White Paper

DERMS: Fact Versus Fiction

Debunking Six Myths About DER and DERMS

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Commissioned by Enbala

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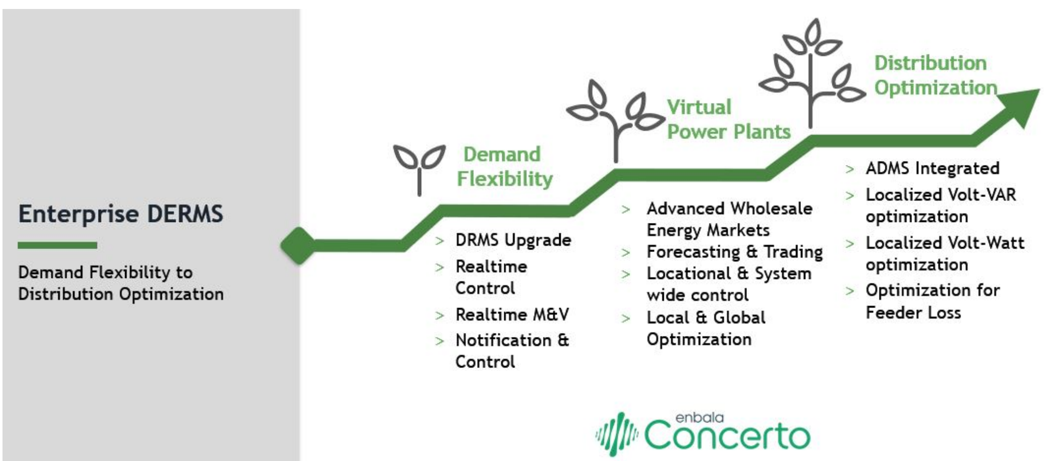
Introduction: The Journey Toward an Enterprise DERMS

Two important trends are occurring in the electric utility industry. The first is a global shift away from centralized generation toward reliance on distributed energy resources (DER). The second is that electricity's share of total energy consumption is increasing rapidly. Beginning in 2021, the amount of new annual worldwide capacity added from DER is expected to surpass centralized generation. Additionally, electrification of transportation (including railway, heavy passenger, and personal transport) as well as heating could easily double electric demand in the coming years. As total electric demand grows and the gap between central and distributed generation widens, finding intelligent methods to manage electric delivery is paramount. While this shift reflects a more sustainable future energy resources portfolio, it also introduces new challenges to grid stability and reliability—challenges that require new solution platforms.

What are the implications of this shift in how society is powered? Utilities will need to lean on smart software platforms to keep the grid in balance. These highly sophisticated platforms will enable greater control and interoperability across heterogeneous grid elements. Advances in power electronics enable DER assets to contribute heavily to improved grid reliability while lessening reliance on centralized generation. Advanced enterprise software that can see, sense, and span large portions of grid networks will become mandatory elements of best-in-class grid management practices. The value of DER assets can only be fully realized if they are integrated at customer sites and brought into markets or the grid network in a way that creates shared value. Among the solutions designed to enable this more sustainable and nimble energy future are enterprise distributed energy resource management systems (DERMS). An enterprise DERMS is a broad umbrella that includes virtual power plants (VPPs) and distribution system flexibility solutions (see Figure 1).

Figure 1 The Journey from Flexibility to VPPs to Distribution Optimization via DERMS

