Unlocking New Value Streams with Multi-Asset Virtual Power Plants

INTRODUCTION

For decades utilities have used demand response (DR) and distributed energy resources (DERs) to reduce peak demand, reduce coincident peaks, manage circuit-specific issues, and support the grid during emergencies. In this new energy economy, virtual power plants (VPPs) enable energy companies to integrate multi-asset DERs into wholesale markets. This strategic shift from offense to defense opens opportunities for additional value streams, greater flexibility, better reserve margins, and reduced emissions.

This whitepaper details how VPP platforms seamlessly orchestrate disparate DERs into single dispatchable resources, covering:

How each resource* type deploys into the market

The pricing strategy for each resource type

Creating resource stack for optimal economic dispatch

Integrating constraints into the resource stack

Automating the re-creation of the resource stack to enable daily or hourly adjustment

---

** In this paper, the term resources is a collective reference to specific types of DERs and DR included in this systematic analysis. However, the types are a highly diverse, heterogeneous set of technologies and capabilities. Further, the electric market these resources will be dispatched into is assumed to be a modern Locational Marginal Price (LMP) market with both energy and ancillary services, and pricing based on Market Clearing Price.*

1. How each resource type deploys into the market

VPP resources are varied, both in size and capability, and each has a different value proposition to the market (see definitions of energy and capacity products in the appendix). Here are several DER types to consider:

Residential HVAC thermostat programs

A utility can signal thousands of thermostats to increase the temperature by three to five degrees during hot summer periods. This reduces demand on the grid by switching off scores of energy-hungry A/C compressors, reducing load almost immediately. However, on really hot days, these homes will simply heat up and the A/C units will switch back on in a half hour or so to maintain the higher setpoint. Operators have developed approaches to leverage this capability; if a large reduction is needed at one time, the entire fleet is deployed. If longer duration load reduction is needed, portions of this fleet are cycled sequentially and deployed every 15 minutes. The residential thermostat program is both a short-term **capacity product** and a short-term **energy product.**

Commercial DR programs

Many large commercial customers can reduce lighting, HVAC, and other loads for specific durations at the command of the utility. These actions are either manually initiated or through an automated signal. This capability is also a **capacity product** and an **energy product**, though limited by contract terms; for example, the customer may not wish to be deployed more than 10 times per month or on sequential days, etc.

Industrial customers able to shift production

Industrial customers have the capability to shut down specific equipment quickly when called upon. If capable to do so within a 10-minute time frame from receipt of notification, this capability can be a **grid product (responsive reserve)**, in addition to **capacity** and **energy**.

Residential energy storage systems

This is probably the fastest-growing category of DERs. Because of their flexibility and robustness, these can be aggregated and offered into the market for **responsive reserves** and frequency regulation, for energy, and for capacity.

Distribution-level storage

Energy storage facilities on the distribution system originally constructed as non-wires alternative to circuit upgrades can be marketed as the grid products **responsive reserves and frequency regulation**, for **energy**, and for **capacity**.

Backup generation

Customers have backup generators that can be started at a moment's notice and contracted to remotely deploy these units for coincident peak reduction, and emergencies. This backup generation can be marketed as **responsive reserves, energy, and capacity**. This segmentation of the types and capabilities of the resources helps to classify what aspect of the market each will participate in, and documents any operational constraints present. It should be noted that backup generators are typically fossil fueled, and so are not as clean an alternative as other resources. This aspect could impact its long-term value in the market, return on investment, etc.

2. The pricing strategy for each resource type

Capacity

Capacity is generally procured in advance of the real-time market to bolster reserve margin, protect a sales position and for other reasons. In some regional markets, a capacity market exists, but this is not uniform in all markets. The VPP will deploy capacity that is available to it on an hour-by-hour and day-by-day basis. Capacity's value, therefore, is that it's a "reservation" of deployable energy, constrained by the specific attributes of the resource. If the energy is flexible and low-cost, then the capacity value is higher, and vice versa. Good benchmarks for valuing capacity are the aforementioned capacity market, as well as market quotes for call options, as well as other statistical methods that have been developed for that purpose. What's important about capacity is once it's procured, it enables the resource to deploy energy or reserves on its own merits and cost structure.

