White Paper

Building the Business Case for Decentralized Control Architectures for Microgrids

How Stone Edge Farm Helped Launch a New Controls Paradigm

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Introduction

The microgrid market hinges on the successful performance of digital controllers that orchestrate distributed energy resources (DER) to achieve resiliency, maximize clean energy, and meet cost-saving goals. Several different control approaches are now available in the market. These range from top-down/command-and-control schemes—derived from methods used on the transmission system—to more decentralized approaches, which push intelligence out to the edge of the grid at the device level. Between these two extremes are other nuanced differences, such as hybrid control schemes, migrations to cloud computing, and even open source platforms.

This white paper tells the story of how Heila Technologies developed a modular, flexible, and decentralized microgrid controls platform, Heila EDGE, to address challenges at Stone Edge Farm, one of the more complex microgrids operating globally. The farm's microgrid uses contributions from eight different battery technologies and multiple renewable and conventional energy sources. Additionally, it creates hydrogen fuel for local transportation needs and both seasonal and diurnal long-term energy storage. The need for instantaneous adjustments among such a large pool of diverse DER assets led to the creation of a decentralized, scalable, and agnostic controls platform.

An emerging consensus within the microgrid vendor ecosystem prioritizes a foundational shift in thinking about how to best control microgrids that feature increased variable renewable energy (VRE) content. This shift is compatible with other emerging trends in energy markets including:

- Greater reliance on VRE as primary energy sources, moving away from traditional fossil fuels and using them to provide the most value (this includes thermal energy).
- Increasingly diverse DER assets, including multiple battery chemistries. Just as microgrids may feature multiple supply-side resources, they are expected to increasingly incorporate multiple forms of energy storage, including hydrogen.
- A need for interoperability rather than siloed proprietary solutions, enabling customers to adjust their microgrids in a modular, streamlined, and efficient way.
- A controls platform that can facilitate open source offerings, further accelerating adoption of microgrids throughout application segments and regions that require resilience and more sustainable energy systems.

One way to think of these trends is the concept of emergent intelligence, where complex systems and behaviors can emerge from the interaction of simple elements.

Controls platforms continue evolving. Emphasis is shifting from hardware devices and on-premise gateways to software customization performed via data-lake aggregation and advanced analytics in the cloud.

The Heila Technologies controls platform moves closer to an open source model. It also features the flexibility to be deployed in multiple system topologies. Stone Edge Farm has facilitated the creation of an end-to-end modular platform that brings intelligence to the (micro)grid's edge, allowing for the organic and agnostic integration of any DER. Using distributed control and optimization, each DER becomes an independent agent capable of determining at split-second intervals their most beneficial operating point relative to system-level objectives. This approach enables a distributed intelligence that preserves the autonomous operation of the system while unlocking new revenue opportunities for the end users.

One way to think of these trends is the concept of emergent intelligence, where complex systems and behaviors can emerge from the interaction of simple elements. These simple elements are paired with powerful edge computers and cloud-based intelligence and so are empowered to act autonomously toward a common set of objectives. This scientific thesis of emergent intelligence underscores how the world is moving away from a hub and spoke model that mimicked this top-down, bigger-is-better mentality was not where the electricity industry began. In fact, Thomas Edison started with microgrids, but existing technologies of his time rendered a highly competitive and decentralized energy industry inefficient. Today, however, advances in digital controls make these technologies the gateway to enable a more resilient and sustainable energy future. While microgrids may not have made economic sense a century ago—as competing distribution lines traversed urban centers in a motley manner—they do make economic and environmental sense today. That is, if they are controlled and designed for scalability, adapting to changing circumstances both inside and outside of the microgrid boundaries.

The Challenge Posed by the Stone Edge Farm Microgrid

Stone Edge Farm launched in 2013, expanding upon conservation practices that had been used at the operating winery and farm for decades. Those efforts to create an organic farming operation were then expanded to incorporate leading energy efficiency and onsite clean energy resources. The goal was to create a fully sustainable and energy independent farming enterprise. Most importantly, this evolving and fully operational microgrid served as the testing ground for a new, revolutionary controls technology that increased the value of emergent intelligence algorithms.

