribution management system (DMS), advanced distribution management system (ADMS), outage management system (OMS), or supervisory control and data acquisition (SCADA) system.

Why does this matter?

Whether or not VPPs or DERMS are the optimal choice for a utility depends upon how the DERs will be used, and when. A VPP is probably the best choice for utilities that envision controlling edge devices for applications, demand response, energy arbitrage and peak demand management. A VPP can deliver significant benefits and meet near-term goals, while avoiding the larger up-front investment of integration with DMS, ADMS, OMS or SCADA systems.

A DERMS platform is needed for a utility with location-specific and distribution-focused applications, operating at a distribution feeder level to regulate grid conditions and better prevent system excursions, blackouts and power outages.

It's important to note that a logical, phased approach that begins with a VPP and transitions to DERMS over time is entirely feasible and provides a logical path to follow as utilities gain more familiarity with real-time control and optimization of DERs and start to experience greater urgency for distribution-level grid balancing support.

"The foundation for a reliable, sustainable energy future rests on more distributed and intelligent networks of power," notes Young. "VPPs and DERMS are the means to this end, enabling both the producers and consumers of energy to harness the power of distributed energy."

Part II:

Virtual Power Plants: Coming Soon to a Grid Near You

Before the 2016 elections in the Philippines, officials worried about the potential for blackouts due to problems integrating solar energy into the grid. Oversupply had been triggering outages, and the system needed ancillary services — especially frequency regulation — to keep electricity flowing, according to local press reports.

The Philippines is not alone in facing challenges due to renewable energy oversupply on the grid. In the US, Hawaii, Arizona, the Pacific Northwest, Texas and California have experienced challenges; so have Australia, Germany, Chile, the UK and other countries. For example, Arizona Public Service plans a "reverse demand response" program to avoid the curtailment of too much renewable energy, and some wind-rich Texas utilities offer free electricity during off-peak hours.

An effort from London-based Carbon Trust plans to bring together a group of energy companies to investigate using energy storage to reduce the costs associated with integrating wind energy into the UK power grid.

The good news: Wind power turbines, solar photovoltaic panels and other renewable energy sources are producing clean kilowatts across the globe. But utilities and system operators are facing challenges grappling with clean-energy oversupplies.

Until recently, utilities and grid operators dealt with this renewable energy variability, along with other modern-day grid balancing challenges, by switching in fast-ramping conventional fossil-fuel based reserves. But as the volume of renewables and other forms of distributed energy on the grid grows, more efficient and carbon-neutral ways of supply-demand balancing are needed.

This is where VPPs enter the equation.

The US Energy Information Administration notes that the cost of building a new coal-fired power plant is roughly $3 million/MW. And while natural gas-fired plant construction costs are less, at about $900/kW, both options carry considerable environmental and stranded investment risks, along with substantial waste associated with ancillary services such as spinning reserves. VPPs, on the other hand, offer a very different future, providing financial and environmental benefits for DER owners while also maintaining a reliable supply and demand balance on the electric grid. The costs are much lower — about $80/kW.

VPPs can replace conventional power plants while also providing higher efficiency, greater flexibility and increased grid reliability.

Providing power — without the plant

Navigant Research defines a VPP as "a system that relies upon software and a smart grid to remotely and automatically dispatch and optimize DERs via an aggregation and optimization platform linking retail to wholesale markets."

Virtual power plants can be cloud-based, central or distributed platforms that aggregate, optimize and control varied and heterogeneous DERs to behave as conventional dispatchable power plants. They deliver power without the physical plant. As such, VPPs can replace conventional power plants while also providing higher efficiency, greater flexibility and increased grid reliability. In orchestrating distributed generation, PV, microgrids, storage systems, controllable and flexible loads, along with other DERs, VPPs provide critical and fast-ramping ancillary services.

Designed to provide flexible grid services that are not highly dependent on the specific locations of the DER assets, VPPs are ideal for applications such as frequency regulation — what was needed in the Philippines example — along with advanced demand response, peak demand management and operational reserves (secondary and tertiary reserves in Europe). They also enable energy trading in wholesale markets on behalf of DER owners who would otherwise not be able to participate on their own. VPPs can act as arbitrageur between DERs and diverse energy trading floors.

This contrasts with DERMS, which enables location specific (e.g., tied to locations of specific assets such as feeders), primarily distribution focused grid services.

Frequency regulation/secondary reserves: Addressing the renewable energy integration problem

Since renewable power sources such as wind and solar are notoriously variable and therefore difficult to predict, new scheduling, control and management systems are needed to ensure a continuously balanced supply/demand mix on a second-to-second basis. This removes the uncertainty that renewables introduce to the energy balancing equation.

