SkySpark® – An Analytics Driven Energy Management System for EV Charging

Addressing EV Charger Uptime from an Energy Management Perspective

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Introduction

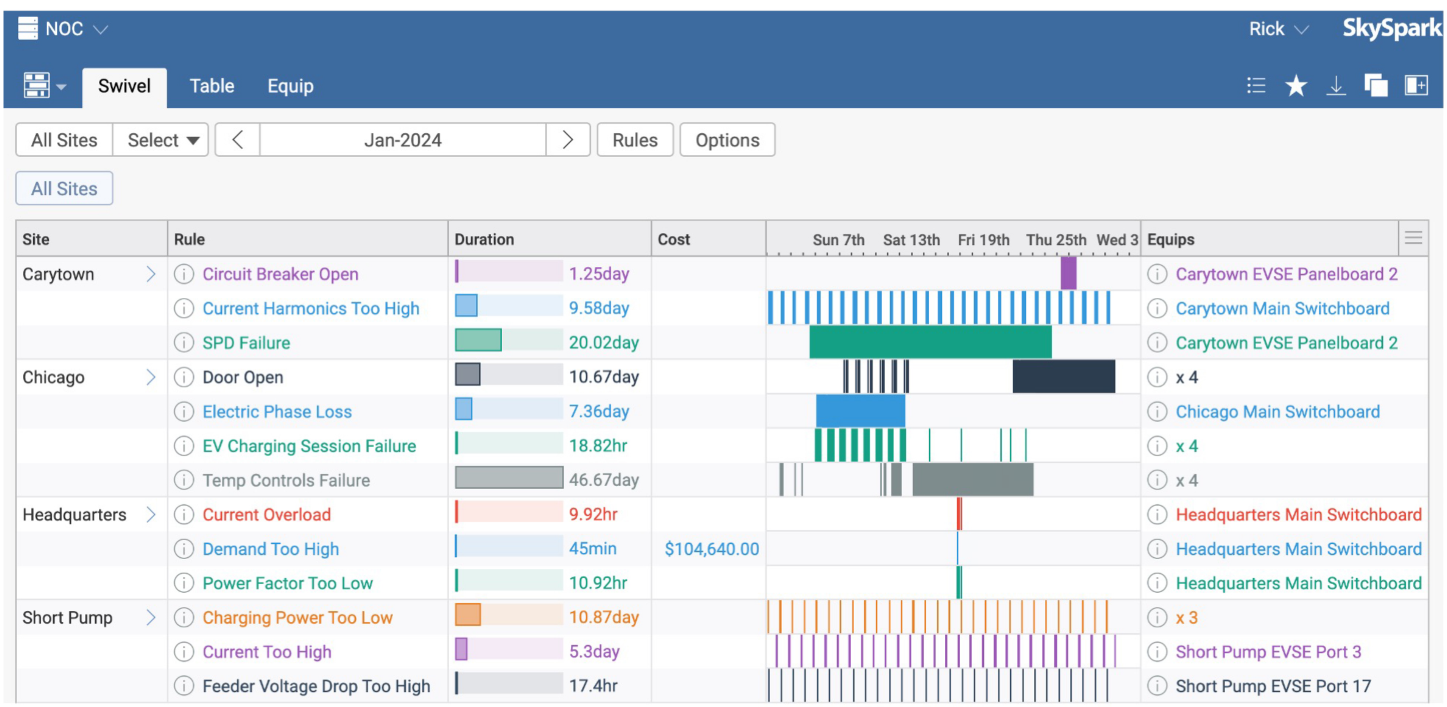
Electric vehicle (EV) adoption is well underway and the need for reliable EV charging infrastructure has never been greater; yet EV chargers are notoriously broken or not delivering their expected power, which is reducing the confidence of prospective EV buyers and creating nightmares for EV charging operation managers.

Hidden in the data exchanged with EV chargers, surge protection devices (SPDs), circuit breakers, and electric meters are answers to questions to help solve these problems. The challenge is how to extract the data, use it to cost effectively "find what matters", and then take corrective actions using those insights on a project-by-project basis.

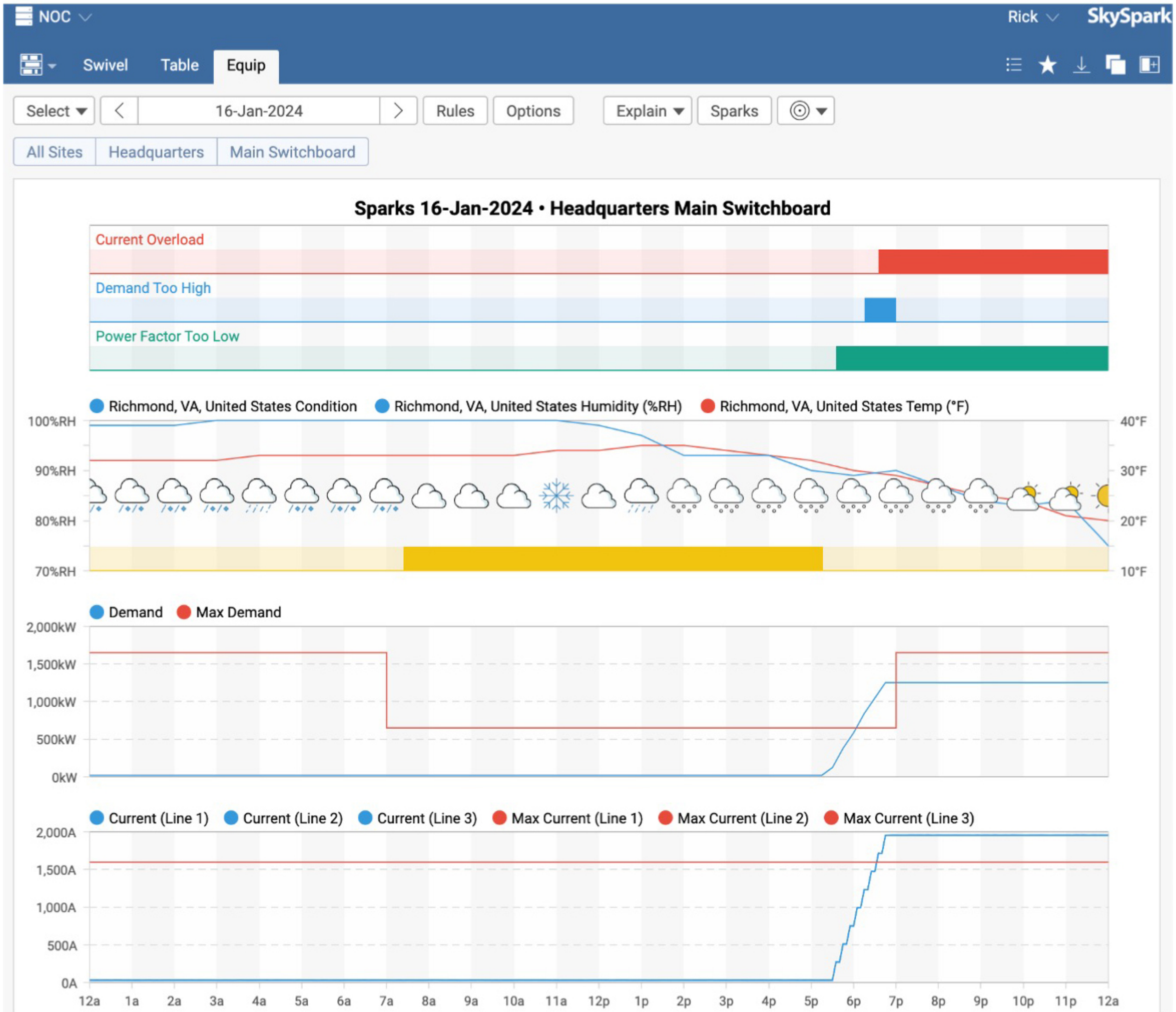
In this paper we will introduce SkySpark, an analytics-driven energy management system (EMS) for management and optimization of EV charging, as a solution to help address these challenges and more.