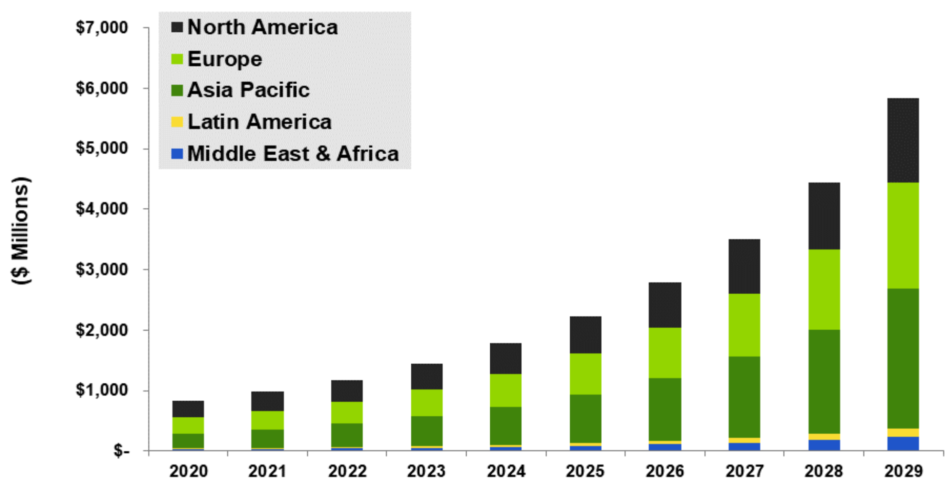


(Source: Enbala)

In many ways, an enterprise DERMS is like a lightweight advanced distribution management system (ADMS). Some also contend that a DERMS is a heavyweight demand response management system (DRMS), since it can also optimize voltage, perform conservation voltage reduction (CVR), and manage thermal limits and reverse power flows. Many utilities may start their journey to an enterprise DERMS with an outage management system (OMS), since it provides the transparency necessary for fault location, isolation, and service restoration services now increasingly in demand in markets due to increased power outages. A common pathway is moving up through these management tools: OMS, then ADMS and DRMS, and finally DERMS. In summary, an enterprise DERMS is a software platform that operates across an entire network to manage, control, and optimize DER assets to support a distribution grid.

The full suite of DER management tools that fall under an enterprise DERMS are aimed at a common purpose, supporting a more nimble, sustainable, and customer-centric energy future—what Guidehouse calls the Energy Cloud. DERMS is one among many DER management solutions that will be deployed globally in coming years (see Chart 1).

Chart 1 DER Management Technology Revenue by Region, World Markets: 2020-2029



(Source: Guidehouse Insights)

Equally important to this optimized end state is the starting point. It is vital that an electric utility can select a set of services to begin its DERMS journey—whether it is modernizing its existing demand response (DR) platform(s), looking to provide flexibility to help manage intermittent generation, or moving straight into specific non-wires alternatives that directly add to the overall reliability of the infrastructure that delivers electricity to consumers.

While new, sophisticated software programs leveraging AI, machine learning, and other Internet of Things (IoT) possibilities may seem to work magic, there are some practical limitations on what is possible with the growing, diverse pools of DER assets populating the world's power grids. This white paper delineates between fact and fiction on DERMS, a platform with significant buzz in today's evolving power markets. The hope is for potential customers to understand the solution's possibilities and how to navigate the technology's evolution as markets begin to fully use the value of these assets. This dialogue has major ramifications for our collective energy future. If DER assets become the leading source of energy and capacity (as well as other grid services), careful consideration and deep knowledge about the grid's mechanics are required. Software may seem to work magic, but it still needs to be grounded in electricity and physics fundamentals.

This white paper delineates between fact and fiction on DERMS, a platform with significant buzz in today's evolving power markets.

Debunking Six Myths About DER and DERMS

Myth 1: All DER Assets Are Created Equal

Markets are shifting toward an agnostic treatment of DER types, with load, generation, and storage among the key categories. However, that does not mean that each asset class can always provide the same grid services. Bundling such diversity into a portfolio may allow for creative synergies, but the grid services required to keep the grid in balance lean toward specific assets. In other words, not all DER assets can provide value for all DERMS services. Consider the following DERMS services:

- **Primary balancing tools:** One example is primary frequency regulation, which is required to maintain a grid frequency of 50 hz or 60 hz, 24/7, depending on the location. Resources are activated typically within milliseconds of significant deviations.
- **Secondary balancing tools:** Examples include secondary regulation reserves, which are needed for resources provided by DERMS to respond shortly after significant deviations or smaller random fluctuations (such as the variability of wind power) to maintain balance in a control area during normal operating conditions. The timeframe is greater than for primary tools but much less than for economic dispatch/tertiary balancing.
- **Tertiary balancing tools:** This category includes load reducing programs such as DR to help balance the grid based on economics signals. This is different than DERMS-based active power management, which requires faster response rates. DR resources can even be scheduled a day ahead, allowing for the resource to be planned well in advance of actual deployment.

Not all DER assets can provide value for all DERMS services.