"If you are a wires operator and get high concentrations of PV on the grid, like in Germany or California, and you have massive changes in demand from when the sun shines to when it is not shining, the entire distribution system has to pick up spikes in load. The system wasn't designed to do that," explains Young.

The same challenges arise with wind power. Variability factors have led to significant price increases in ancillary services, such as the spinning reserves needed to stabilize the grid with traditional generation.

If one wind power source generates more energy than predicted and another generates less, a VPP will balance the two, resulting in a more accurate forecast.

Today's VPPs offer an ideal optimization platform for providing the supply and demand flexibility needed to accommodate the fast ramping needs of renewables, to balance wind and solar intermittency and to address corresponding supply forecast errors. For example, if one wind power source generates more energy than predicted and another generates less, a VPP will balance the two, resulting in a more accurate forecast. In addition, the wind power becomes a more reliable source of capacity in the market.

Often, utilities fire up large and less efficient power plants to grapple with small gaps in demand. They may deploy a 600-MW gas plant when only 5 MW is needed. With a virtual power plant, when the operator asks for 5 MW, the virtual plant will do two things. It will look for places to reduce load, so the system may not need all of the 5 MW. It will also look for places where it can self-generate electricity by discharging batteries, or dispatching hydropower, wind or solar facilities.

Moving beyond traditional demand response programs

When the wind stops blowing or clouds shade sunlight destined for PV panels, system operators need flexible and reliable resources that can come on line immediately. The need to handle shifting loads and over-generation requires more than just meeting demand peaks. Traditional demand response programs — with alerts that go out a day or several hours ahead — are simply unable to support the rapid response times needed to keep today's evolving grid stable and balanced. But VPPs can perform this critical function.

Unlike typical demand response programs, VPPs incorporate short-term load, distributed generation forecasting and aggregation capabilities. They perform near real-time shifting of commercial and residential net loads to provide the services needed by the grid. Under the control of a VPP, demand on the system can be optimized and tweaked automatically, making day-ahead call-outs a thing of the past.

Furthermore, VPPs do this without triggering by the utility or grid operator. VPPs can respond automatically based on grid signals or price signals. They achieve this without impacting or even being noticed by the customers from which DERs are being aggregated.

"What we are doing with virtual power plants is not shutting a bunch of stuff off, but using flexible capacity to move demand to another time, reducing the difference between base and peak load," says Young.

VPPs have the ability to go way beyond simple load curtailment and to leverage continuous communications and bi-directional control to deliver dispatchable grid support. As a result, aggregated DERs — orchestrated by VPPs with sub-second response speeds — are becoming the new demand response.

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– Eric Young, Enbala

Just as the grid is changing because of bi-directional electricity supply, demand management must change as well. The future of VPPs is likely the end of demand response as we know it today. Utilities and grid operators will benefit more by looking at VPPs — and also DERMS — to continuously and bi-directionally manage all the DERs connected to their electricity network.

Transforming peak demand management

Peak demand, when demand is at its most extreme, occurs only a small percentage of the time, but it's expensive to use load shedding and to build traditional generation plants that are rarely used but are available "just in case." In Australia, it's estimated that 10 percent of the network was constructed just for such infrequent peak demand occurrences. Not only is this hard on utility and customer pocketbooks, but also on the environment.

VPPs can coordinate and control more efficient and clean sources of distributed energy so there's no need to over build or fire up wasteful fossil-fuel plants to balance electric demand and supply.

A VPP can automatically detect that capacity is needed on the grid. Or it may be fed an automatic generation control signal that indicates the utility needs a certain amount of capacity at a certain point in time. The system can then go get that capacity within the bounds of what is currently available, at a specified confidence range, such as 2 MW with 95 percent confidence or 3 MW at 70 percent confidence.

The capacity available to the VPP is based on a variety of factors such as the assets that are under the system's control, the time of day, and the historical usage of those assets at that time of day. Advanced learning algorithms, which search for regularities in great masses of data, can create a predictive model of grid electricity usage by consumers and businesses. This allows the VPP to better allocate resources and more accurately anticipate electric demand.

Mitigating the operational reserve challenges

The high reliability of the power grid is based on maintaining sufficient operational reserves. Historically, these reserves have been almost exclusively maintained in the form of traditional generation. Much like the peak demand scenario, this leads to the construction of costly, carbon-emitting plants that are rarely or perhaps never used. VPPs provide a mechanism for changing this paradigm.