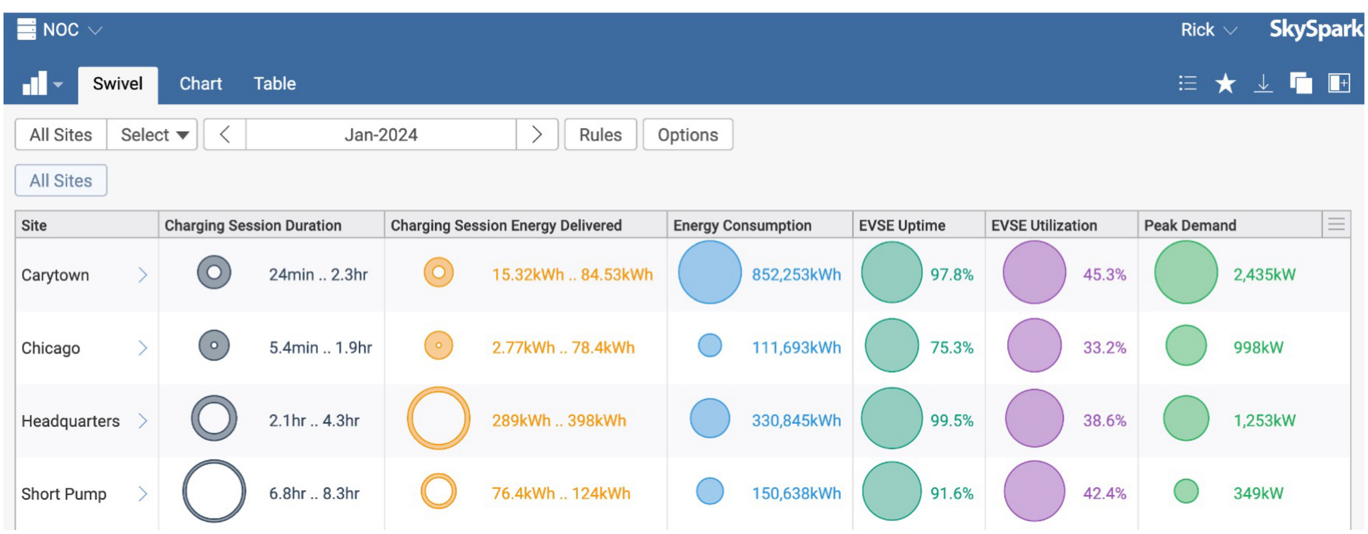
The Role of an Analytics Driven EMS

An analytics-driven EMS for EV charging ensures that energy is delivered to electric vehicles as expected while avoiding circuit overloads and exceeding target demand limits. It continuously calculates key performance indicators (KPIs) and identifies equipment faults, we call them "sparks", and communicates those results to operators and managers in a meaningful way. When expectations are not met, it can show exactly what went wrong in an EV charger, building, or microgrid and even show raw data to eliminate bias.



Imagine having a legion of engineers constantly surveying and engaging with these equipment systems to verify and optimize their performance – that's what it is like to have an analytics-driven EMS for EV charging.





Site	Charging Session Duration	Charging Session Energy Delivered	Energy Consumption	EVSE Uptime	EVSE Utilization	Peak Demand
Carytown	24min .. 2.3hr	15.32kWh .. 84.53kWh	852,253kWh	97.8%	45.3%	2,435kW
Chicago	5.4min .. 1.9hr	2.77kWh .. 78.4kWh	111,693kWh	75.3%	33.2%	998kW
Headquarters	2.1hr .. 4.3hr	289kWh .. 398kWh	330,845kWh	99.5%	38.6%	1,253kW
Short Pump	6.8hr .. 8.3hr	76.4kWh .. 124kWh	150,638kWh	91.6%	42.4%	349kW

Key Features

Let's review key features of an analytics-driven EMS. Remember that no project is the same and not all available features will be required on every project.

Communication protocol features:

1. Support the role of an OCPP Local Controller
2. Connectors for OPC-UA, BACnet, Modbus TCP/IP, and MQTT

Supervisory control features:

1. A Charging Station Management System (CSMS) based on the Open Charge Point Protocol (OCPP) may control EVSE port load setpoint values
2. Resolve contention between various applications vying for control of the same data point
3. Verify electrical codes are being followed and override setpoints as necessary
4. Incorporate basic, well understood EV charging load management algorithms (e.g., Equal Share and First In, First Out) for when the EMS must override setpoints

Data access features:

1. Expose tagged data over a highly secure Project Haystack defined REST API
2. Sparks, KPIs, and other data unique to SkySpark may be exposed over SkySpark's REST API, which is a superset of Project Haystack's REST API

Other features:

1. Capable of being deployed on a desktop computer or field-installed hardware without a required internet connection
2. Make weather data accessible
3. Normalize data using Project Haystack tagging conventions
4. Ability to customize rules and KPIs
5. Communicate KPI and Spark results in a meaningful way
6. Provide a "Tariff engine" to allow for modeling every electric utility's unique rate schedules
7. Ability to create custom views and tools
8. Support onboarding data points from microgrid and building systems
9. Allow for ad hoc data analysis via a timeseries database and charting tool