The farm's investigation into the concept of onsite power generation began with the purchase of a fuel cell. Though powered by natural gas, fuel cells have much lower emissions than traditional fossil fuel-based generation, such as diesel or gas generators. Quite small in terms of capacity (15 kW), the purchase was the first step in a long journey to create a localized energy system capable of operating on 100% renewable energy. The owner of Stone Edge Farm, Mac McQuown, and his lead engineer, Craig Wooster, decided that it would be better to rely on sustainable energy supplies, such as solar PV, rather than a technology still using fossil fuels. However, the intermittency of solar resources was deemed an issue, leading to the exploration of energy storage as part of the project. Throughout the process of adding and arranging DER in these beginning stages, Stone Edge Farm was slowly learning that they were creating a microgrid. A microgrid is an onsite energy system capable of energy self-sufficiency that integrates a variety of resources and could still supply power through a process called islanding if the surrounding utility grid failed.

Initially, a battery capable of long-duration storage was purchased, but its control system was difficult to integrate with existing building-management systems. Seemingly constant challenges arose in trying to pull together the microgrid, and the company brought in some interns to help solve this puzzle. The question to address: How does one design a resilient and sustainable onsite energy system comprised of an ever-expanding list of energy assets?

Rather than making the communications between each device more complicated, the complexity should remain within each DER asset while simplifying communication and optimization.

As new resources were added to the grid—including lithium-ion and other batteries, each with different manufacturer inverters—it became clear that these DER assets faced coordination issues. The farm started with the typical top-down controls approach used in most microgrids at the time. The existing systems were both considered the leading technology of the time but relied on hierarchy. Adding new resources was complicated and time-consuming, requiring customized engineering.

In 2015, Jorge Elizondo, who was working at MIT on his PhD thesis about a new method of decentralized controls for microgrids, was invited to the site. At this point, the fuel cell was abandoned and replaced with a Capstone gas microturbine, which posed its own set of integration challenges. While the microturbine burned fossil fuels, it could be augmented with sufficient energy storage capacity to extend the intermittent solar resource beyond daylight hours. The microgrid would rely on the generator as a last resort.

Luckily, research being conducted at MIT offered a potential solution for Stone Edge Farm: a controls path that was more distributed and autonomous. The research exploring this new way of organizing diverse assets within a single system was awarded the MIT Clean Energy Prize in 2016. It was recognized the same year with the US Department of Energy's University Cleantech Prize after competing with 21 other startups, setting forth a new prototype for controls technology.

In the meantime, the list of DER assets being added to the Stone Edge Farm energy system kept growing, ultimately reaching 20 separate DER assets, with the majority of the batteries installed between 2015 and 2017. Figure 1 shows 16 of these, while the remaining four were controllable loads. The team working on the microgrid, which would eventually involve over 70 interns, explored how new forms of logic could make such a microgrid work more efficiently. It would simultaneously need to meet both the resiliency needs of a farm located in a region plagued by wildfires and the farm's key sustainability goals.

Figure 1 Stone Edge Farm DER Mapping

(Source: Stone Edge Farm)

Diving deeper into the challenge at hand, the team came to a profound realization: the complexity of such a system required a more elegant approach. Rather than making the communications between each device more complicated, the complexity should remain within each DER asset while simplifying communication and optimization. Stripping out systemwide complexity reduces vulnerability. These insights are what led to the creation of the flexible, distributed Heila EDGE microgrid controls platform.