A VPP can quickly ramp to maintain balance and avoid more costly spinning reserves. This reduces the quantity and duration of spinning assets required. The fast-acting, non-impactful response an advanced VPP provides gives system operators the confidence they need to depend on unconventional operational reserves. VPPs can simultaneously prevent participation fatigue that is all too common with existing demand response programs. This is a key point of differentiation between VPPs and demand response. VPPs operationalize the use of DERs for direct support of the grid, as determined by the system operator. Demand response participants drop out at a fairly predictable, and quite measureable, rate as the calls become more frequent. On the other hand, a VPP uses the flexibility of the entire fleet to modulate participation in a way that does not impact process or comfort, making it "always on."

DERs aggregated and controlled by a VPP can provide operational reserves when they are needed, while also enabling much greater customer participation in ancillary grid services markets. By linking DERs to markets, VPPs provide real-time operational reserves that can be bid into ancillary markets. This provides an economic return for the participant, along with the ability, based on situational awareness, to instantly adapt to changing grid situations.

Energy arbitrage market bidding

As alluded to in the previous section, VPPs have both operational benefits and energy market benefits. Acting as an intermediary between DERs and the market, the VPP aggregates diverse and heterogeneous DERs, with the purpose of trading energy on behalf of DER owners who would otherwise not be able to participate in energy markets on their own. As a result, VPPs have the added value of meeting their end-customers' demand for services that help monetize the capacity of DERs.

In other words, the VPP acts as an arbitrageur between diverse energy trading floors. The VPP can potentially remove the need for additional physical power plants by making a whole energy system more efficient, especially in competitive power markets. This creates a positive impact for every ratepayer served by the system that employs a VPP because the VPP reduces the delta between base and peak loads. The higher confidence that grid planners and operators have in shrinking this gap — and increasing the system's capacity factor — the greater the capital efficiency that can be achieved. Rather than throwing money at the problem, VPP software takes advantage of the unique characteristic of each asset to provide services that were incomprehensible just five years ago and does so in near real time.

With a virtual power plant, the customer stays in control. The flexibility and ease of program participation make most customers highly amenable and loyal to the program. More than a give-and-take exchange, the VPP is a partnership between power suppliers and the consumers they serve. "Because local demand adjustments are rarely, if ever, felt locally," says Young, "participants commonly approach the VPP operator to inquire how they can offer even greater flexibility and contribution to the service." The premise of being present but not felt is core to a VPP's success, given that it may be called upon often, without notice, any time of the year.

Conclusion

What if, instead of building new peaker plants, the industry could meet our energy needs by making hundreds or thousands of DERs work together to create VPPs?

What if we could create a VPP-driven "Internet of Energy" — a web of inter-connected solar panels, battery storage, wind farms, combined heat and power units, flexible process loads, fly wheels and other energy resources — that can be flexibly and reliably dispatched as needed?

This is the future when it comes to making the most of DERs and keeping the world's power grids in balance. This is the reason Navigant predicts that VPP spending will reach $2.1 billion a year by 2025. VPPs — coming soon to a utility near you.

Part III:
DERMS: Next Generation Grid Management

DERMs are essential to today's new generation of grid control and optimization. These state-of-the-art systems seamlessly integrate high penetrations of solar energy and other distributed energy resources into the grid. When properly deployed, DERMS' capabilities provide multiple benefits to both utilities and their customers, a win-win.

DERMS consist of a suite of software management tools that allow distribution utilities and wire operators to manage a wide array of DERs through near real-time control of grid assets. Navigant Research defines DERMS as "a control system that enables optimized control of the grid and DERs, including capabilities such as Volt/VAR optimization (VVO), power quality management and the coordination of DER dispatch to support operational needs."

DERMS-controlled grid services are delivered by manipulating power and voltage along individual feeders, giving the utility precise control of a wide range of equipment, including smart inverters, capacitor banks, on-load tap changers, voltage regulators (VRegs) and customer loads.

DERMS use a real-time communications infrastructure to monitor, control, coordinate and manage distributed energy assets connected to the utility at the local level. DERMS-controlled grid services are delivered by manipulating power and voltage along individual feeders, giving the utility precise control of a wide range of equipment, including smart inverters, capacitor banks, on-load tap changers, voltage regulators (VRegs) and customer loads. This contrasts with VPPs, which also control the active power contributions of DERs but at a broader, system-wide level. VPPs are used to provide grid services such as demand response, frequency regulation and operational reserves. These are services that require increased or decreased generation or load, rather than precise, local-level control.

Managing grid events locally

"Because a DERMS knows exactly where every asset is located on the distribution system, it can precisely target specific assets of the distribution system," explains Young.