Energy

The chief consideration when arriving at a price for the energy available by the VPP (defined as the demand reduction from the DR and energy produced by DERs) is the following question:

What price must the market reach before I'm willing to deploy that resource, knowing its limited duration, and the fact that it may not be available later? In other words, what is the opportunity cost of deploying now versus later?

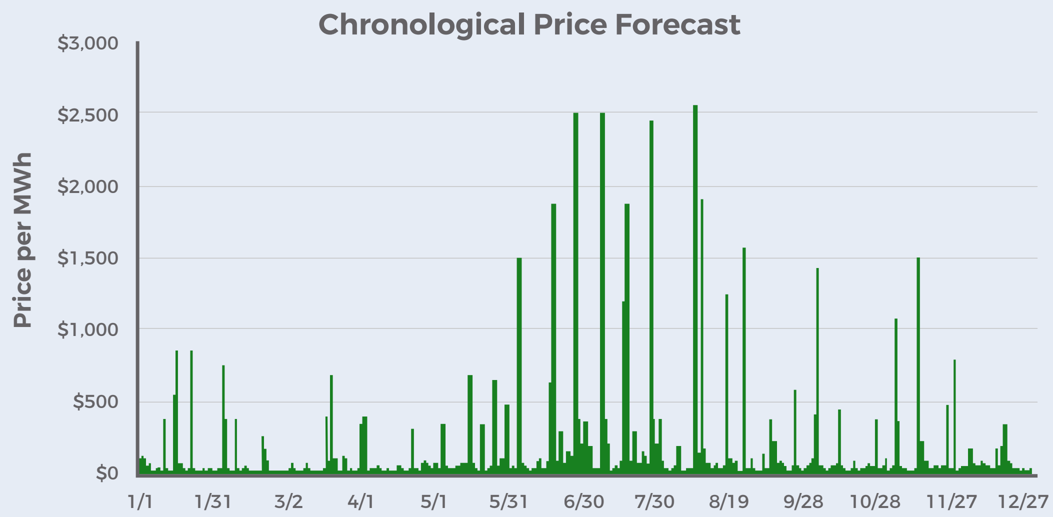
Obviously, the threshold price should at least compensate the company for the lost sales of energy during the deployment. Above that, the pricing should reflect either the marginal cost for deployment (for energy storage and backup generation resources), or a market analysis of scarcity (for DR resources).

Output limitations

Certain backup generators are hours-limited, and can only be used for a limited amount of time each year when not actively backing up a facility during an outage. These limits can be based on air emissions permits, warranty provisions, or other reasons. Energy storage resources (batteries) may be limited by the number of design cycles per year. As a result, if not carefully monitored, a unit could be dispatched profitably (based on market conditions) for long stretches at the beginning of any given year, only to reach its limit and miss out on lucrative market conditions later in the year.

Scarcity pricing method

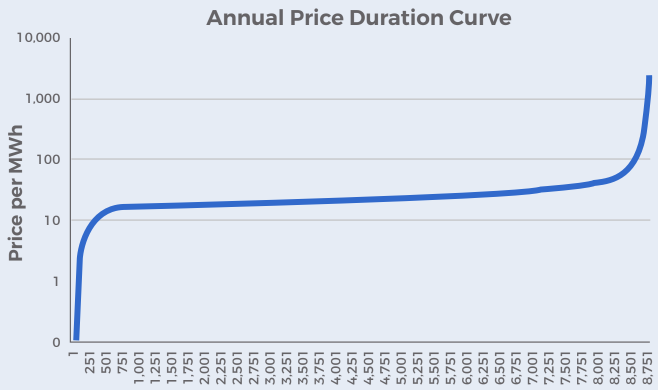
There are several approaches to pricing DR and DERs into the market, including Marginal Cost Dispatch and Option Value Analysis. This paper, however, will offer a simplified method in which the offer prices position the underlying assets to deploy at optimal points during market scarcity events. For this, a price forecast must be developed to estimate scarcity-induced high prices, and when the unit can capture the most value in any calendar year.