For an enterprise DERMS, the trick is that each of these control services are best-suited to different types of DER assets. Devices such as smart thermostats, for example, do not lend themselves to a primary or secondary balancing tool application since it is difficult to determine how much of a load shift would occur within such a tight window of time. On the other hand, a battery can offer an instantaneous reaction to frequency deviations. Other load shifting options, including pumps and water heaters, also can be armed in advance to provide similar responses, accounting for bandwidth, latency, and local and remote intelligence. Each of these factors must be included in the aggregation and optimization equation for DERMS. Common automation techniques include an “if this, then that” methodology for disparate systems to optimize potential DER resources for grid support. The ability to arm these DER assets allows utilities to sense and respond according to preconfigured triggers, with data on DERMS-instigated performance then retrieved, validated, and stored in the cloud to drive the payment or incentive process.

Purchasers should select a DERMS to extract maximum value from the transmission and distribution network’s available DER mix in combination with the services they intend to optimize for. This is inclusive of monetization in market services (primary/frequency response, secondary/regulating reserves, tertiary/DR) and distribution system services such as thermal management and voltage optimization. Extracting all the value streams from DER is vital to ensure that all DER are affordable. With a DERMS, the more DER that are available, the better the overall contribution to the reliability of the grid.

Eversource, an energy company serving customers in Connecticut, Massachusetts, and New Hampshire, uses the Enbala platform as part of its broad energy efficiency and demand management initiatives. For example, all of its flexible load from behind-the-meter peak load reduction programs are funneled up through the Enbala platform. Eversource's customer priorities, needs, and behaviors can vary widely from one DER asset to another. The company seeks to incorporate a variety of devices into these load reduction programs and sees everything from thermostats to EVs as potential DER assets. It seeks to minimize operational interference with its customers. The utility calls upon some resources (such as batteries) more frequently than others (such as load reductions from reducing HVAC setpoints). In short, Eversource is device agnostic but customer focused. It acknowledges that some assets are better than others in terms of minimizing customer interference, which in turn can deliver additional value for specific services at any particular point in time.

Myth 2: Deploying an ADMS Negates the Need for a DERMS

An ADMS has similar end goals to a DERMS. As a result, some utilities and grid operators ask: If an ADMS is already in place, why invest additional capital into an enterprise DERMS? ADMS systems typically help control front-of-the-meter utility resources, switchgear and transformer banks, and other grid-connected technologies. They predominately do this via traditional SCADA systems using a centralized, top-down, and iterative approach to problem-solving. The challenge with this control approach lies with the exponential growth in DER assets, which often operate intermittently. The volume of these assets slows down iterative load flow processing time and makes grid management more challenging for utilities. Consider the timeframe differences between an ADMS and a DERMS. An ADMS operates at a periodicity of calculation circa 5-, 15-, and 30- minute intervals. This contrasts with an enterprise DERMS, which reoptimizes the system 4-8 times per minute. The ADMS is focused on substation and primary conductor optimization, whereas the DERMS' boundary of control extends to the entire feeder as populated with both load and supply DER assets.

An enterprise DERMS will deliver market services with DER assets without causing distribution network reliability issues.

ADMS and DERMS are symbiotic. ADMS excels at state estimation, load flow and fault location, and isolation and restoration based on measured and approximated points on the electric network. DERMS needs to take a different and more direct approach to enable a much greater scale of problem-solving. The Newton-Raphson or Gauss-Newton calculations used by an ADMS are too slow for a DERMS to do its job, which is to optimize tens of thousands of DER devices on a circuit in parallel against both technical and commercial constraints for the services provided. In contrast, DERMS optimizes and controls DER assets to stay within set operational constraints (both local and network) and provides a level of demand side optimization never before possible, including the provision of real power, apparent power, and voltage. When properly architected, an enterprise DERMS will deliver market services with DER assets without causing distribution network reliability issues.

While good control system design provides that there should only be one master controller over a target asset at any single point in time, services that can use four-quadrant inverters enable DERMS to lead voltage optimization during the day when the sun shines and PV panels produce electricity. ADMS can then take its turn and lead the optimization at night based on more traditional grid operating envelopes. In this way, both systems leverage each other's strengths; however, only one master can be responsible for the utilized assets at any single point in time. This master can change depending upon the time of day or the available flexibility of the assets under control.