"For example," he continues, "this allows the DERMS to control devices down-line of specified transformers or measured points on feeder lines so that when a utility experiences challenges with too many renewables coming online, the system knows exactly which assets to control to mitigate associated problems."

These assets might include smart inverters or more traditional utility control equipment. This location-driven focus allows the DERMS to exercise a high degree of control over both real power (watts), voltage and reactive power (VARs). Operators can increase load on one part of a feeder while decreasing load (or increasing distributed supply) on another part of the same feeder. Utilizing DERMS, utilities and wire operators can also bias the reactive power of DERs to manage voltage or regulate distribution feeder voltage profiles.

DERMS reap advantages by teaming up with devices such as smart inverters to protect the grid feeder systems. For example, too much solar on the grid can cause voltage problems. To address this challenge, DERMS can sense this is happening and control real-time voltage signatures and power flows on a distribution feeder to regulate grid conditions, preventing voltage excursions, brownouts and power outages. DERMS can dynamically control a variety of settings on smart inverters, which optimize the voltage and phase angle at the inverter's terminals, resulting in better line voltage regulation and decreased technical losses throughout the distribution system.

Greater grid flexibility and resiliency

The ability of DERMS to manage large numbers of distributed assets can lead to a more flexible and resilient grid. This is especially important as more renewable energy sources come online. For example, voltage fluctuations that result from the high variability of PV can be effectively dealt with by optimizing DERs, including client loads, on the grid.

DERMS balance the grid by using advanced optimization algorithms that can compute the most efficient usage of each grid asset. To do this, DERMS utilize data obtained from DERMS-enabled devices, smart metering infrastructure and other distribution grid sensors. By sending control signals, DERMS will adjust, turn on or off the devices connected to the DERMS network, including behind-the-meter resources, such as on-site generators and batteries. The systems can even efficiently regulate client assets. These might be chillers, fans, lights or other assets able to both cut costs for the customer and optimize the operation of the entire distribution network.

In conjunction with a distributed management system, DERMS will automatically control all the devices along a feeder line, including customer loads and utility equipment, to achieve this goal for peak energy savings.

The DERMS platform can monitor and control tens of thousands of devices, including battery storage, PV and utility control equipment in order to support the power requirements of the grid. For example, to support volt/VAR control, a utility only needs to request a nominal voltage/VAR flow along a feeder. In conjunction with a distributed management system, DERMS will automatically control all the devices along a feeder line, including customer loads and utility equipment, to achieve this goal for peak energy savings.

"Let's say the utility operator needs to urgently relieve congestion on a key part of the distribution system," explains Young. "The DERMS will assess the capability of each controllable device on the line, taking into consideration the operational constraints and requirements that have been specified by the asset owner to identify the best solution to alleviate that specific point of congestion."

"It is important to note that these constraints can include limits on heating, air conditioning and hot water temperature changes for loads, cycling requirements of batteries and other assets, as well as technical and economic limits of other distributed options, to name a few," he adds.

All of this is completely transparent to clients, who will not notice the control exerted over their devices. It's also transparent to the utility; DERMS aggregate the responses from all the devices so that the utility sees only a single dispatchable resource moving automatically based on grid conditions.

If the assets are not owned by the managing entity, then compensation may need to be provided to the owner.

While a VPP is a specialized system that enables always-on, highly scalable, cost optimized, secure and automated services into a wholesale market product for regulation or capacity, DERMS allow medium and low voltage utility-operators to utilize DERs and IoT technology within their very local paradigm to drive optimization capabilities that simply cannot scale to even the most modern advanced distribution management systems.

DERMS Benefits

- Utilizing DERs to eliminate load congestion points local to a distribution feeder, even if more than one point is constrained on the same feeder
- Managing load to prevent a reverse power flow condition attempting to drive the substation transformer(s)
- Using reactive power-capable assets to perform legacy functions. These range from conservation voltage reduction, where short term peak reductions can be realized, all the way to determining and operating the system at an optimum voltage to reduce the technical losses in the distribution system that were previously unavoidable.

Regulatory challenges to DERMS

DERMS are highly scalable systems that will be employed by a utility to control DER assets coupled to their distribution systems. The assets under DERMS control can be utility owned, supplier owned or privately owned. If the assets are not owned by the managing entity, then compensation may need to be provided to the owner. Under current systems, the amount and method of compensation is not yet being set by a market product, which leaves an ad-hoc process, if any, to ensure the usage of these assets when called upon.