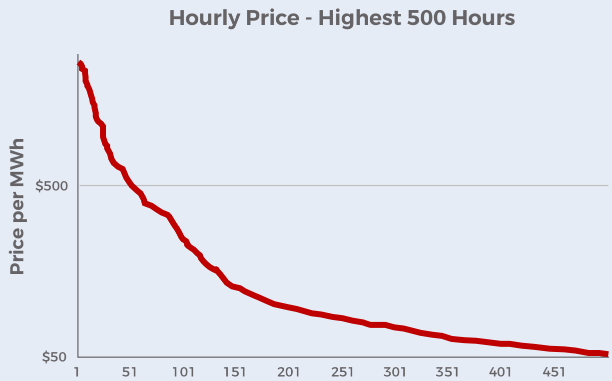


Chronological Price Forecast, by hour, for the entire calendar year. Periods of high prices (scarcity) correspond with the peak usage across summer months.

For example, if a unit can only run 500 hours per year (which is 500/8760, or 5.7% of the year) then an analysis of a price forecast can pinpoint the threshold price to offer the unit such that it will most likely capture the top 500 highest priced hours of the year. To do this, a price duration curve is developed by sorting the prices in the chronological (daily and hourly) price forecast low to high. The high-priced end of the resulting curve is analyzed to draw the pricing threshold.

The annual price duration curve on the next page, clearly shows the average region of prices (roughly $20-$50/MWh), but also the "tails," at the high and low ends. There are periods of extremely low prices as well as high-priced hours. Focusing on the highest 500 hours of the year enables analysis of the extent and duration of market scarcity. Both graphs are on a logarithmic scale for clarity.





On the above chart, we see the top 500 hours of this price duration curve are above approximately $50/MWh. Offering a unit to deploy at this price allows one a chance to fully utilize the available hours.

Granted, this is only a forecast of the price. Actual prices will certainly be different, but this can be a starting point. The actual deployment of the resource throughout the year, plus actual pricing experienced in the real-time market must be monitored, and plans should adjust to fit real-world trends.

Market analysis for thermostat programs and other DR

Thermostat programs may have even more limited availability than backup generators. Most residential customers will tolerate the utility company's temperature setback during times of genuine power emergencies or when voluntary conservation appeals have been made. Frequent use of this program has been shown to lead to "customer fatigue" and customers opting out of the programs. For these reasons, even more care should be taken in pricing this capability for the wholesale market.

If each deployment is for two hours, then the VPP should offer this capability into the market at such a price that it's only likely to be deployed at the highest-priced, 10 hours each month. Again, the price duration curve can point the way.

Commercial customers with contractual DR obligations can be analyzed in a similar way. The number of deployments could be explicitly agreed-upon in the contract. It's therefore useful to consult the price duration curve to arrive at an offer price that is likely to fully use this resource while reducing chances it will miss opportunities for profit.

Responsive reserve and frequency regulation

We have discussed energy and capacity pricing analysis for DR and DERs. Responsive Reserve Service (RRS) and Frequency Regulation (FR) are types of specific services (called Ancillary Services {AS}) procured each day by the grid operator to maintain the reliability of the system. Prices are set in a daily auction conducted by the regional grid operator, but they can also be bought and sold using bilateral contracts directly between sellers and utilities. Most energy storage resources can provide both services, and some backup generators can provide at least one of them. Even some curtailable load can sell RRS if it meets certain criteria.

An important feature of RRS is that when the particular resource has sold its resource capability to the market, this capability cannot participate in the energy market. Selling RRS is an opportunity because the resource can earn revenue during times when it wouldn't have been otherwise deployed for energy. It's a risk because once obligated, it could miss out on high-priced energy sales. The offer price for RRS must be carefully developed to earn revenue during times when the resource's energy is out of the money, but enable energy sales during times when it's in the money. This "co-optimization" of energy and AS is a crucial skill that successful energy companies have integrated into their daily operations.