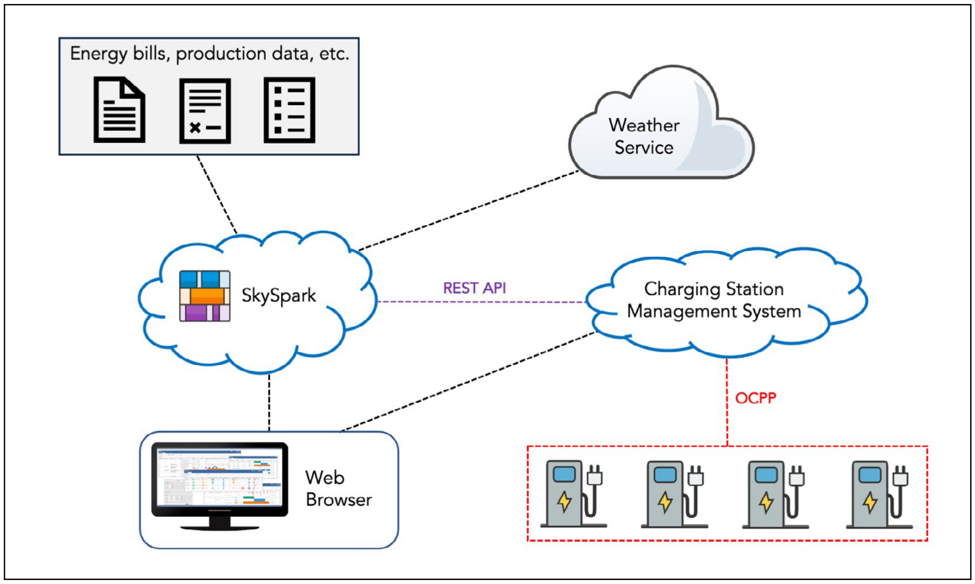
Deployment

An analytics-driven EMS is intended to augment a Charging Station Management System based on the Open Charge Point Protocol (OCPP).

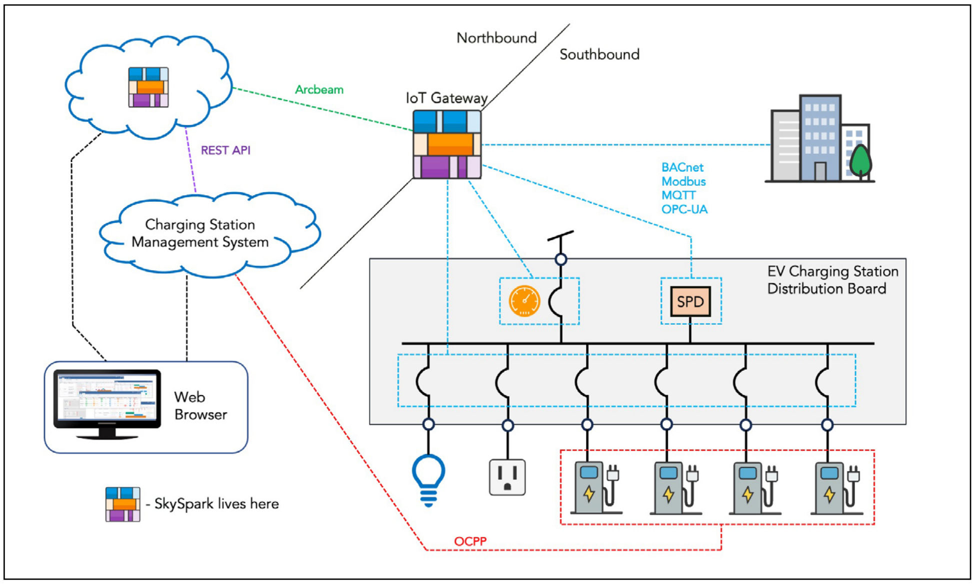
There are four deployment scenarios for an analytics-driven EMS that we will highlight. The applicability of these scenarios depends on project requirements and available hardware and software products at a site.

Deployment scenarios 2, 3, and 4 below mention Arcbeam. Arcbeam is SkyFoundry's highly secure binary protocol layered over WebSockets that is used to implement clustering. Arcbeam uses a multiplexing design to allow multiple application channels to share a single socket efficiently. Once an Arcbeam connection is established it is peer-to-peer. This allows Arcbeam to work through firewalls with no special network configuration. A typical example is an edge device behind a firewall with no public IP address which initiates connections to a public IP address running in the cloud.

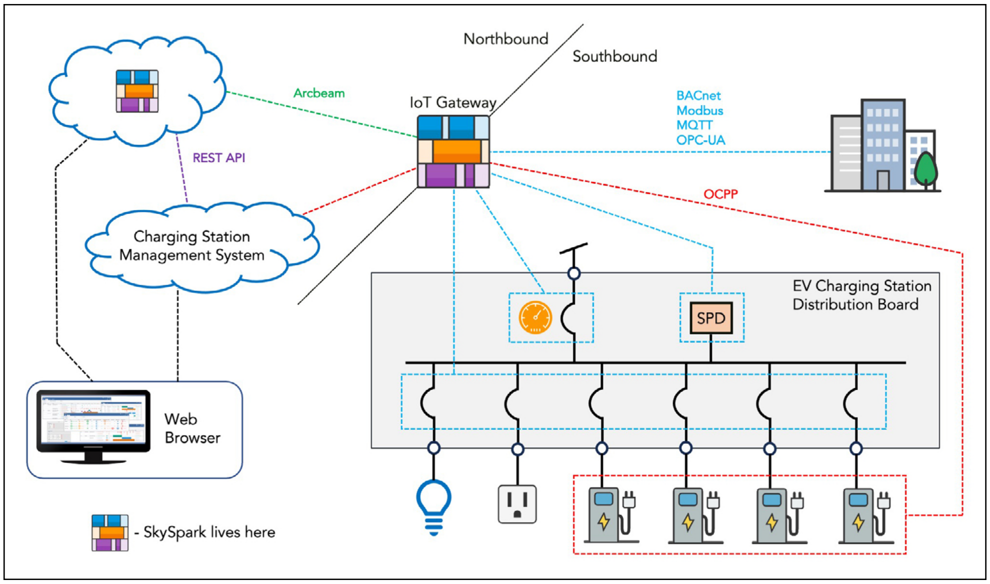
Scenario #1*: Using an analytics-driven EMS for Fault Detection and Diagnostics (FDD) and KPI, energy and other reporting*