In the near future, several regulatory challenges that currently hinder the widespread usage of DERMS are likely to be resolved. For example, today no established markets or pricing mechanisms exist for reactive power at the distribution level, so no means exist to compensate the owners of the assets. Additionally, some states do not allow distribution utilities to have any control over power generation or power export capable systems such as batteries or privately owned solar and wind turbines. This prevents utilities from taking advantage of the full capabilities contained within DERMS. (See Part V for more on regulation.)

In addition to regulatory obstacles, there are also technical challenges facing the implementation of DERMS by utilities and grid operators. For example, to unlock all the benefits of DERMS, a fairly accurate representation of the distribution system is required, including how and where loads and DERs are connected. In addition, a method to supply more sophisticated telemetry may be required that can quickly inform the software of problems or issues with the grid. So, to properly implement DERMS within their distribution networks, utilities may need to make new infrastructure investments, mostly in sensing but also perhaps other equipment. In the simplest case, utilities can employ a less detailed grid representation, which would allow them to implement VPPs now. This would also enable DERMS deployment as other projects drive the creation of a phase-representative grid model (and supporting systems) to ensure it stays in sync with the actual grid.

Going green with DERMS

The same fundamental technology that allows us to order a ride via smart phone — from where we are to where we need to go — can be leveraged to build a more efficient, reliable and resilient electrical grid. Utilities, regulatory agencies, and grid operators can embrace wireless communications, cellular, and technologies such as DERMS to overcome the inefficiencies of today's power grid.

"With DERMS and other resources in action, the next-generation grid will be able to seamlessly support magnitudes greater renewable and distributed energy sources, while harnessing the unnoticed flexibility in the demand side of the system," says Young. "This will enable not only a cleaner, but a sustainable energy future."

Part IV:

How DERMS and Smart Inverters Safely Bring Distributed Resources to the Grid

As use of renewable energy grows, grid management becomes more complex for utilities and grid operators.

The same inverters that are required to export renewables onto the grid are also the key to protecting the grid's feeder lines, ensuring the uninterrupted flow of electricity when used within the context of grid reliability needs, without driving the need for excess fossil reserves.

The problem with traditional inverters

Inverters are necessary to convert DC voltage from solar panels and other sources of renewable energy, such as asynchronous wind turbines, to AC grid voltage. However, legacy inverters lack the flexibility to manage large penetrations of renewable energy and ensure system reliability.

For example, most legacy inverters autonomously disconnect from the grid at specified frequencies or voltages. IEEE 1547 requires full disconnect at nominal voltage +/- 10 percent for excursions longer than two seconds.

If there is a sag or spike in voltage that reaches this threshold — caused by rapid changes in renewable solar photovoltaic output — the inverter will cut off, potentially exacerbating the voltage excursion even further on the system. This may also look like a fault to the protection equipment installed on the feeder or can lead to voltage collapse, both resulting in systemic power outages.

The versatility of smart inverters

Smart inverters can prevent these problems. They can be managed so that they continue to allow power to flow when traditional inverters would shut off. Smart inverters are remotely programmable devices that allow precise control of ramp rates, outputs and inputs of the converter. Their thresholds are adjustable, which means they won't just cut out in the way traditional inverters would.

Smart inverters not only regulate line voltage, but also allow for two-way communication with utility control centers. In addition, advanced capabilities such as

frequency and voltage sensing mechanisms allow smart inverters to detect grid abnormalities and send this information back to utility operators. Smart inverters can also operate under a variety of situations, including when a battery is being charged or solar energy is offered to the grid.

"We are now able to sense in real-time voltage signature and power flows on a distribution feeder — and control smart inverters to regulate conditions to support the grid," says Young.

The combined power of DERMS and smart inverters

When connected to DERMS, smart inverters can respond to signals from the utility to stabilize the grid. DERMS can, in real time, reprogram the smart inverter so that the inverter can optimally respond to events on the grid, such as the aggregate generation of significant amounts of solar energy on a specific distribution circuit.

Operators can use DERMS to exercise this control remotely without overloading the same operators with the detailed data produced from tens of thousands of individual units.

Combining DERMS and smart inverters is a powerful way to protect feeder systems on the power grid, dramatically reducing the risk of voltage collapse, blackouts and brownouts. The ability to manage smart inverters remotely can allow utility operators to control solar installations as they would traditional fossil-power plants, regulating electricity generation based on the real-time energy demand of customers in an elegant, optimized and resilient way.

Smart inverters and DERMS can react quickly

DERMS can precisely control today's smart inverters and enable the utility operator to tailor them for specific grid conditions. If it is apparent that an event will occur on the grid — such as cloud cover approaching a PV installation that will lead to a sag in voltage — an operator can adjust the threshold at which the inverter drops due to a low voltage condition. In this way, the solar PV, which is attached to the inverter, can still be producing energy and supporting the voltage on the grid while the inverter prevents the voltage from dropping further. With less sophisticated, earlier inverter technology, when thresholds are reached, everything is shut off, further dropping the grid voltage.