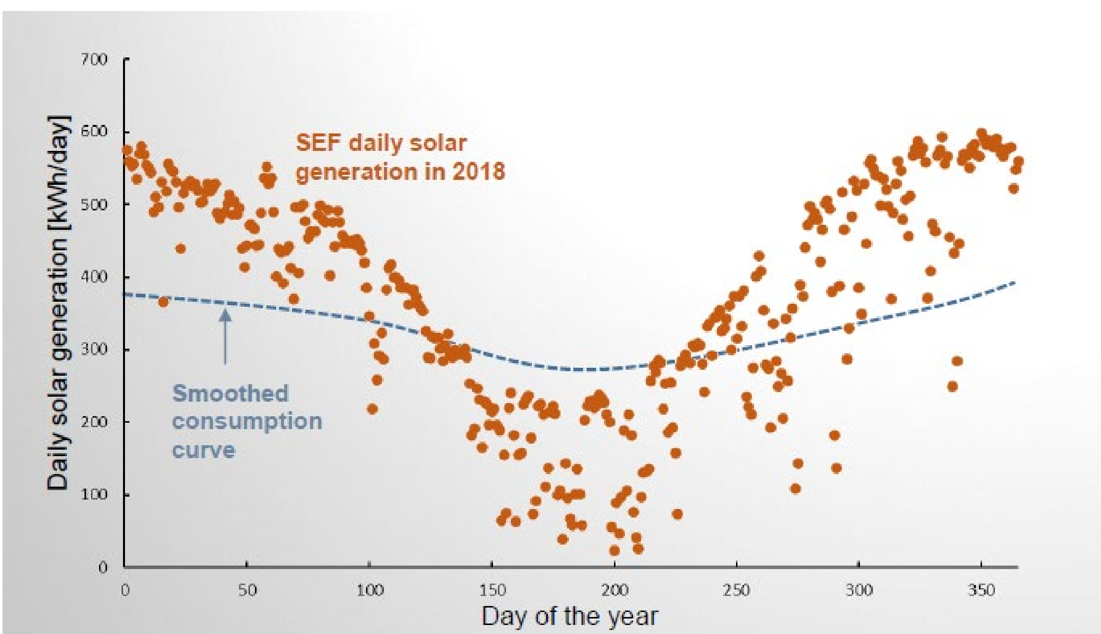
The fundamental concept of emergent intelligence allowed Stone Edge Farm to continue operating without internet access during a major wildfire in 2017. This ability for each DER asset to operate autonomously while still serving the needs of the overall system was a breakthrough. The approach creates a virtual market, internal to the microgrid, in which a DER asset is allocated according to a price. Each asset independently determines what price it is willing to pay and what price it is willing to sell at.

Much like organized wholesale markets, competition guides the assets to orchestrate themselves in the most efficient manner possible at any moment.

The next challenge to arise was the farm's overproduction of renewable energy during summer, when the days were long and solar energy was plentiful. (Conversely, the system contained less renewable energy supply during winter when days were short.) The team investigated the regulatory requirements to sell excess renewable energy back to the grid during summers, when peak prices were often high due to shortages, and considered selling it to either the host distribution utility, Pacific Gas & Electric, or at the wholesale level under a new program offered by the California Independent System Operator (CAISO). In both cases, the regulatory barriers and costs associated with telemetry requirements and other matters rendered this option uneconomic. In addition, using the surrounding distribution grid as a form of energy storage did not facilitate further sustainability development; seeking full energy independence would push controls technology forward by testing the outer limits of decentralization. The team decided to add hydrogen-production technologies that could harvest excess renewable energy and convert it into a fuel storage medium, further diversifying the microgrid. This, in the end, emerged as another piece to the puzzle. In fact, one large French company—one among many international visitors—was convinced of the efficacy of hydrogen after several site visits and has since launched hydrogen ventures inspired by Stone Edge Farm.

In 2017, the microgrid added electrolyzers, technologies that can create hydrogen at small scale and that have been deployed in a few remote microgrids in Latin America and the Asia Pacific, most often on small islands. At Stone Edge Farm, the hydrogen is used for vehicles onsite, but the hydrogen can also be used for longer-term seasonal energy storage, especially during periods of reduced daily solar generation (see Figure 2). With the help of hydrogen and the array of batteries, Stone Edge Farm has been able to island for months at a time, exhibiting a model case study of energy self-sufficiency and sustainability. In fact, the microgrid has been operating in island mode since December 2019.

Figure 2 Use of Green Hydrogen for Seasonal Long-Term Energy Imbalances



(Source: Heila Technologies)

The team is now working on another microgrid at Silver Cloud Vineyard. This new microgrid involves two new partners along with Heila Technologies: Jacobs Engineering, a large multinational engineering company, and Emera Technologies, a spin-off from a utility active in eastern Canada and the US. The company is focused on direct current (DC) applications for microgrids. Interest in DC technologies—which Thomas Edison deployed in his first microgrids—is growing due to technological advances in DC.

As the economy becomes more digital, most loads in buildings are natively DC. In addition, both solar PV and batteries are DC and require inverters to convert to the alternating current (AC) that is used in distribution networks. Eliminating these conversions reduces energy losses. A DC microgrid is also more resilient. It automatically islands when the larger AC grid goes down and does not have to resynchronize once the grid is operational again.