Case Study: Conservation Voltage Reduction

ADMS and DERMS can offer significant value to the CVR service goal. CVR is the process by which one can lower voltage slightly on distribution feeders to help shave peaks in demand on the larger grid. However, the shift to a greater number of reactive loads on the network translates into greater challenges for ADMS systems to perform CVR. Traditional purely resistive loads are migrating to reactive devices, including lightbulbs, smartphones, and heat pump-based water heating. Most modern assets now operate in such a way that voltage and current are independent, creating the need for faster and more active control beyond what most CVR services do today.

Historically, smaller consumers have not been charged for their reactive loads that, in effect, drive down effective system utilization, so innovation in this area lagged. As markets evolve to be more price sensitive (and cost based), this may no longer be the case. For example, Spain charges households for reactive power mismatches. A DERMS system is particularly adept at managing DER resources such as inverter-based equipment and “caps, taps, and regs,” or capacitor banks, on-load tap changers, and voltage regulators. The combination of utility control equipment with behind-the-meter inverters allows for a significantly higher fidelity of control without the severe transients and equipment wear and tear from high break-current switching operations. Collectively, these unheralded resources are vital to proper voltage management of the power grid.

Capacitor banks demonstrate the value of coordinating DERMS with ADMS. They feature a mechanical versus financial lifetime limitation, usually up to five operations per day. Otherwise, these technologies degrade faster than expected, driving up delivery costs. If a DERMS can use other technologies such as battery and PV inverters to help keep the grid in balance (especially with the anticipated high penetrations of these devices), the expected life of capacitor banks can be maintained since capacitor banks can continue to live within these preferred operational parameters. A similar argument can be made for taps and regs.

Myth 3: Precise Forecasts Are Required for a DERMS to Provide Value

To increase value, utilities should focus on improving reliability within their budget for DER control and optimization. A utility DER strategy should be to control what can be controlled while managing what cannot. “All we really need to know in real-time operation is what DER options are available a few minutes before scheduling. The future is distributed flexibility, large pools of cheap assets that are highly scalable,” said Patrick Luig of RWE, a German utility that pioneered concepts such as VPPs over a decade ago. Luig noted that in the past, grid operators would focus on forecasts of large centralized generation. With the right telemetry, software, and market rules, DER assets can be marshalled to support a variety of grid services. RWE is starting with the most challenging markets first, using the Enbala platform for secondary reserves, before moving on to other grid service use cases.

There is the myth that if a utility or grid operator does not have a precise forecast, a DERMS will not solve the problem. A precise forecast of electricity daily load and corresponding price swings—with near 100% certainty—is probably not possible, even with an unlimited budget. This confluence of budget and accuracy never exists in the real world, yet humans are preprogramed to rely on a forecast to try and predict both consumer demand and what nature will do to solar and wind resources.

A more realistic and pragmatic approach is the 70/30 rule, relying on a best-guess forecast for the next 4 to 24 hours that is correct approximately 70% of the time (and wrong 30%). Alternatively, a 60/40 rule may be sufficient for optimization engines under some circumstances. Applying this to DERMS, forecasts are used to set a coarse strategy for grid optimization without locking it in. By instituting a bias in decision-making toward the predictive management capacity functionality embedded in the DERMS' DNA, often linked to a market outlook and guiding the ADMS (if available), the DERMS role is to react in real time to actual conditions with all available resources. Under this realistic market-based approach, the DERMS helps steer outcomes to the goals outlined in the forecast by allowing for adjustments that react to real-time conditions. While a compromise, it is an extremely cost-effective way to harness the power of both forecast outcomes and incremental adjustments that respond to ever-shifting weather and market conditions. It hedges, bets, and fine-tunes delivery of the right grid services on an as-needed basis.

Myth 4: Real-Time Control of DER Is Overkill

Masked customer load getting unmasked, en masse, all at once. Sag and swell voltage violations. Reverse flows tripping protection systems. These are not 5- or 15-minute optimization calculations. They need to be calculated for—and solved—in parallel, in seconds. These changes are impossible to account for. Without the capability of a quick response, if a segment of the electric grid goes down, the power goes out.

If utilities, grid operators, or other market participants could somehow afford a perfect planning forecast, then it is overkill to have the capability of real-time control. However, even a perfect forecast becomes outdated with every second that ticks by. This is why a DERMS is needed for real-time control. But what does "real-time control" really mean?