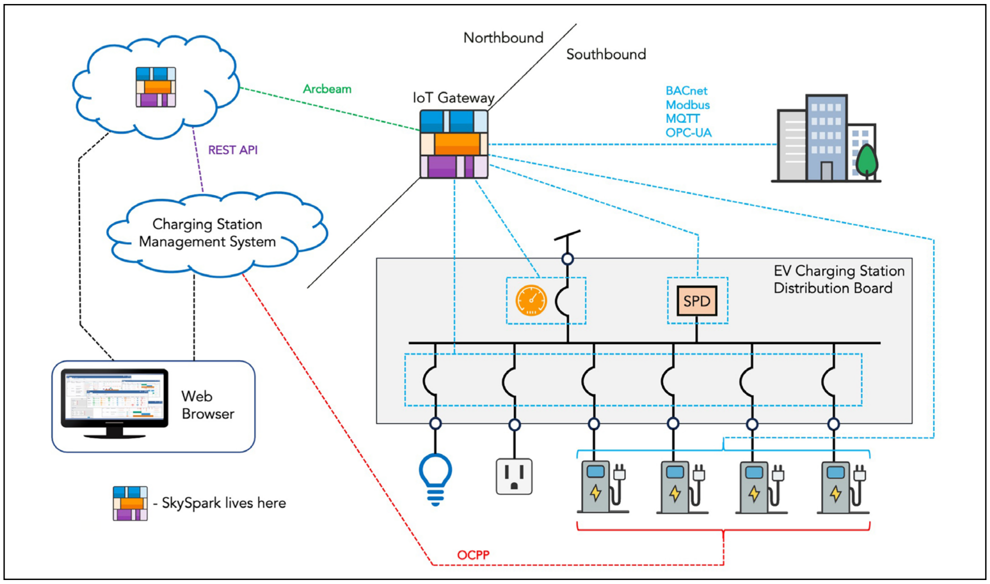
Scenario #2*: Applying an IoT gateway that does not control EVSE loads due to missing conduits and cabling on site (may also include features described in Scenario #1)*



Scenario #3*: Applying an IoT gateway that performs local control of EVSE loads via OCPP (may also include features described in Scenario #1)*



Scenario #4: Applying an IoT gateway that performs local control of EVSE loads via Modbus or OPC-UA (may also include features described in Scenario #1)



Next, we will review motivation for some of these product features and deployment scenarios.

Achieving Capital Expenditure Savings

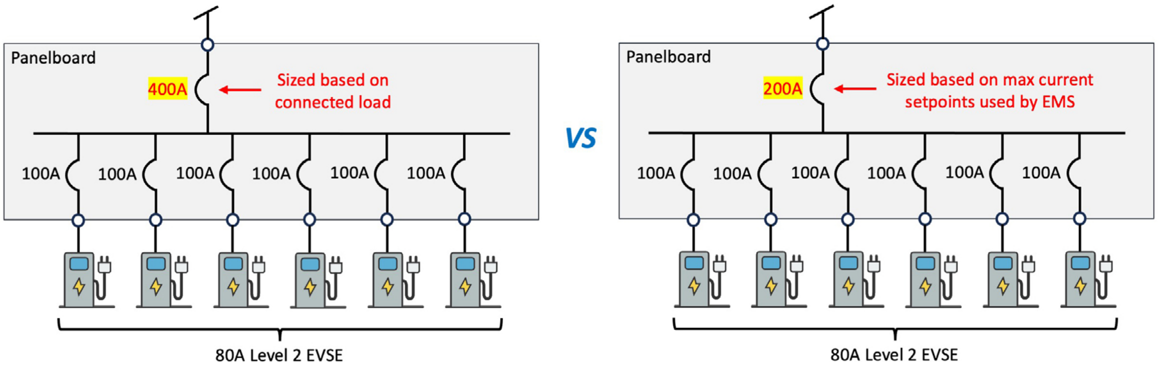
Typically, electrical codes require sizing electrical equipment and wiring using the maximum input amps of the connected loads. An Energy Management System (EMS) offers significant capital cost saving opportunities when installing EV chargers by allowing for sizing electrical equipment and wiring using maximum amp setpoint values instead. Note that these opportunities are subject to local electrical code and application requirements.

Let's illustrate these principles in the two examples below.

Example #1 *– Reducing the ampacity of a distribution board*

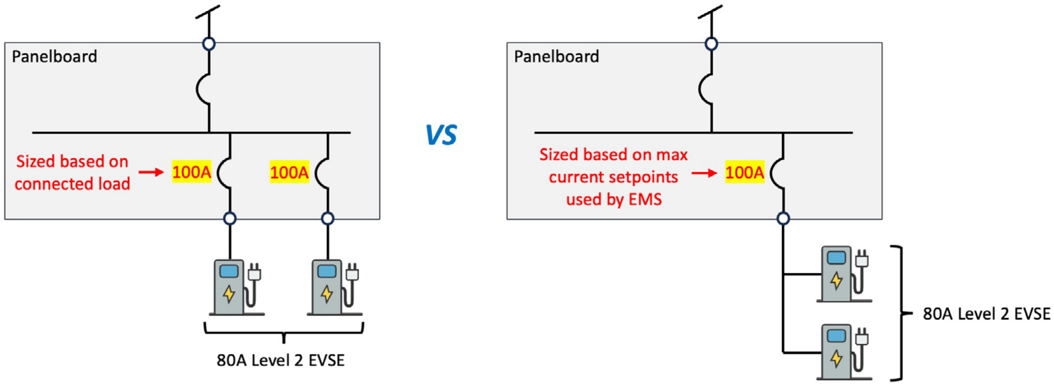
An EMS may be used to limit current on a distribution board's primary bus so that it does not exceed its maximum amp setpoint values. For example, a 200-amp panelboard with an 80% rated main circuit breaker may be installed instead of a 400-amp panelboard with an 80% rated main circuit breaker to power six 80-amp Level 2 AC EVSE UL if the EMS ensures the panelboard's primary bus does not exceed 160 Amps on all three phases.

In this example a 50% reduction in the panelboard's ampacity is achieved by using an EMS, which translates to potential physical space and money savings for the panelboard. Also, the described EMS reduced the size of the panelboard's input feeder and may have even helped avoid an upstream switchboard upgrade.



Example #2 *– Powering multiple EV chargers with a single circuit breaker*

An EMS may be used to limit current through a single circuit breaker so that it does not exceed its rating. For example, one 100A circuit breaker may be installed to power two 80A Level 2 AC chargers instead of two as shown in the below figure.