FR is unlike RRS in that the backup generator or energy storage resource will receive constant signals to increase or decrease production in order to help manage system frequency. When the grid frequency falls below certain set points, a signal from the system operator calls for the resource to produce more energy, which helps to increase frequency back to the setpoint. This energy production is compensated for at the prevailing energy price (the "spot" price). When grid frequency climbs above desired setpoints, a signal from the system operator calls for resources to reduce output, helping to decrease frequency to the setpoint. This reduction in output settles in the market as if the resource has purchased the energy at the prevailing price. Upward deployment at high prices is good, although upward deployment at low prices may not cover the energy cost of the resource. Similarly, downward deployments when prices are high cause the resource to lose opportunity and indeed can cost money, and downward deployment at low prices is not as much of a risk. Once again, careful analysis of a resource's suitability to deploy frequency regulation is needed.

3. Creating resource stack for optimal economic dispatch

Next, an approach to building an integrated deployment strategy for the VPP is described here. How can the utility offer the combination of these resources to the grid such that its individual components are utilized economically and profitably for the utility, yet reflect all the capabilities a "real" power plant would confer to the grid?

The Three-Part Offer

A traditional power plant can signal its willingness to operate in the wholesale market by submitting a Three-Part Offer, or TPO. The TPO includes the Start-up Cost, the Minimum Energy Cost, and the Energy Offer Curve. This process is important to understand, but must then be adapted to be used for VPPs.

Start-up cost

Traditional thermal units require fuel to heat boilers, produce steam, and bring the generator online and synchronize with the grid. Including start-up costs allows the grid to choose between alternatives; it may be less expensive for the grid to continue to operate a higher-priced unit that's already online instead of paying for the start-up of a more efficient unit that's offline. Naturally, wind and solar resources have zero start-up costs. Most, but not all, VPP components will have zero start-up costs as well.

Minimum energy cost

Once a thermal generating unit is brought online and synchronized with the grid, what is the cost of operating the unit at its minimum load? (Once again, wind and solar resources generally have zero minimum energy costs.)

Energy offer curve

Once a thermal unit is online and at minimum load, at what price is it willing to throttle up to higher loads? Throughout the operating day, the Independent System Operator (ISO*) raises and lowers spot market prices to match supply and demand. As market supply tightens, the ISO raises prices. The increasing prices provide the incentive to resources to produce at higher output. The reverse also occurs; as loads decrease at nighttime, the ISO lowers prices, signaling resources to decrease output. Each resource must supply the ISO with bid pairs (MW/Price) in a monotonically increasing curve to signal the price points at which it is willing to increase or decrease output.

Like wind and solar resources, a portfolio of DR and DERs will generally have **no start-up or minimum energy costs**, so the focus of analysis will be the development of an Energy Offer Curve to position the individual elements of the portfolio for deployment in response to market prices.

Building an example energy offer curve for a VPP portfolio

Let's take an example VPP portfolio of the following components:

40 MW

Thermostat program involving many thousands of customers, capable of reducing aggregate load up to **40 MW**. Focus groups and customer surveys indicate they are willing to tolerate **five events per month** but do not like deployments on sequential days. The VPP software control platform can deploy and recall any or all of these thermostats through intuitive GUI screens in the control room.

20 MW

Commercial and industrial customers with an aggregate of **20 MW** of available DR. **25 deployments of two hours each have been contracted** for the summer season (June-September), which, once again, can be controlled by the VPP platform.

** There are different ISOs in different regions, such as the California ISO (CAISO), ERCOT in Texas, Midwest ISO (MISO) and so on. This is not the same as Regional Transmission Operators (RTOs), whose responsibility is focused on system reliability rather than energy dispatch. Note that each of these ISOs also falls under the jurisdiction of the Federal Energy Regulatory Commission (FERC) with the exception of ERCOT, which historically avoided federal oversight by not transmitting electricity service with neighboring states (absent a single direct current transmission line.) FERC jurisdiction is limited to the traditional alternating current (AC) grid transmission infrastructure network.*

10MW/ 20

The utility operates a **10 MW/20** MWh battery on the distribution system. Originally installed to avoid circuit upgrades, it can be controlled for both energy and ancillary services. Assume one charge/discharge cycle per day for each day May-September (122 deployments possible, up to 2 hours each).

