Information model for the integration of EVSE into a Grid-Enabled CEMS

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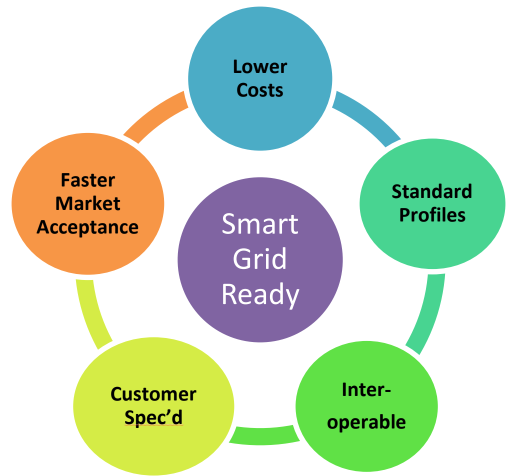
Abstract

In cooperation with the major US EVSE (electric vehicle supply equipment) manufacturers, the Energy Information Standards (EIS) Alliance is developing the use cases and information model that connects EVSEs to a Customer Energy Management System (CEMS). This model follows the ASHRAE SPC201 Energy Information Model and defines a set of customer interactions to improve EVSE system reliability, cooperation, and ease of use within a residential, commercial, and industrial premise. The model is being proposed to the ASHRAE SSPC135 BACnet committee for inclusion in its protocol standard. The model includes the ability to exchange management, bi-directional control, and operational information from a CEMS perspective. This paper will outline the customer requirements used to determine the model characteristics and explain the model. This will smooth the integration of EVSEs in buildings that are managed by a CEMS connected to the smart grid, allowing residential, commercial, and industrial customers to manage consumption while still providing a rewarding charging experience.

1. CUSTOMER ENERGY MANAGEMENT SYSTEM

A Customer Energy Management System (CEMS) is defined as any system that can monitor and manage building equipment. The complexity and feature sets can vary drastically between vendors and across industries, but they all serve one fundamental purpose – to save the customer energy. Sophisticated CEMS will be able to monitor not only the status of its connected equipment but also the health of the electrical grid upstream, providing new services to the grid in order to maintain a reliable and economical power infrastructure.

Figure 1: Advantages of Smart Grid Ready



1.1. Importance of Architecture in Smart Grid

No longer can building systems vendors continue to develop disparate systems which warehouse islands of information that are inaccessible or incompatible with each other. Common communication interfaces and methodologies are necessary in order to take full advantage of a facility's resources. Extending intelligence into the existing utility grid infrastructure is a monumental task. As an industry, the building controls suppliers must not remain reactive, developing supporting technology only when the market matures. We must lead the change by developing "Smart Grid Ready" technology today, enabling customers to take full advantage of future energy markets. Clearly defining the architecture of the control and communication of energy-consuming devices provides us the structural integrity required for implementing advanced energy-saving algorithms.

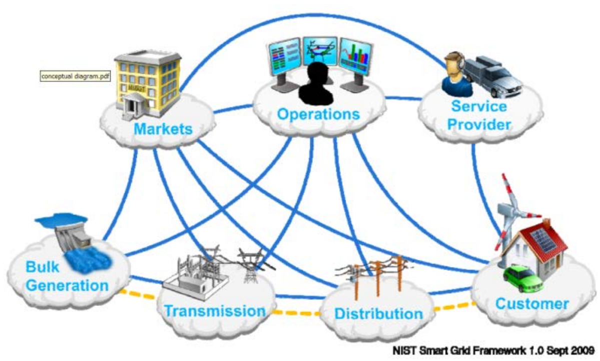
1.2. Grid Stability

A smart and responsive CEMS will provide invaluable services to the electrical grid. If a CEMS has an accurate depiction of its present and forecasted energy usage, it can provide that information to its energy supplier, enabling him to make better decisions. This lends itself to an increase in overall grid stability, not only under times of normal operation, but during unforeseen events such as maintenance or weather issues. Since buildings are distributed loads, they are in a coveted position to provide real value to the local grid in which they reside.

1.3. EIS Alliance

The EIS Alliance was formed as a group of domain experts uniquely skilled at identifying the requirements necessary for a CEMS to provide real value to both the customer and the smart grid. Previously, the Alliance has developed use cases around the standardization and transfer of energy-related information between customers and energy service providers. This document was submitted and adopted into the NIST Priority Action Plan 10 regarding the standardization of energy usage information, to support the overall NIST Smart Grid Framework, as shown in Figure 2. The Alliance has recently released a set of use cases around the interactions between electric vehicle supply equipment and a CEMS, hoping to springboard the research and development in Vehicle-to-Building (V2B) technologies.

Figure 2: NIST Smart Grid Framework



2. ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) BACKGROUND

The term "charging station" is a bit misleading, as it doesn't perform any charge management services. The charging intellect resides in the vehicle itself, which is a critical distinction – a successful and seamless charge program relies heavily upon an open and standardized method of data exchange. The Society of Automotive engineers have developed recommended practices and use cases (J2847 and J2836 respectively) on the communication interactions between electric vehicles and an EVSE. However, no automotive manufacturer currently supports data exchange to an EVSE, nor do they currently support two-way power flow. Obviously this is a major roadblock in utilizing electric vehicles as a load resource, and considerable work still needs to be completed in this area.