Once the system is installed, it will cost a lot of money to go back and redo anything! In conclusion, it is essential to consult with local authorities, electrical inspectors, engineers, electric utilities, and other experts to carefully design electrical systems based on EMS setpoints to ensure:

1. EV charging application requirements are satisfied
2. Sensor data is available to validate max setpoint values are not exceeded

Reducing Electric Utility Costs

In the United States alone there are around 3,000 electric utilities and over 30,000 different rate structures. Now imagine how many electric utilities and rate structures there are throughout the world! SkySpark addresses this challenge with a built-in powerful and flexible tariff engine to compute the current cost of electricity.

Many of these rate structures in commercial applications have three primary factors that influence costs over a billing period:

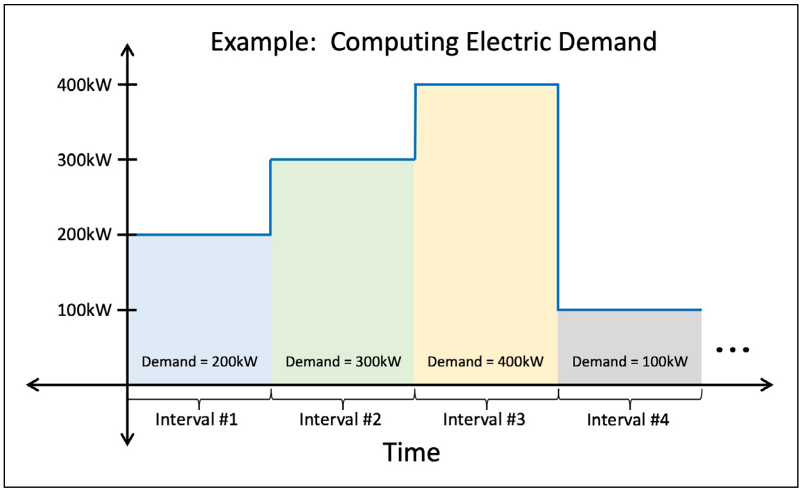
1. Total energy consumption
2. Peak demand
3. Power factor

These costs may also vary depending on the season, time of day or calendar day.

The electric utility typically has their own metering equipment used for billing at the point of demarcation, or the dividing line where the responsibility of equipment ownership transfers from the electric utility to a commercial entity. For electric utility cost optimization it is crucial to understand that exactly at this transitionary location is where it matters the most. And at this location it is important to consider the aggregate of power delivered to electric vehicles, EVSE power losses, and power to support other loads on the same utility service.

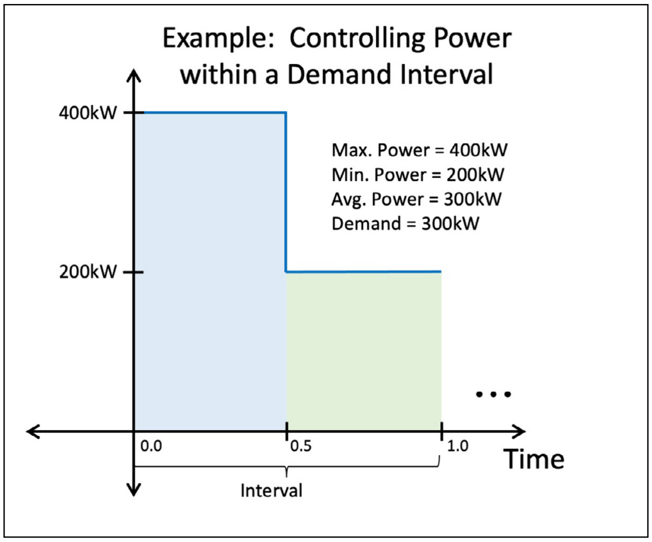
Load setpoints on EVSE ports may be optimized to minimize energy losses and maximize power factor, thereby reducing electric utility costs. However, often there is a more significant opportunity to reduce electric utility costs by reducing peak demand.

Electric demand is the average instantaneous power over a rolling interval (e.g., 5-minute, 15-minute, and 30-minute) defined by the electric utility. It can be determined by computing the area under a curve between the start and end times for each interval. Let's look at a simple example that does not require calculus in the below diagram.



After demand for every interval within an electric utility's defined bill period is captured, the peak demand used for billing can be determined by finding the highest demand within the bill period. For the bill period in the above example the peak demand would equal 400kW assuming all other not shown intervals did not have a demand that exceeded 400kW.

Within an interval it is possible to have instantaneous power values that exceed the interval's demand used for billing. Therefore, software controls may be applied to respond to excessive power draw to avoid establishing a new peak demand value used for billing as shown in the below diagram.



There may be another important aspect to how peak demand is applied in the electric utility's bill calculation called a demand ratchet. A demand ratchet is a billing policy imposed by the electric utility that uses whichever is greater:

1. Actual peak demand for the billing period
2. A percentage of the highest peak demand reached during the previous specified number of billing periods (e.g., 90% of the highest peak demand over the previous 12 billing periods)

A demand ratchet means that incorrect equipment operation within one short interval (e.g., 5-minute, 15-minute, or 30-minute) may determine peak demand used in the next 11 electric utility bills!

For example, let's consider what are the additional demand charges incurred if the target maximum total demand is exceeded by 600kW in a single event. In this example (Table 1) it is assumed that the cost per kW is $16 and that a demand ratchet using 90% of the highest peak demand over the previous 11 billing periods is in effect.

In summary, we reviewed factors that influence the electric utility bill that the analytics-driven EMS should consider. Though the key takeaway here is that the electric utility cost optimization strategy for EV charging strongly depends on one of many electric utility rate structures. An analytics-driven EMS may consider specific rate structures to define setpoint values in a way to minimize electric utility costs or to validate controls performed by other software are meeting defined objectives or both.

Table 1.