Any definition of real time is shaped by the service being provided, not the clock on the wall.

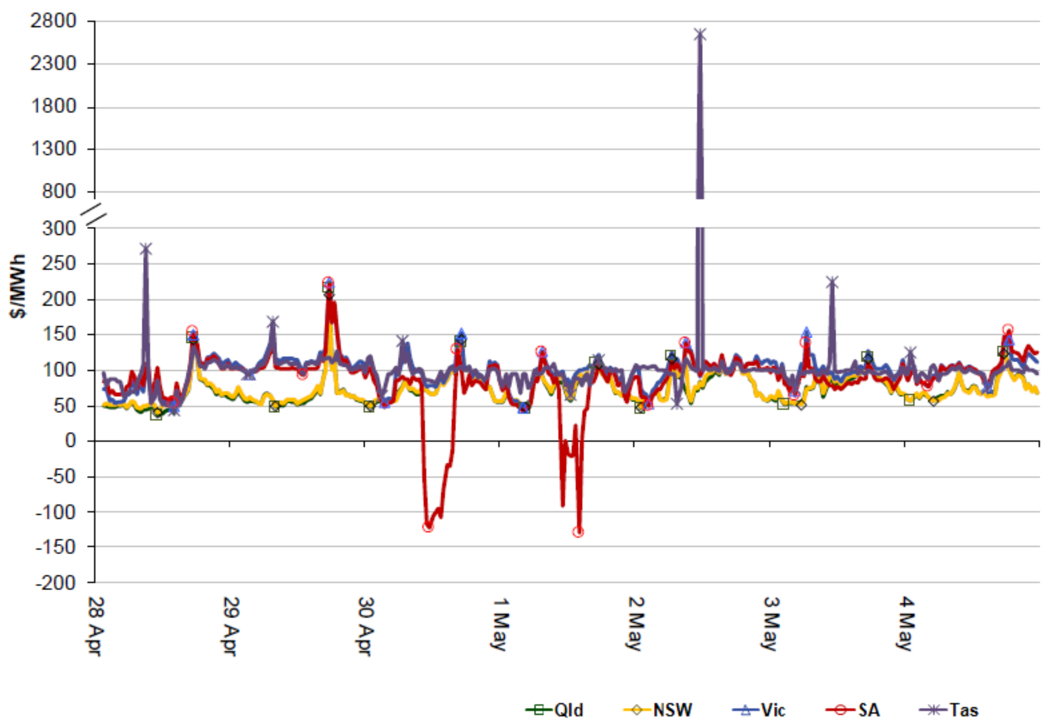
Any definition of real time is shaped by the service being provided, not the clock on the wall. So, the definition of real-time changes depending upon which grid service one is trying to extract from each type of DER asset. Assets pre-enabled and then called upon to deliver primary reliability services ideally respond within milliseconds. In this service type, real time is virtually simultaneous. For a secondary frequency regulation service, real time is a response within 4 seconds. For applications such as DR provided by a VPP, real time is more like 1 minute and call signals may occur hourly or even less often.

The obsession with real-time fidelity traces back to early thinking about the smart grid during the 2008 recession, when the American Recovery Reinvestment Act stimulus funding was earmarked for electricity infrastructure. The argument then was that a significant number of fiber-optic lines would be necessary throughout the electric grid to manage this explosion in smart grid and DER growth. The worry was the system's latency. This misconception traces back to the myth that all DER devices are created equal. It is easy to be carried away with the notion of needing absolute control over every single asset on the grid, large and small, in milliseconds. However, loads may only need to be measured and integrated into operations about once a minute. If an enterprise DERMS is in place, a range of DER assets can serve as a buffer to the system, bridging any gaps between expected and actual grid operations, in real time, stretching from less than 1 second up to 1 minute. This buffer solves the lag or gaps between actual and forecasted load, with flexibility resources optimized by AI smoothing things out with creative aggregations of generation, load, and storage.