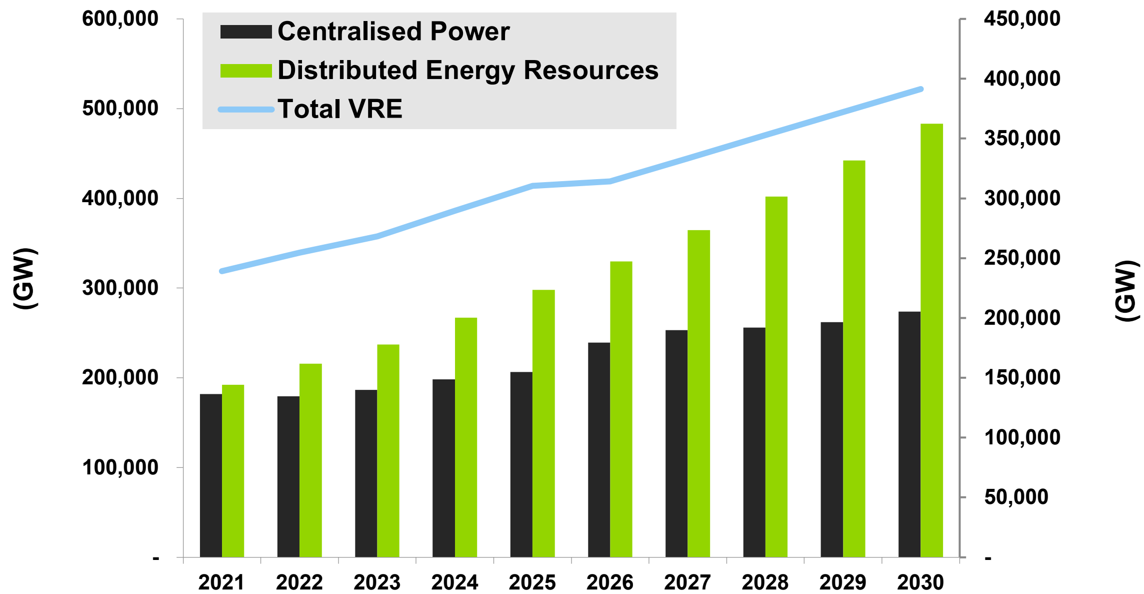
Silver Cloud Vineyard will also explore hydrogen, using the Giner technology originally installed at Stone Edge Farm. Unlike this existing system, new technology by the startup OxEon Energy will be incorporated into the Stone Edge Farm microgrid: a bidirectional technology that can create electricity from hydrogen and vice versa. This kind of flexibility will become increasingly important as companies, utilities, and consumers seek to reach net-zero carbon in the coming decades. Energy use and transportation are likely to become increasingly intertwined. Microgrids that incorporate hydrogen can potentially support both systems, as is already taking place at Stone Edge Farm.

In May 2021, Heila Technologies was awarded a $1 million National Science Foundation grant to explore a truly decentralized microgrid architecture that revolves around peer-to-peer energy trading, integrating additional, leading functionality to the Heila EDGE platform.

The Basics of Decentralized Controls Architectures

The evolution of the Stone Edge Farm microgrid highlights the inherent value of a decentralized control architecture in adapting to incremental upgrades incorporated over time at most microgrid projects. Most often a combination of hardware and software, microgrid control systems orchestrate generation, storage, and loads, bolstering DER assets to improve resiliency and to meet economic and environmental goals. Energy markets are shifting from a reliance on large, centralized power plants to smaller, smarter, and cleaner DER assets—which include flexible customer loads and EV charging systems—and microgrid control schemes echo this shift. As Chart 1 shows, DER assets are expected to supersede centralized generation beginning in 2021, with the gap growing over time. The uptake of VRE is also expected to increase over time with contributions from both distributed and centralized resources.