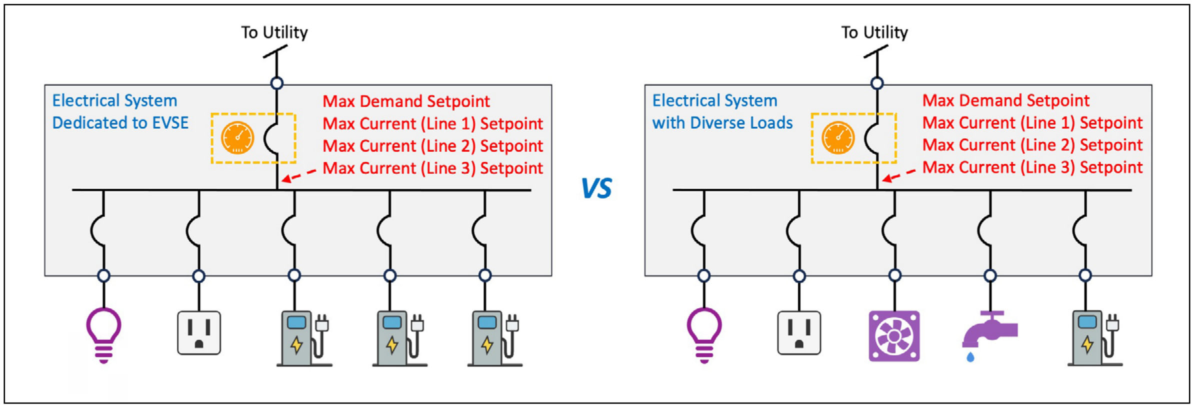
Bill Period	Additional Cost
1	$9,600
2	$8,640
3	$8,640
4	$8,640
5	$8,640
6	$8,640
7	$8,640
8	$8,640
9	$8,640
10	$8,640
11	$8,640
12	$8,640
Total	**$104,640**

A Review of EMS Setpoints in Various Electrical Systems

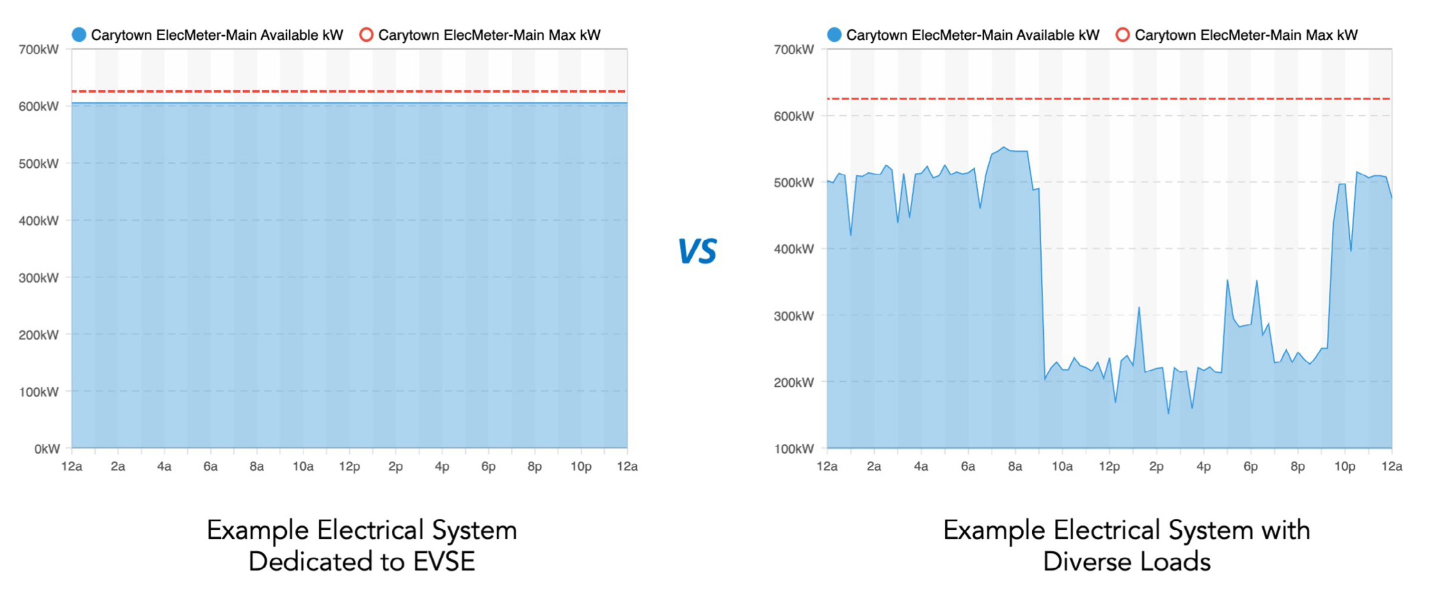
Now let's dive deep into setpoints used by the EMS in various types of electrical systems.

There are two types of electrical systems to be aware of which are illustrated with examples in the below diagram.

1. An electrical system dedicated to EVSE and its auxiliary loads
2. An electrical system with diverse loads, including EVSE



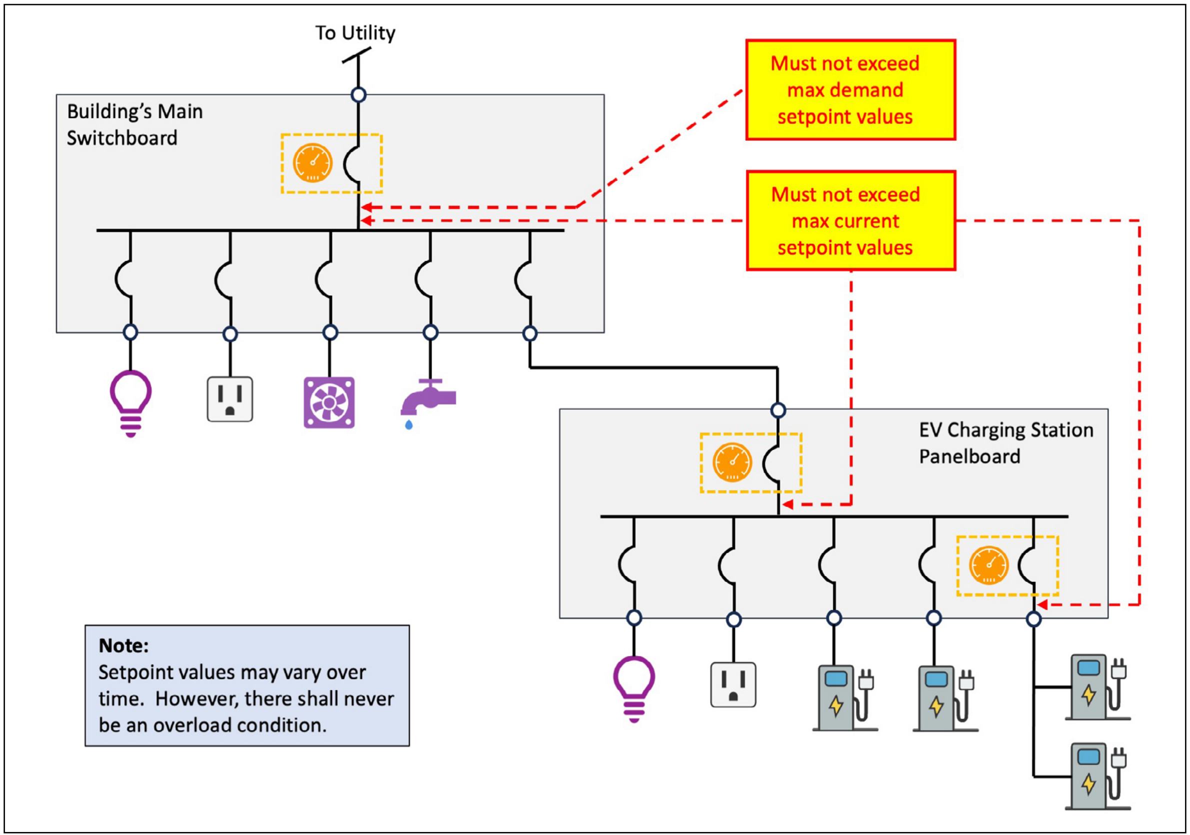
Both examples show the same setpoints. However, the strategies for defining the setpoint values will depend on the types of loads within the electrical system, EV charging application (e.g., workplace, fleet, multifamily housing, public charging, etc.), charging schedule, and maybe even the building schedule. Generally controlling EVSE load setpoints within an electrical system that has diverse loads will be considerably more complex as reflected in the examples in the below figure.