Australia represents an extreme case where everyone involved needs to be focused on real-time optimization is evident. In Australia, intraday and intra-seasonal swings in demand create demand peaks that can be 2-3 times the average loads. These are often sporadic and noisy loads, typically driven by weather, like air conditioning load. This dynamic can be traced down to specific low voltage grids in distinct geographies, which require surgical control interventions to be most effective. As the Australian market moves from a 30-minute to a 5-minute settlement market, volatility and notions of real time amplify. “Price forecasting is critical, but complex in this market, and so the ability to access our fleet in near real time is equally critical,” observed Greg Abramowitz of AGL, a utility operating as a retailer in Australia’s deregulated market. Price swings can dip from a floor of -$1,000 up to $14,000 within any 24-hour period. With that level of volatility, AGL sees a need for DERMS, especially since distribution system operators (DSOs) historically had limited visibility into their networks and relied upon modeling to approximate expected load and supply balance forecasts. For AGL, real time is the ability to collect and react to data on a 5-minute cycle. “While we are working toward providing DERMS-like network services, we can only go so far today as the markets for those services evolve,” said Abramowitz.

Figure 2 illustrates AGL’s predicament. The utility operates in South Australia (the red line), were prices dipped below zero for several hours on April 30 and May 1, 2020. This hypervolatility in spot prices can instill tremendous pain or incredible profits, all within in a single day of operation.

Figure 2 Spot Market Prices per Region in Australia, April-May 2020



(Source: Australian Energy Market Operator)

Myth 5: DERMS Must Be Installed On-Premise

Traditional thinking still permeates the electric utility industry, especially when it comes to control and operation of grid infrastructure. Hardware that serves as the basis for basic controls, such as utility SCADA systems, are familiar and have withstood the tests of time.

SCADA systems are connected to switchgear and related devices that adjust grid supporting devices or turn them on and off. It is logical to assume a DERMS would sit alongside the SCADA (and ADMS) in more advanced control topologies. The challenge to this traditional control paradigm is that most DER are connected via 3G/4G (and the coming 5G) technologies as it is not cost-effective nor cyber-secure to install a SCADA connection at every home that could offer up a DER asset for grid services. Furthermore, SCADA systems were not built to scale to all the new kinds of DER assets being called upon to provide value, such as water heaters and EV charging infrastructure (or EVs themselves).

Managing the grid through data in the cloud may seem risky on a conceptual level for many. However, today's cloud services providers spend more on security in a day than many private data centers might spend over an entire year. Proper security postures and architecture must be designed in from the beginning, not tacked-on as an overlay. A DERMS architected with the intention of in-cloud delivery will out-perform any security test versus an application designed for on-premise, served locally, or from the cloud.

A DERMS managed via the cloud is typically more secure than any non-air gapped utility SCADA system.

Depending upon the cloud for secure grid service transactions places a tremendous burden on proper IT design. Since it is not affordable to install a SCADA at every single site that offers DER assets for grid services, creativity is necessary. Alternatives include installing firewalls and proxy systems for internet communication exchanges, using VPN and other security protocols to protect these data transfers from hackers. Use of such proxy servers is well established for DER control, aggregation, and optimization. For this IT approach to work, all data is encrypted at flight and at rest. This shift from on-premise to cloud-based control is not a reason to not have a DERMS. In fact, a DERMS managed via the cloud is typically more secure than any non-air gapped utility SCADA system. They can better serve DER management applications and services to epitomize the value proposition of a DERMS.

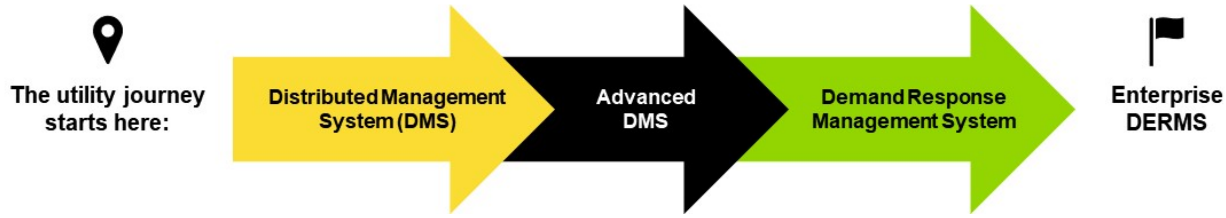
In 2016, AGL initiated a residential aggregation pilot program where the use of a local on-premise gateway device alongside the storage asset was commonplace. As it looked to the future, however, AGL saw focus trending away from gateways and instead toward an open platform leveraging the cloud, pushing control functions of DER assets out to the edge to inverters armed with a little bit of logic. AGL wanted to innovate with new technology and integrate a greater variety of batteries and other DER assets. Instead of growing a network of DER assets reliant on centralized controls, AGL chose the Enbala platform to explore enhanced DER management opportunities.