Chart 1 Annual Total DER vs. Centralized Capacity by Region, World Markets: 2021-2030



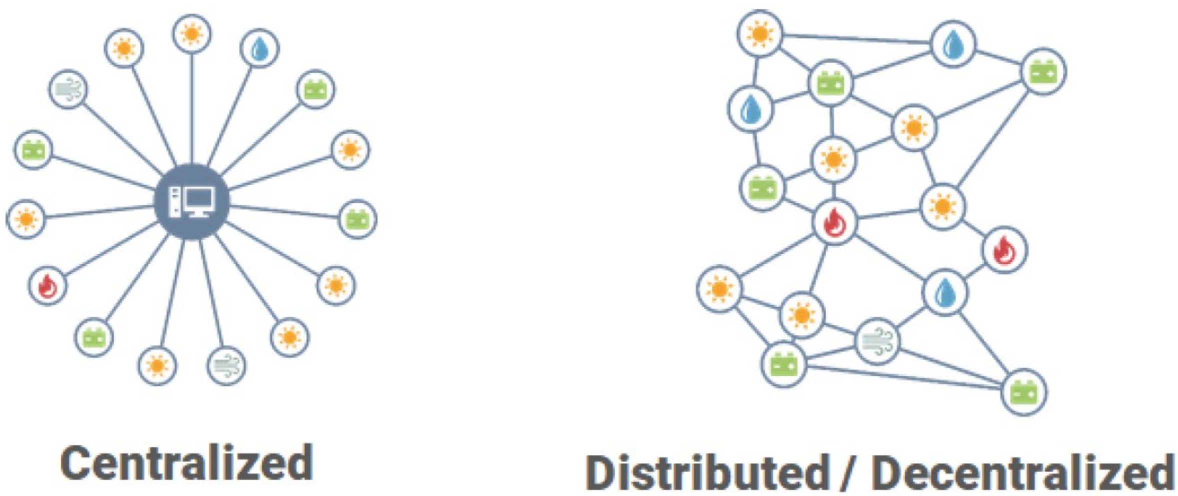
(Source: Guidehouse Insights)

As microgrids shift to a greater reliance on renewable resources, microgrid controls have responded by evolving away from centralized to distributed and decentralized systems—from top-down to bottom-up. Ironically enough, many larger, more established vendors initially theorized that a centralized approach was vital for efficient performance. One major vendor, working on a microgrid for a major utility in Texas, shared this perspective going into the project. However, they learned that increased DER diversity led to complexity challenges beyond the management ability of a centralized decision-making paradigm. Too many variables needed to be processed at once. VREs that might drop off suddenly (or start up) created latency issues. Response times from the central decision maker for balancing loads, generation, and storage simultaneously were too slow. The experience led the company to purchase its own microgrid controller company, which had been developed during military operations for smaller, more modular systems. Little did they know they had stumbled upon an insight that would soon be shared throughout the industry by innovators.

Contrasting Centralized and Decentralized Microgrid Controls

As Figure 3 illustrates, a decentralized microgrid architecture does not rely on centralized decision-making with top-down commands, with subsequent DER assets following behind this microgrid boss. The centralized approach requires complex data to flow through a single point of processing and decision-making. As the number of assets increases, latency issues hinder the ability of algorithms to capture the dynamic nature of DER assets to increase value. Both distributed and decentralized algorithms are inherently easier to scale. With a decentralized architecture, DER assets—such as generation, storage, and loads—become the fundamental building blocks of any microgrid, creating control and efficiency strategies organically. As Figure 3 shows, DER assets interact and coordinate with each other rather than receive dictates from a single command-and-control source.

Figure 3 A Centralized vs. Distributed or Decentralized Control Perspective



(Source: Helia Technologies)

One could think of the distributed or decentralized model as a more communal approach. Many engineers assumed this would lead to chaos and the inability to meet performance metrics (See Table 1). However, advances in AI and machine learning, and concepts such as game theory, have proven that such decentralized and distributed systems are more than capable of efficiently orchestrating diverse assets in real time, avoiding the latency issues that plagued early centralized control microgrid applications.

Game theory, a principle that serves as a foundational element of Heila Technologies's control solution, originated several decades ago. It is grounded in mathematical models for strategic interactions among rational decision-makers. In the case of microgrid controls, these models allow for decentralized dispatch and self-governing, pre-programmed actions of DER assets to contribute to overall microgrid performance. These distributed and decentralized algorithms have been recognized and developed in academia for many decades now. However, their implementation has been limited due to their dependency on the distributed computational architectures that have only recently become available in microprocessors and in the cloud. Consequently, most control and efficiency solutions for microgrids have taken the more straightforward, centralized approach.