Example Electrical System Dedicated to EVSE

Example Electrical System with Diverse Loads

Also, there is a possibility to have cascading EMS setpoints in either type of electrical system, which adds another layer of complexity. In this case we would need ensure that setpoints are being followed throughout the entire electrical system. For example:



The Role of Electric Metering

Strategically applied customer owned electric metering plays a key role in the analytics-driven EMS. Specifically electric metering allows for using sensor values instead of computed values to verify that the EMS setpoint values mentioned earlier are being followed. There are other details, use cases, and benefits which we will review.

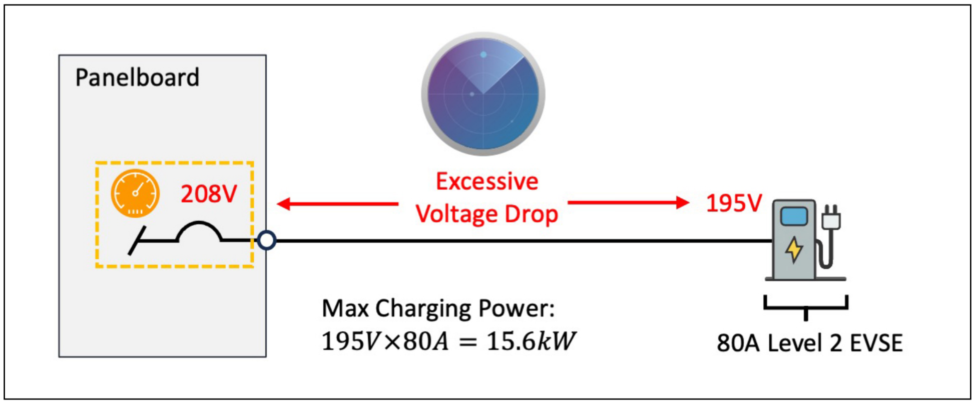
1. *Detection of Level 2 AC EVSE phase connection mismatch*
   If there are single phase input Level 2 AC EVSE then the site control algorithm relies on electrical phase connection metadata (e.g., Line 1 to Line 2, Line 2 to Line 3, and Line 3 to Line 1), which may easily be inaccurate by a mistyped form or incorrect field commissioning. Afterall verifying electrical connections used by control algorithms would require safely looking at input wire connections at both ends, involving time intensive, skilled labor.

2. *Measuring EV charging efficiency, power factor, and harmonics*
   Often EVSE do not report data via OCPP on their efficiency, power factor, or harmonics. Also, the EVSE manufacturer's technical specifications may rely on assumptions such as full load operation. Data points from additional electric metering may be used to detect equipment not performing according to expectations or to help devise control strategies for more optimal performance or both. For example, there may be certain setpoint values on EVSE ports that result in higher efficiency of power conversion or lower current harmonics.

3. *Validating quality of incoming power from the electric utility*
   Customer applied electric metering near the point of demarcation allows for validating the quality of power received by an electric utility. Several examples of patterns that electric metering may detect include:
   a. A blown fuse on the utility's side of the interface resulting in two phases of incoming power instead of three
   b. Incoming voltage outside of the expected range
   c. Excessive incoming current harmonics.

4. *Accounting for voltage drop on feeders to EVSE*
   The maximum charging power that an EVSE may deliver is a function of its efficiency and input voltage and current. Charging power may be derated to avoid current overloading circuits if the input voltage to the EVSE is too low. And voltage drop on an EVSE's input feeder, which is based on the length and size of its wires, may contribute to the EVSE's lower input voltage.

   Metering in the panelboard shown in the example below would allow for accounting for the input feeder's voltage drop to help manage EV charging expectations or to even identify excessive voltage drop which should have been addressed in the electrical design.



5. *Reducing assumptions*
   Computed values used to validate EMS setpoint values require the use of assumptions on energy losses, voltage drops, etc. Inaccurate assumptions could result in missed opportunities from being too conservative, violating electrical codes, exceeding a target demand limit, or even the slow deterioration of electrical components or wires which may lead to their eventual catastrophic failure.

6. *Electrical code considerations*
   For example, the National Electrical Code 2023 used in the United States indicates that the EMS must use monitoring and controls to automatically cease current if the EMS malfunctions. Using electric meter sensor values to determine and validate EMS setpoint values helps achieve these required capabilities.

7. *Managing average power within a demand interval*
   Granular sensor data from electric metering near the point of demarcation allows for tracking average power within each demand interval. This data assists the controls application to make setpoint value change decisions to ensure the maximum total demand setpoint value is not exceeded.

8. *Electrical capacity planning*
   Electric metering provides insights on available electrical capacity at different times of the day which may help schedule EVSE loads. There may also be benefits to collecting data from electric meters prior to having EVSE loads installed.

   For example, in existing electrical systems, electric metering may help identify available electrical capacity for EV charging and provide data to help justify adding electrical capacity.

9. *Insufficient metering data from the electric utility*
   Often when utilities offer timeseries electric data, it is based on a 5-minute, 15-minute, or 30-minute rolling interval. Electric meters that may report power, voltage, and current sensor values for different phase combinations at a one second interval or even less are desired for an analytics-driven EMS.