5MW/ 2.5

The utility has approximately **5 MW/2.5** MWh of aggregated residential battery capacity it can access through its VPP software platform. Due to the size of the individual components of the aggregated resource, the strategy is to offer this resource no more than once per day as a **2.5 MWh asset for 2 hours each deployment.** Extending the reasoning from the distribution storage asset group, expect deployment each day May-September – 122 deployments. This capacity is essentially the same as the distribution-connected storage, so **the capacity is added to this category.**

10 MW

A group of commercial customers with an aggregate of **10 MW** of natural gas-fired backup generators capable of running up to 150 hours per year in non-emergency mode. Like the other assets, the availability, capacity, and status of each of these individual assets are visible in the utility's control room and deployable from the ISO control screen.

Resource stack – capacity

From this info, we now have a "resource stack," consisting of

- **10 MW** DERs capable of 150 hours of run time
- **12.5 MW** energy storage available for 122 deployments
- **20 MW** commercial DR available for 50 hours of deployment
- **40 MW** of thermostat programs available for 20 hours (five events per month for four summer months, 1 hour each event)

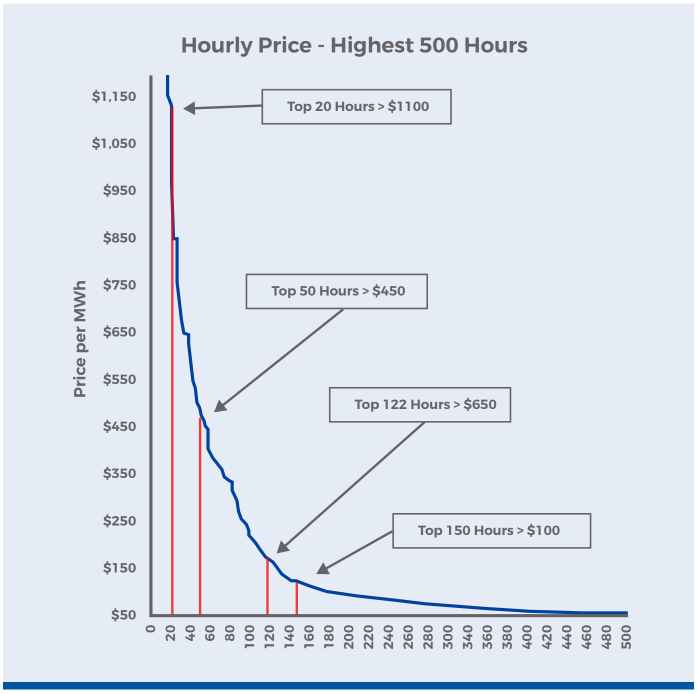
This is the capacity component of the Energy Offer Curve. Next, a price must be derived for each capacity level.

Pricing approach

To determine the pricing aspect, the deployment capacity listed above can be seen as an "inventory" of energy to be sold. With this in mind, the following guidelines are reasonable:

- The segments with the **smallest** inventory should be the **highest** priced
- The segments with the **largest** inventory should be the **lowest** priced

To determine the optimal pricing, at least at the outset of the season, let's suppose an hourly price forecast has been developed for the summer season (June through September). This has been transformed into a price duration curve with the following findings:



Our Energy Offer Curve can now take the following shape:

MW	Price	Resource	Rationale
40	$1,100	Thermostat program – initial offer	Top 20 hours threshold
20	$450	C&I DR program	Top 50 hours threshold
12.5	$160	Batteries in energy deployment mode	Top 122 hours threshold
10	$100	Commercial backup generators	Top 150 hours threshold

Yielding a Three Part Offer as such:

Start-up Cost	$0	
Minimum Energy Cost	$0	
Energy Offer Curve	**MW**	**Price**
	10	$100
	12.5	$160
	20	$450
	40	$1,100