Myth 6: We Are Not Ready for a DERMS

A DERMS is not an ADMS. A DERMS can serve as a gateway to an ADMS. However, do not expect a DERMS to see into every dark corner of the grid and react to every single event. No, a DERMS cannot do everything.

Since geography and policy shape DER growth, utilities that do not yet see major impacts on the grid ask: Why do we need a DERMS? The answer rests on the premise that this is a journey for any utility service territory or control area, with many entry points to reaching the end goal of an enterprise DERMS (see Figure 3). Rather than rushing to a solution once a problem occurs, it is better for utilities to modernize their grid infrastructure early without adding exponential risk to the project. That way there is never a customer-visible problem or a crisis to manage, allowing for logical decision-making to prevail ahead of time.

Figure 3 Platforms Evolve Toward Enterprise DERMS



(Source: Guidehouse Insights)

This approach also allows for detailed tests and analysis on how to provide incentives for consumers to become prosumers and for testing out DERMS in pilot programs at grid hotspots. “We are using an incremental and evolving approach to DERMS,” acknowledged Michael Goldman, director of energy efficiency regulatory, planning, and evaluation for Eversource. The energy company is incorporating DERMS first within energy efficiency to optimize its broad suite of behind-the-meter energy efficiency programs in parallel with its grid modernization initiatives. Goldman continues, “One doesn’t need to do full-scale SCADA integration with DERMS to realize initial benefits such as those associated with system-level peak load reductions. The platform is already creating value for our customers. Over time, with integration into real-time system operations, DERMS technology will provide additional value to customers leveraging locational value. We can use DERMS wherever we are in terms of our grid modernization journey. It’s not an all or nothing value proposition.”

Patrick Luig of RWE also acknowledges the value of investing in a DER management platform in an uncertain world. “Extending the grid will take years and encounter not in my backyard opposition,” he said. While it also takes a long time to adapt market rules, all signs point to markets moving in the direction of greater reliance upon DER assets. Utilizing a platform to tap this distributed flexibility will significantly reduce the cost of grid extensions. While such opportunities may or may not be completely commercially viable today, they most certainly will be tomorrow. “Due to current market rules in Germany, we are focused on industrial behind-the-meter loads today, but we will expand our available DER portfolios in the future as markets evolve,” he added.

An enterprise DERMS should be able to immediately replace the functionality of a DRMS, monetizing DER in markets or alleviating coincident system peaks and price spikes and also providing value for the asset owner. In addition, the DERMS must allow continuous growth into more advanced services as the need arises, eliminating the need for multiple competing products and tools. Utilities should select a DERMS vendor that helps them grow, rather than one they will need to drag along as DER deployments increase over time.