10. *Additional benefits*
    Electric metering creates access to more data points that may be used by the analytics-driven EMS in many other applications. For example, site electric power points used with weather data may identify when EVSE humidity and temperature controls are inactive or active when they should or should not be. Another key reason to get the data is to try to anticipate the questions we may want to later answer with our data.

In summary, electric metering for an analytics-driven EMS is used to establish and validate EMS setpoint values. There are other benefits of having strategically placed electric metering that help justify the additional costs to install and maintain them.

Exercising Setpoint Control On-Site and Why It Matters

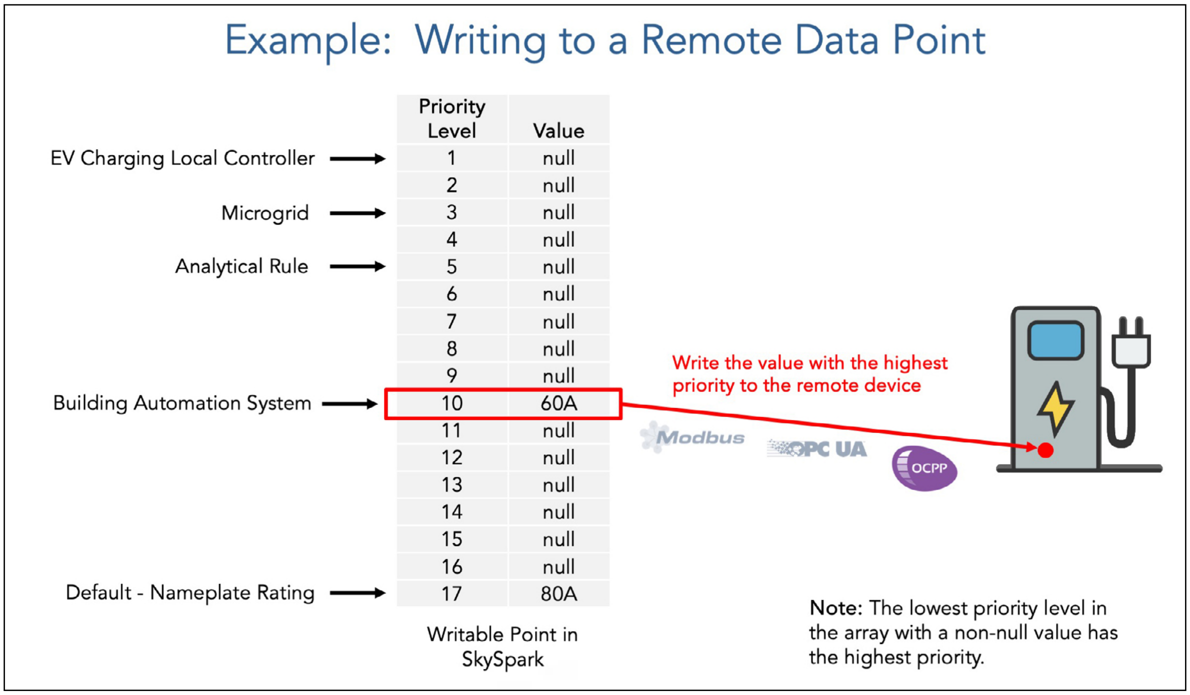
There is a high volume of sensor and setpoint data that may be required for an analytics-driven EMS for EV charging, especially if there are integrations with microgrid or building systems. Transmitting all this information by cellular connectivity results in higher data transfer costs and latency that could impact system performance. Also, EV chargers that lose cellular connectivity to a cloud based CSMS may require applying conservative fallback settings to avoid overloading circuits or exceeding target demand limits. This could severely impact the EV driver experience.

Fortunately, SkySpark supports locally exercising control of data points as shown earlier in deployment scenarios #3 and #4. SkySpark models writable points using a 16-level priority array with default level 17. The priority array allows for up to 16 different applications to control the same data point. The lowest level priority in the array with a non-null value has the highest priority and its value is written to the remote data point.

For example, CSMS, microgrid, EV charging local controller, and Building Automation System (BAS) applications may want to control the same data point. SkySpark's writable point provides a mechanism for each of these applications to have control of a single level of the writable point's priority array. This requires the system integrator to rank the priority of the applications, which often vary project-by-project. Analytical rules that consider all these applications at once may even be used to define priority array level values.

Writing to a remote data point is made possible by SkySpark's built-in connectors (e.g., Modbus TCP/IP, OCPP, OPC-UA). SkySpark leverages a cleverly designed "Connector Framework" to streamline the system integrator's interaction with writable points that reference different connectors.

The below diagram brings these concepts together.



Project Haystack: Making an Analytics Driven EMS Market Accessible

An analytics-driven EMS is built on the foundation of a meticulously thought-out data model based on the open-source Project Haystack initiative. Without such data model analytics would not be cost effective or viable. Or in other words, every data analytics application requires a data model whether it is hidden behind a curtain or not.

Project Haystack

Project Haystack's data model enables system integrators to:

1. Provide semantic meaning to sites, equipment, and data points and their relationships to one another
2. Normalize project data from building systems, EV chargers, and microgrids that will be used by internal and external data users
3. Scale their work by using abstractions made available by the data model instead of needing to explicitly program every configuration
4. Create data interfaces with well-defined REST APIs
5. Validate data models

Also, an analytics-driven EMS requires bringing data together from various equipment types and manufacturers via several communication protocols. An open data model like Project Haystack is critical to help reduce the risk of equipment or service vendor lock-in.

SkySpark® – Analytics for a World of Smart Device Data

The past decade has seen dramatic advances in automation systems and smart devices. From IP connected systems using a variety of standard protocols, to support for web services and xml data schemas, it is now possible to get the data produced by the wide range of devices found in today's buildings and equipment systems.

Access to this data opens up new opportunities for the creation of value-added services to help businesses reduce energy consumption and cost, and to identify opportunities to enhance operations through improved control, and replacement or repair of capital equipment. Access to the data is just the first step in that journey, however. The new challenge is how to manage and derive value from the exploding amount of data available from these smart and connected devices. SkyFoundry's SkySpark directly addresses this challenge.

About SkyFoundry

SkyFoundry's mission is to provide software solutions for the "Internet of Things". Areas of focus include:

- Building automation and facility management
- Energy management, utility data analytics
- Remote device and equipment monitoring
- Asset management

SkyFoundry's software helps customers derive value from their investments in smart systems. Learn more and request a demonstration at www.skyfoundry.com.