Under DERMS control, smart inverters can also dynamically regulate the power factor on local distribution lines, which helps to maintain line voltage. Utilized this way, the reactive power capability of smart inverters is intelligently used to support the voltage on the power system, reducing losses and allowing more renewable energy to be supported on a given line segment or distribution feeder. The old adage, "reactive power does not travel well," has been widely understood for decades.

DERMS can provide voltage ride-through that helps keep solar generators connected to the grid during times of low-grid voltage, while triggering charging actions when solar production is exceeding demand — all in one system.

However, as our new loads and even historically resistive loads are now increasingly not just resistive anymore, we ask these VARs to be road warriors. This is increasingly inefficient. DERMS utilize smart inverters to keep reactive power "home," reducing its need to "travel."

Additional smart inverter functions, which can be controlled by DERMS, include active power curtailment to help balance power generation and load. In addition, DERMS can provide voltage ride-through that helps keep solar generators connected to the grid during times of low-grid voltage, while triggering charging actions when solar production is exceeding demand — all in one system.

When connected to DERMS, smart inverters can respond to signals from the utility to stabilize the grid.

Flexibility is key to responding to variable renewable energy

Flexible smart inverters are key to maintaining grid stability in the presence of highly variable renewable energy sources such as PV. Smart inverters are crucial to bringing more DERs safely to the grid. This technology can allay worries that the variability of new sources of electricity will disrupt utility services.

Young concludes, "When paired with DERMS, smart inverters respond with speed, intelligence and flexibility at the local level." This is just what's needed to solve the difficult challenges faced by utilities and grid operators as they strive to smoothly integrate a quickly growing supply of renewable energy attached to their systems.

Part V:
Smoothing the Path for DER Orchestration: New Rules for a New World

The impact of DERs on the electric grid is real and growing, fueled by two converging factors. Forward-thinking utilities are seeking to leverage DERs to better meet their grid balancing needs and also to generate new sources of revenue. And consumers and businesses want to save money, exercise greater control over their energy use and minimize their carbon impact.

The desire and need for DERs are well-documented; the challenge is how utilities, vendors and regulators can best deal with the shift from relying on centralized power plants to including a healthy mix of distributed resources.

"Wire operators and utilities are faced with the problem of how to bring renewable energy and other DERs into the existing power grid, and manage these resources so they support the grid, rather than burden it," says Young.

Technology has far outpaced utility rules and regulations

Modern VPPs and DERMS provide the control and management technology needed to seamlessly integrate distributed energy assets into the existing grid.

But in order for DERs to truly meet their potential in modern energy markets and the changing economics of electricity, regulatory and market obstacles need to be overcome. These stand in the way of utilities looking to maximize their DER investments. While DERMS and VPPs can efficiently manage the increasing amount of distributed energy online, these barriers prevent VPPs and DERMS from being optimally used by utilities and wire operators.

Current rules and regulations reflect the central power plant model of the last century's grid. These rules and regulations were set up for utility management of centralized power plants — rather than distributed resources — and reflect the technology of the 1960s to 1990s, not current capabilities.

Operating the distribution grid under these outdated regulations is like being forced to use a cassette tape in a Walkman to listen to your favorite music when digital technology can now instantly stream your personalized playlist to your smart phone, on demand. Regulators and policymakers must change current rules and regulations to fit the new technologies. Here are some examples of current regulations that are in need of reform:

DER interconnection standards

IEEE 1547 defines DER interconnection standards. It's out-of-date and currently undergoing reform, but most states have not adopted any modernized/revised standards. This prevents smart inverters from being deployed at scale and used for voltage/frequency support. In fact, most states require inverters to "autonomously disconnect" in the event of voltage or frequency excursions. When a large number of DERs suddenly go offline at the same time, it further deteriorates grid operations.

Battery safety regulations

Battery safety regulations can add significant delays and expenses for stationary storage projects. This is particularly true for lithium-ion energy storage projects in New York City, where there are extensive water and ventilation requirements. Every project must apply for approval by the New York Fire Department on a site-by-site basis. Consistent and repeatable guidelines are in the works — and badly needed.

Utility ratemaking regulation

Traditional utility ratemaking regulation creates incentives for utilities to build new peaker plants, for which capital expenditures can be recovered through rates. This discourages utilities from meeting resource needs through advanced DER management, even though DERs may ultimately prove less costly.