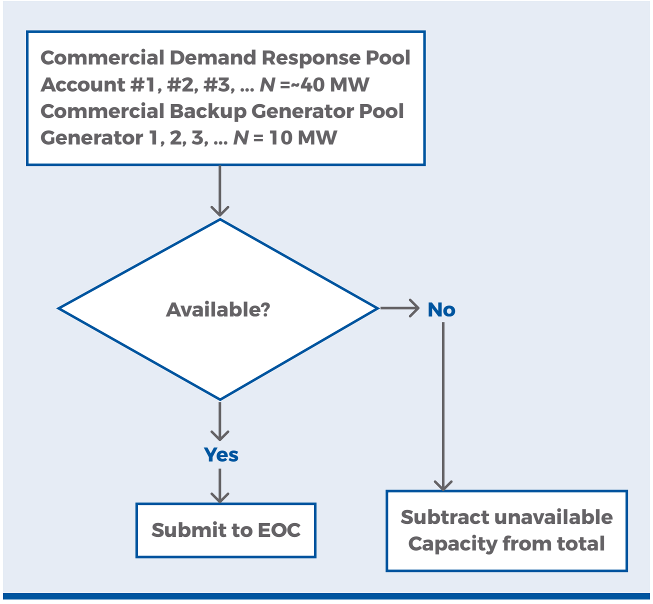
Offered into the market's security constrained economic dispatch system (SCED), this energy offer curve enables the first 10 MW of capacity to be deployed when the energy price reaches $100/MWh, then the next 12.5 MW to be deployed when prices reach $160/MWh, the next 20 MW when the price reaches $450/MWh, and the final 40 MW when the price reaches $1,100/MWh.

It's important to note that this is a useful beginning for market operations. As the summer season unfolds, hourly market pricing could be lower or higher than the original forecast. As these trends become clear, the pricing should be constantly scrutinized for over- or under-deployment, and adjusted appropriately.

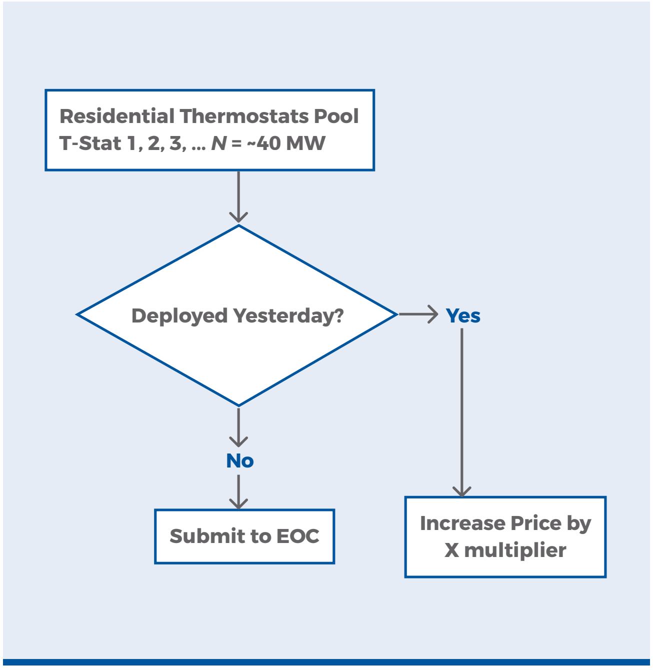
4. Integrating constraints into the resource stack

As discussed before, the resources making up this VPP have unique constraints not encountered with conventional thermal generating units. In addition to the daily or seasonal operations limits, there is the consideration of customer opt-out due to equipment issues or fatigue (in the thermostat programs). For these reasons, a business process should be established to verify available capacity on a continuous basis.

Commercial customers performing maintenance (either as part of the C&I DR or on the backup generation segment) will lead to curtailed capacity available for deployment. This is akin to a “de-rate” or outage on a thermal generating unit. This capacity must be subtracted from the resource stack for appropriate time frame.