The common industry perceptions of advantages of centralized control were outlined in an Asian Development Bank (ADB) publication, *Handbook on Microgrids For Power Quality and Connectivity,* published in July 2020.[1] The ADB only ranked decentralized systems higher than centralized on a single metric: complexity of multi-ownership and competition. Ironically, it is these features that are advancing what microgrids can do in today's increasingly diverse and competitive markets as interest in peer-to-peer energy trading and multi-customer microgrids grows. The Heila EDGE platform has debunked four myths the ADB noted (see Table 1) as challenges for decentralized systems, solving these issues first at Stone Edge Farm and then at a series of microgrid and virtual power plant (VPP) projects throughout the US.

Table 1 Debunking Myths About Decentralized Controls

Assumption About DER	EDGE Counterpoint
Lack of Clear Objective for Whole Microgrid	A decentralized microgrid architecture can marshal DER assets to any goal, it just uses a different pathway to meet these objectives.
Optimal vs. Sub-Optimal Solutions	Thanks to self-learning algorithms, a decentralized controls approach is better designed to find the most efficient solution, avoiding the latency issues that plague many centralized systems.
Islanding and Ease of Synchronization to the Utility Grid	Decentralized systems can orchestrate renewable DER assets more quickly than centralized systems, with the latter often resorting entirely to fossil fuel generators during islanding events.
Possibility of Online Operation and Optimization	Decentralized controls are ideal for this purpose since DER assets are self-organizing and can be improved elegantly through internal market mechanisms steered toward efficient results.

(Source: Guidehouse Insights)

Most of microgrid capacity, particularly larger projects interconnected with the traditional utility grid, relies on a hybridized controls strategy, incorporating aspects of both distributed instantaneous device controls and a hierarchy overlay for longer-term decision-making. In terms of sheer numbers, however, distributed controls technologies (such as inverters) dominate the numerous kilowatt-scale systems for remote power applications. This is not the case for all remote power applications, as remote island microgrids lean heavily on distribution automation and SCADA systems.

With the ability to run both directly on-premise or through a cloud-based platform, a decentralized architecture for controls provides a flexible and scalable way to securely collect data, configure DER and systems for tailored programming, visualize performance in real time, and monitor the system's components for faults and alerts. The fundamental change resides in the decentralized nature of the algorithms. Under this emergent intelligence paradigm, each DER independently calculates its most effective schedules and setpoints, forming a distributed intelligence network. Game theory-based techniques automatically coordinate their behavior to work toward economic and technical system-level goals.

Under this emergent intelligence paradigm, each DER independently calculates its most effective schedules and setpoints, forming a distributed intelligence network.

The other advantage of anchoring a microgrid control architecture with a decentralized structure is flexibility. If necessary, one can move toward a more hierarchical architecture for a specific project's DER asset mix or application, or to incorporate legacy equipment. One cannot do the opposite with a

[1]Asian Development Bank, *Handbook on Microgrids for Quality and Connectivity,* 2020.

centralized microgrid controls architecture. In short, distributed or decentralized controls can be deployed in configurations to meet any microgrid's needs.

Flexibility, a Key Advantage of Distributed Controls

What is the difference between distributed and decentralized controls? A distributed system, which is much more common today, still has a central clearinghouse that serves as a market operator. While intelligence is pushed out to a grid's edge at the individual device level, there is still a single entity serving as, essentially, a traffic cop. In a decentralized system, all transactions are peer-to-peer, and no such higher authority exists. While such peer-to-peer trading has been conducted on a pilot basis for microgrids, VPPs and other DER asset aggregations, existing utility regulations and relationships, and existing market structures for provision of grid services are all still centered around having a market operator. A truly decentralized system probably makes the most sense in remote microgrids that would never sell a service to an outside entity. In this circumstance, a distributed controls system would maximize the value from internal assets, especially if DER assets were owned by multiple parties in a microgrid serving an entire community. This is the space where a truly decentralized grid architecture and controls scheme would offer the most value, democratizing the provision of energy for residents, businesses, and institutions alike.

The other advantage of anchoring one's microgrid control architecture with a decentralized structure is flexibility.

Though Stone Edge Farm launched the decentralized architecture, its microgrid could be considered distributed since all resources of the microgrid are shared among all loads at the farm. In that sense, the farm is akin to a campus microgrid since there is a single customer. (The next section provides more detail on this microgrid's specific challenges and solutions.) The decentralized architecture was particularly useful for Stone Edge Farm in integrating eight different manufacturer batteries and nine inverter types into a single microgrid. Since the DER assets are not co-located with specific loads, but rather contribute to the pool of resources that serve the entire farm's operations, the architecture leans on innovations that enable a decentralized architecture that prioritizes serving the entire farm over individual loads.