Regulation updates

On the plus side, significant advances are being made to update regulations, among them mandates that require regulated utilities to consider non-wires alternatives (NWA) to conventional infrastructure. Leaders in promoting NWAs include New York and California.

Plug-in electric cars, rooftop solar systems and battery storage are often sitting idle when they could be earning money serving the needs of the grid.

Opportunities to take advantage of underutilized energy resources

"Utilities and grid operators have many opportunities to become network orchestrators and take advantage of distributed energy resources that might otherwise be wasted," says Young.

Plug-in electric cars, rooftop solar systems and battery storage are often sitting idle when they could be earning money serving the needs of the grid.

However, once again, policy stands in the way. For example, while behind-the-meter assets in a home can be controlled, few markets compensate the residential utility customer for providing demand response. Therefore, these assets remain under-utilized.

Taking advantage of capacity markets

Additional opportunities exist for utilities to utilize distributed assets in capacity markets. Leveraging VPPs and DERMS, utilities and grid operators can exercise real-time automated control over these resources and bid them into markets such as ancillary services, demand response programs and frequency regulation.

The boundaries between the regulated side of distribution and the non-regulated side of capacity markets are blurring. Ideally, the same asset could be used in both places and stay true to the regulatory model. However, current regulations do not provide a clear path for this to be accomplished. This is another example of how current rules and regulations need to be modernized so that new technical advances can be employed to their full extent.

Further, regulators in many regions don't allow utilities to control any generation assets, including distributed generation. If utilities have capacity problems on the network, such as rapid PV penetration, they can't manage this even though the distributed resources are connected to their systems.

Getting personal with the grid

In addition to regulatory hurdles, utilities and grid operators face some technical challenges when it comes to optimal DER utilization. On the DERMS side of the equation, where grid services are delivered by manipulating real and reactive power flows along individual feeders, effectiveness is highly dependent on the specific location and grid connection of each asset. "This requires a fairly accurate representation of the distribution system, including reasonable latencies, and with a fair amount of transparency," says Young.

With an accurate distribution system representation, utilities can address problems quickly and effectively. For example, if a transformer is overloaded, operators shouldn't continue to increase its load, and if it's under loaded, operators should carefully manage higher percentages of intermittent sources as opposed to total load. By knowing the grid topology — the ways wires are built out through a neighborhood — operators know how the transformer is going to be affected by both planned and unplanned changes within in its geo-spatial regime. They can then up- or down-regulate the assets feeding that transformer and make logical decisions based on this information.

Utilities can use a geographical information system in conjunction with a Distribution Management System (DMS) to obtain information about grid topology.

Utilities can use a geographical information system in conjunction with a Distribution Management System (DMS) to obtain information about grid topology. They can then add DERMS, which interface with these systems and function as a "brain" that optimizes and coordinates a very disparate set of distributed devices and assets.

Shifting to a renewable-friendly grid

The tools — including VPPs and DERMS — that utilities need to compete globally and shift to a more sustainable and responsible operating environment are available today. More and more utilities have the vision and commitment to adopt these new technologies. Now what's needed to truly unlock the power of these innovative technologies are new policies and regulations that allow markets to form so that the technologies developed can be effectively utilized.

Utilities and wire operators are in an excellent position to harness these technologies and play a central role in shaping the next generation power grid. When this happens, no longer will our energy markets be restricted by technology as outdated as a Walkman.

Part VI:
Blazing the Path from VPPs to Holistic Grid Control with DERMS

For utilities that see an increasing amount of DERs connected to their grids, what is the best strategy to most effectively manage these new energy resources? Software management systems, including VPPs and DERMS, allow real-time control of these resources to balance both electricity generation and demand on the power grid. But there are important differences in how these two platforms aggregate and control distributed grid resources. “While DERMS provide the highest degree of grid control, regulatory and technical challenges may make it difficult for utilities to transition to these systems all at once, especially where a market-based compensation is mandated,” says Young. For this reason, VPPs provide a logical first step in the management of distributed resources.

VPPs can perform a variety of functions, such as system-wide calls for increased/decreased generation or load shedding, energy trading, capacity relief, frequency regulation, replacement reserves and ancillary services.

Virtual power plants provide entry into the world of network orchestration

VPPs typically provide benefits to the grid by aggregating assets over an entire region or service territory. For example, the wide collection of generation resources in a VPP can be aggregated and presented to the utility or grid operator as one dispatchable resource. VPPs can perform a variety of functions, such as system-wide calls for increased/decreased generation or load shedding, energy trading, capacity relief, frequency regulation, replacement reserves and ancillary services. These functions are not dependent on the location of particular grid assets such as transformers or feeder lines.