Conclusion

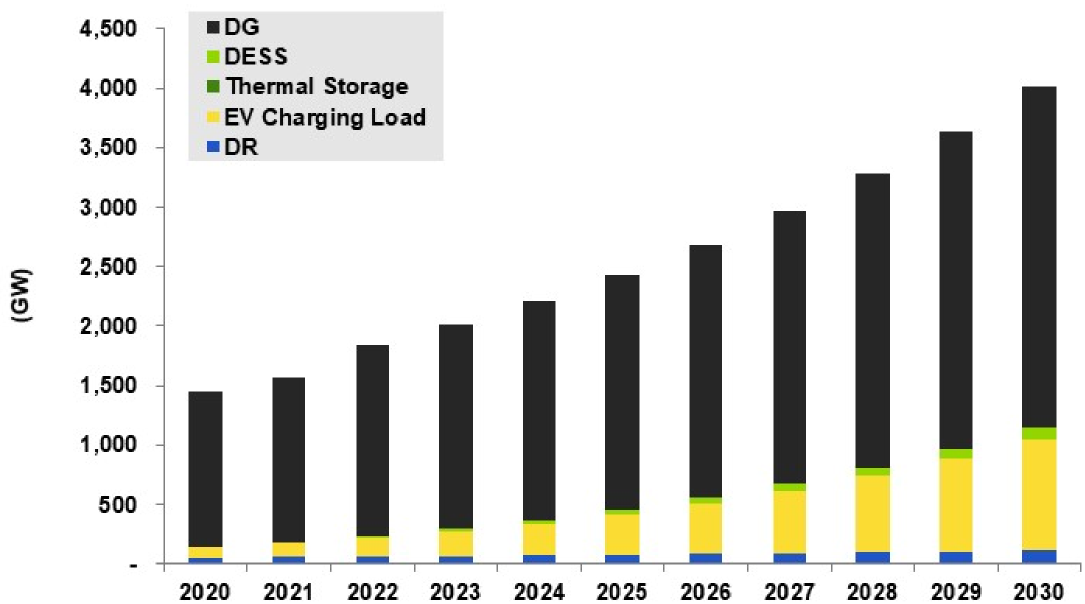
The DERMS hype cycle is peaking. Along with technology like IoT, microgrids, VPPs, and blockchain, these solutions to the explosion in forecast DER growth are touted by many far and wide. However, not all DERMS are created equal. The overlap between each of these platforms will only increase with time, further clouding any clear delineation on what any customer may actually need today—or tomorrow.

When utilities ask for a DERMS, they may really be asking for a modern DRMS or perhaps even a VPP, both of which are more focused on economics and capturing value from distribution network-level resources up into wholesale markets. Is a microgrid a DERMS? Yes and no. A microgrid can be acted upon by a DERMS as it has the specific capability of islanding when the larger grid requires that kind of relief. Regardless of semantics, the need for DERMS increases as DER assets proliferate global markets. Demand flexibility started this journey, which then evolved to VPPs looking to take advantage of opportunities to provide value upstream. An enterprise DERMS, a comprehensive software platform to manage DER complexity on the distribution system, is the end goal. It becomes a necessity to maximize value from the entire flexibility stack: providing load reduction/shifting at a system level, while also providing local active power management and voltage control by grid operators to drive reliability and determine that the more market-based transactions do not attempt to violate the basic laws of physics.

DERMS does not calculate a load flow, do state estimation, or undertake Monte Carlo simulations. These calculations are too slow for a DERMS to optimize tens of thousands of DER assets in parallel against grid and for DER asset constraints to provide the specific grid service called upon. DERMS instead runs algorithms frequently and quickly to keep the distribution grid in balance.

Chart 2 shows the diverse pool of DER assets. These assets represent about 1,500 GW of global capacity today and will likely more than double over the next decade—highlighting the need for DERMS. While DERMS cannot do everything, it is critical tool for grid operators to manage these diverse assets.

Chart 2 Cumulative DER Capacity by Technology, World Markets: 2020-2030



(Source: Guidehouse Insights)

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Acronym and Abbreviation List

ADMS .... Advanced Distribution Management System

CVR .... Conservation Voltage Reduction

DER .... Distributed Energy Resources

DERMS .... Distributed Energy Resources Management Systems

DMS .... Distribution Management System

DR .... Demand Response

DRMS .... Demand Response Management System

DSO .... Distribution System Operator

EV .... Electric Vehicle

HVAC .... Heating, Ventilation, and Air Conditioning

hz .... Hertz

IEA .... International Energy Agency

IoT .... Internet of Things

OMS .... Operations Management System

PV .... Photovoltaic

SCADA .... Supervisory Control and Data Acquisition

VPP .... Virtual Power Plant

Scope of Study

This white paper is sponsored by and coauthored with Enbala, a software company offering DERMS platforms for global markets. Guidehouse Insights conducted all interviews and developed all forecasts. The white paper is designed to dispel some common myths about the value of DERMS while also laying out what an enterprise DERMS could and should look like. The intent is to shed light on this emerging market opportunity while providing guidance to the DERMS ecosystem of providers to accelerate market growth by sharing insights, clarifying definitions, and offering use case examples.

Sources and Methodology

Guidehouse Insights' industry analysts use a variety of research sources in preparing research reports and white papers. The key component of Guidehouse Insights' analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Guidehouse Insights' analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Guidehouse Insights' reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

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