Conclusion: Future Microgrid Control Trends

Microgrid control vendors previously sought to lock customers in to their products and services for the long term, committing clients to arrangements that precluded them from switching to a competitor. Despite this intent, multiple technology vendors are usually involved in microgrid deployments. Most microgrids—especially large and complex microgrids—feature hardware components, and perhaps software, from a variety of vendors. Proprietary end-to-end offerings might have initially seemed like a good strategy, but customers are looking for more choice and flexibility. Here are a few key trends to monitor as this market matures.

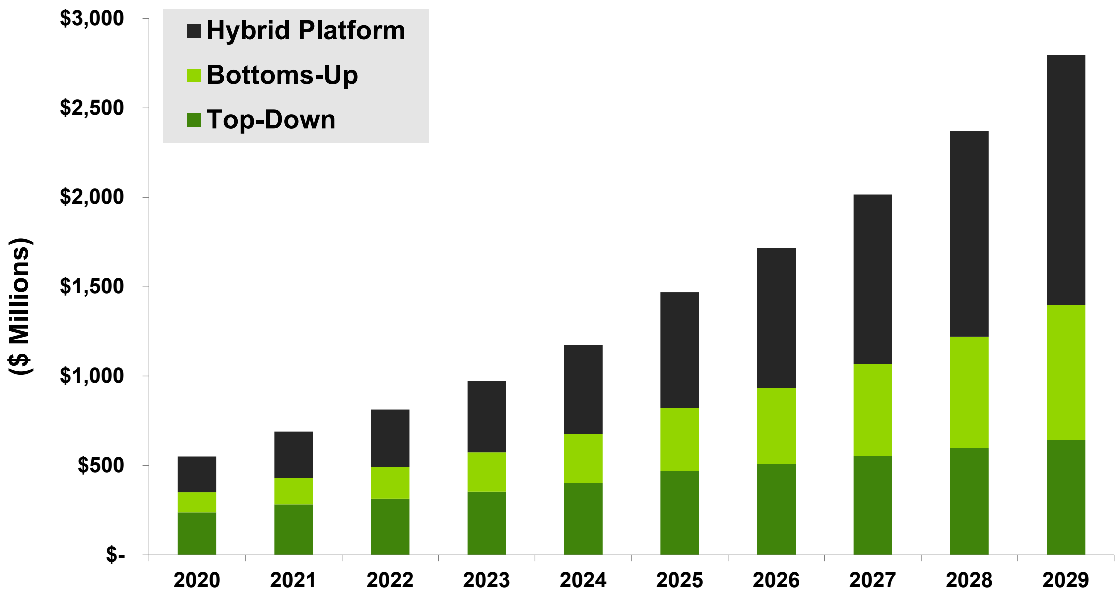
Open Source Controls

One effort to resolve the issue of interoperability is being led by the Linux Foundation. Inspired by interoperability achievements in computing, LF Energy is an ongoing project supported by the foundation. This project has developed an open source controls platform at the FREEDM microgrid located at North Carolina State University in Raleigh. Open source software (OSS) is software with source code available to anyone to inspect, modify, and enhance. In the case of open source microgrid controls, creating a platform becomes a community effort, enhancing cybersecurity based on the premise that greater exposure leads to quicker bug fixes. The idealistic goal of the LF Energy project is to apply the transformative power of OSS to electricity sources, accelerating the transition to a decarbonized power grid.

Consensus Emerging on Hybrid Controls

As Chart 2 shows, top-down approaches lead the market today but are expected to fall increasingly out of favor over the next decade. Bottom-up approaches are expected to gain market share in the future, but it is the hybrid approach that is anticipated to emerge as the market leader by the end of the forecast. These hybrid systems, though, in part relying on a central decision-maker for longer-term goals, are expected to increasingly push as much intelligence as possible out to the grid's edge. The hybridization will be made possible by cloud-based data analysis. In many cases, microgrids connected to a distribution network will likely be able to leverage weather forecasts and real-time market data for internal asset value enhancement as well as external market value creation.