“VPPs make use of existing energy markets for signals, whether via automatic generation control or price signals, and are very easily integrated to new market constructs where the durations of events are growing and/or notification time decreasing (or absent),” says Young.

The difference with DERMS

In contrast to VPPs, DERMS are much more location-based, and are crucial when the utility needs to fully integrate distributed resources into the electrical distribution system. The DERMS software can simultaneously manage thousands of assets on different parts of the distribution system based on local conditions to those assets. In this way, the utility knows exactly which assets have been controlled to address problems throughout the distribution network. A VPP does not provide this fine-grain control of the grid; it doesn’t have this degree of granularity. With DERMS, the utility knows exactly where each asset is located — on which specific transformer or feeder. When there’s a grid event, the utility’s DERMS can mitigate problems by controlling devices, such as smart inverters, as well as more traditional distribution control equipment.

Voltage profiles on feeders can be easily managed with DERMS since these systems can increase load on one part of a feeder while decreasing load (increasing generation) on another part of the same feeder.

The DERMS can perform advanced operations such as distribution system optimization, coordinated resource utilization and voltage and power management. In short, a DERMS platform is the ultimate step toward the holistic control of grid resources.

It’s important to recognize, however, that DERMS require larger up-front costs. Utilities may need to install telemetry equipment and integrate the DERMS with DMS. The DMS provides information about grid assets and their topology and, combined with DERMS, gives utilities and grid operators unprecedented control over the power grid.

With DERMS, the utility can manage both real power (watts) and reactive power (VARs) on the distribution lines. Voltage profiles on feeders can be easily managed with DERMS since these systems can increase load on one part of a feeder while decreasing load (increasing generation) on another part of the same feeder. They can also bias the reactive power of DER to manage voltage. This advanced control of the distribution network is not possible with VPPs.

Making a smooth transition from VPPs to DERMS

From a regulatory and technical standpoint, VPPs are significantly easier to implement than DERMS. Therefore, VPPs are typically the first step for a utility to begin managing increasing numbers of DERs on the grid. For example, to begin unlocking the benefits of DERMS, utilities need a fairly accurate representation of the distribution system, including the location of all assets and how they are interconnected within the feeder lines. However, utilities can use a less detailed grid representation as the foundation to begin the VPP-to-DERMS path.

> *By managing demand response with the VPP, operators can begin to not only utilize, but trust, the capabilities of the VPP.*

How can utilities best begin thinking about using VPPs in their existing markets?

"As a first step, they can enter wholesale capacity markets. Historically the wholesale operations [unregulated] and the distribution operations [regulated] parts of a utility rarely mix," says Young.

By managing demand response with the VPP, operators can begin to not only utilize, but trust, the capabilities of the VPP. Traditional demand response, including customer load shedding, can be effective but has limited capacity to regulate the grid. VPPs can be applied to demand response markets to allow the grid to shed load and increase generation in an automated way through active control systems.

If DERMS becomes necessary when grid systems can no longer appropriately manage power and current from large numbers of DERs, the operator can start from a place of confidence in the technology that enables the DER control. This may also help utilities recognize the need for DERMS before they begin scrambling to find a solution to unexpected growth.

The best approach for utilities is to take incremental steps in adopting a DERMS platform. Utilities don't need to make this transition all at once. Making the transition is like buying products with a minimum of features, becoming familiar with their operation, then adding capabilities to improve performance.

"Utilities can convert VPP assets to a DERMS platform down the road and use them as regulations change and new markets open up," says Young. For example, depending on the direction of the regulatory market, utilities will be able to use VPP assets for DERMS when they need them, and when they don't, utilize them in the capacity market.

This phased approach provides utilities with a viable path from VPPs to DERMS that has high value and low initial investment costs. The process begins when an asset is initially brought into a VPP. At this time, certain parameters and capabilities are configured. At a later time, when the utility decides to enable the asset within the DERMS platform, the asset enablement and configuration is already waiting. This allows the DERMS project to carry lower economic risk. The existing asset base is a strong indicator of the value the DERMS can provide in both the near- and long-term.

Without a VPP, building and running DERMS is still possible, but the commissioning and enablement costs may be larger at the start of the project than if a VPP were already in place, and the overall project risk may be greater until confidence and experience with the technology increases within utility walls.

VPPs provide the ideal foundation for utilities to gain experience with managing and optimizing the increasing amount of DERs coming onto the electrical grid. The migration path from VPPs to DERMS provides a logical and balanced approach for utilities to gain greater control of new distributed energy resources such as solar, wind and battery storage, which are transforming power networks.