Residential customers have expressed a desire not to be deployed two days in a row during a heatwave. The VPP will wish to honor this desire, but there are cases in which deployment on the second day is necessary for various reasons. To accomplish this, we change the energy offer for the residential thermostat portion of the VPP just after the deployment on the first day to a much higher price for the next day. This makes deployment less likely, but not impossible, and ensures that if major scarcity occurs, the program will respond.



For energy storage resources that are part of the VPP, battery state of charge must be constantly monitored and daily strategies must be accomplished to ensure availability. Nightly charging could be scheduled either based on the hour of the day or through a price-based mechanism.

The business process can also take into account planning for deployment of resources to capture coincident peaks. The days those coincident peaks occur may or may not coincide with the highest priced days, and changes to operations should reflect this strategy.

5. Automating the re-creation of the resource stack to enable daily or hourly adjustment

As a utility operating a VPP goes about its daily and hourly operations, different resources will be deployed and recalled throughout the day and week. Battery state of charge constraints, backup generator availability, and thermostat deployments all represent potential changes in state of the resource stack.

Automation of these updates using an integrated, comprehensive VPP operations platform (like AutoGrid Flex) can ensure these operational constraints are reliably and consistently introduced into the most updated resource stack. Automated routines that verify offer parameters can present the most updated intelligence to the grid operator for daily and even hourly operations plans. In control rooms with teams of operators, it’s important to have a consistent source of the latest information to lessen the risk of operator error as operations move from day to night and vice versa.

Conclusion

VPPs can aggregate and optimize multiple types of DERs, including traditional DR, and leverage these disparate resources to create multiple value streams bridging distribution and transmission power grids. These diverse resources can offer key products and services necessary to balance regulated and deregulated markets across the U.S. and the world. The type of analysis needed to identify the exact market aspect each DER is capable of is hopefully clearer now, as well as strategies for presenting these resources to the market. By mimicking the attributes conventional resources rely upon to be scheduled for market participation, VPPs can be understood and managed universally, though clearly strategies will be shaped by the specific rules governing each market jurisdiction. The analysis results in the creation of a Three Part Offer so that the VPP can be presented to the wholesale market for participation in the same way that a thermal generating unit would be.

These examples were simplified by necessity; the analysis, pricing, and offer a strategy for a given utility's VPP will be much more involved and tailored by whether the VPP is operating in a tightly regulated or deregulated market, by the type of utilities involved (investor-owned, municipal or cooperative) as well as retailers in many cases. Yet the basic principles outlined here can serve as a roadmap to organizing this disparate, heterogeneous group of resources consisting of loads, generation and energy storage into a seamlessly functioning resource very similar in operations as a physical power plant. Think of a VPP as the logical endpoint for the digitization, decentralization and ultimately the decarbonization of the world's energy systems.

Definitions of capacity and energy products

Energy is simply electrons that are pumped into the grid by a generating resource, or the reduction of consumption of energy by a load. It is denominated in megawatt-hours (MWh) and usually priced as $/MWh.

Capacity is generally defined at the capability to produce energy when called upon. For example, a power plant can produce up to 100 MW of power when called upon. It can be thought of as a "reservation" of a certain amount of energy at some future time. An electrical load such as a large motor, HVAC system, or lights can also represent capacity if they can be shut down on command at some future time.

Grid products are specific technical energy and capacity capabilities that the energy grid procures from marketers for grid reliability and stability.

Responsive Reserve (aka Spinning Reserve) is a capacity product the grid procures each day to ensure enough energy is available to make up for a sudden loss of generation supply due to a unit trip or equivalent disruption. It is a capacity product that can ramp up to full energy within 10 minutes. This is usually supplied by "reserving" a certain amount of capacity on an operating unit, or having the ability to shut down a customer load within the same time frame.

Frequency Regulation is a service that generators can provide to help maintain proper frequency on the grid. If frequency drops due to increases in load or loss of generation, a resource providing frequency regulation will ramp up to boost frequency. Conversely, if frequency rises too high due to drop in load or overgeneration, the resource will reduce load to help bring the frequency to normal.

AutoGrid

Contact us

info@autogrid.com

auto-grid.com

Learn more about AutoGrid FlexTM