Chart 2 ***Microgrid Controls Spending by Fundamental Controls Approach, World Markets: 2020-2029***



(Source: Guidehouse Insights)

The Pros and Cons of Cloud-Based Analytics

Customizing microgrids with cloud-based software is also an important trend. While offering tremendous cost efficiency and flexibility, there are downsides to complete reliance upon cloud-native technologies. For example, Heila Technologies had been asked to revive a project by a cloud-based startup that went bankrupt. The only way to get that project operational would be to hack into the system. Though Heila Technologies does use the cloud for some higher-level efficiency, the company relies on two internet providers for these cloud services as a form of virtual resiliency. (A similar approach has been deployed by major data centers, which may be co-located where they interconnect with two different utilities.) The value of the cloud cannot be overstated, but it does pose risks as well. Cloud-based data analytics offer advantages for cost, making it one of the primary drivers for the microgrid industry's movement toward a hybridized control solution.

Distributed and Decentralized Is the Future

Decentralized and distributed systems that can harness the efficiency of device-level intelligence are needed as DER assets make up a larger and larger portion of our total energy supply.

The push for more sustainable and resilient systems will critically increase the need for proper DER coordination and control at scale. The algorithms responsible for managing these large fleets of smart and controllable devices at the grid edge should be prepared for a future where hundreds of millions of them will be operating simultaneously at any given time, a complex scenario that most of these devices have not been designed to handle.

To address this exponential growth in diverse DER assets anticipated to populate power grids throughout the world, here are five emergent intelligence concepts that can guide the microgrid industry toward developing a more sustainable and scalable microgrid controls solution ecosystem:

- **Allow intelligence to grow with the microgrid as it expands in scope and size:** Every time an agent (DER or controllable device) is installed in the grid, a new point of data-processing and decision-making should be added so the system's capabilities can increase over time.
- **Simplify decision-making:** Since decisions to guide microgrid operations are local on an agent-by-agent basis (each agent being an individual DER asset), simplified messages that can be sent peer-to-peer facilitate new, transactive energy business models. No single agent incorporated into the microgrid needs to know the energy available in every battery in the system—just the status of those agents that matter when scheduling, controlling, and improving efficiency in real time.
- **System architecture flexibility:** As DER growth spreads throughout the world with varying degrees of uptake, customers will inevitably seek a greater diversity of microgrid configurations—behind-the-meter and front-of-the-meter, all-renewable portfolios and hybridized renewable and fossil systems, incorporation of EV charging, and the provision of thermal energy. Controls platforms need to be agnostic to system architecture required or preferred by the client. With a distributed and decentralized algorithm approach, architectures themselves can become more flexible to accommodate customer needs.

Decentralized and distributed systems that can harness the efficiency of device-level intelligence are needed as DER assets make up a larger and larger portion of our total energy supply.

- **Remain technology agnostic**: Though many large vendors seek to sell generation or energy storage devices as part of a complete microgrid package, controls platforms should remain technology agnostic to address customer needs and future-proof the system. Whether a project integrates legacy resources or features all new DER assets, an ideal decentralized controls platform allows agents to hide the complexity of underlying DER assets, creating equalized space for any type of energy storage, generation, or load control. Increased numbers of manufacturers add to the complexity of this challenge, but interoperability is vital for the microgrid market to become fully commercialized.
- **Rapid response to changing weather and market conditions as overarching need**: Autonomous DER operating as part of a larger network can respond rapidly and efficiently to first meet the local needs of the microgrid. They can then look out at the larger needs of the surrounding distribution and transmission grid, balancing the system before problems escalate to cause larger, systemwide events that a system operator (such as the CAISO) would need to respond to. Quick responses—and the right responses—are paramount for the microgrid to meet its prescribed performance metrics and serve as a good neighbor to the larger grid network.

Acronym and Abbreviation List

ADB .... Asian Development Bank

AC .... Alternating Current

CAISO .... California Independent Systems Operator

DER .... Distributed Energy Resource

DC .... Direct Current

EV .... Electric Vehicle

OSS .... Open Source Software

VPP .... Virtual Power Plant

VRE .... Variable Renewable Energy

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Scope of Study

This white paper was sponsored by Heila Technologies and focuses on the development of a distributed or decentralized microgrid controls platform that was launched at the Stone Edge Farm microgrid in Sonoma, California. It highlights emerging challenges facing microgrids as they increase renewable energy uptake and solutions based on shifts in the global microgrid industry toward platforms that are flexible, scalable, and able to reduce the overall cost of microgrids.

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