2.1. Anticipated Load

Numerous studies exist on forecasting the market penetration of plug-in vehicles. It certainly is a complicated challenge, encompassing economic, political, environmental, and social variables. The Center for Automotive Research estimates by 2015, roughly a half million plug-in vehicles will be on the road in North America.[i] While this conservative estimate only represents about 0.3% of total passenger vehicles on the road, it is still a sizeable electric load. The SAE J1772 Level 2 charging specification allows a draw of up to 19.2 kW. 15 electric vehicles drawing a full Level 2 charge would be a draw of around 290 kW – about the same as a 350 ton chiller! More importantly, if the tenants are plugging in during normal office hours, they are drawing that extra load during the peak of your usage curve, thus ratcheting up your demand charges.

Long term this could cause incredible grid stability issues as thousands of EV owners are continuously loading and unloading potential megawatts of power at indeterminate points on the grid. CEMS integration is a crucial component to managing this additional load to eliminate spikes and maintain a consistent building-level load profile. Numerous studies on the grid impact of electric vehicles assert that our current generation infrastructure is adequate, citing that most charging will be done at night when demand is low. While I agree that we have adequate capacity for this additional off-peak demand, they underestimate the on-peak potential. The addition of electric vehicles is fundamentally going to require either new base load generation or additional hours on load following power plants. Furthermore, running fossil fuel generation at a higher nominal capacity for longer periods of time induces accelerated wear on the generation system, requiring more downtime for maintenance and repairs. This cascades itself down to the transformers, power lines, and other transmission equipment which will bear the burden of moving this additional on-peak load. These issues put a heavy stress on maintaining the reliability of the electrical grid, and smart end loads are a necessary component of providing stress relief for the grid operator. Additionally, integrated end loads can become a marketable resource for the building owner, as intelligent CEMS can sell these resources on electrical markets.

2.2. Vehicle-to-Building Services

Load Rolling

Load rolling is an energy-saving measure in which a set of electric loads are systemically turned off for short periods of time. First, the user defines a set of loads he deems as sheddable. He then sets up a timeframe during which each load is allowed to be offline. A load rolling algorithm then cycles through the list, shutting down loads under non-overlapping timeframes so the total demand is reduced, while minimizing the time each individual load is offline. For instance, a set of lights in a parking garage might be cycled offline in an alternating pattern to reduce demand but eliminating any permanently dark places.

The type of load that is an ideal candidate for a load rolling program is one that is instantaneous in its energy reduction and is not prone to damage under short cycling. An electric vehicle fits this perfectly. Utilizing EV's in load rolling programs has very little drawback, as each individual EVSE is only offline for a short period of time.

Peak Demand Limiting

Any facility manager will tell you that demand charges compose a sizeable portion of their energy bill. Demand charges are typically determined by taking the highest level of demand used by the building during the on-peak period over the course of the billing cycle. The implications for increasing your peak demand can be huge, as it locks in your demand rate for the entire year.

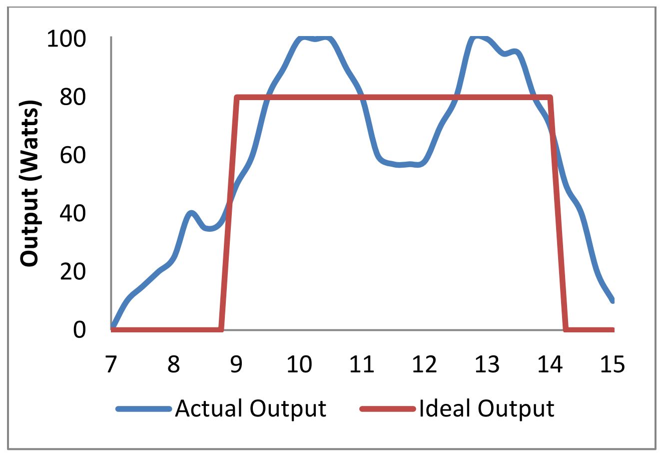
The proposition of simply plugging in a few EVSE's behind the customer meter got a bit more complicated. For example, a facility wants to install ten SAE Level 2 charging stations for its tenants, allowing a maximum demand of 19.2 kW each. Assuming a demand charge of $11 / kW, if all ten charging stations are in use during the peak demand period of the facility, it would increase their demand charges by over $2,100 a month. If the facility owner then decided to remove all ten charging stations, he would still be stuck with this new demand rate until the next billing cycle.

Integration with a CEMS is therefore crucial for not only the EVSE operation, but for the facility as a whole. A CEMS is already designed to consume a large amount of facility data from other various subsystems, such as HVAC and lighting. Integrating EVSEs allows the CEMS to ideally manage its entire load profile, giving it the flexibility to manage its entire peak demand.

Renewable Energy Firming

Renewable energy assets provide valuable clean energy for a facility, however there some drawbacks – they are neither constant nor dependable. A typical solar panel output, shown in Figure 3, is riddled with spotty generation. Practically, it is more beneficial to the building owner to see a consistent generation profile, and it is necessary if the owner is under a contract to supply a minimum amount of power to the grid. Currently, this issue has been resolved by using battery storage systems to firm the output. However, an owner could use his connected electric vehicles not only to firm renewable generation to meet a minimum supply, but to also maximize their profit during peak grid demand periods.

Figure 3: Sample Output of a Solar Cell



2.3. V2B Services for Grid Stability

Demand Response

Demand response is particularly well suited and arguably the most "shovel-ready" application for an EVSE to CEMS integration. The benefits of using electric vehicles for demand response are twofold – the owner can lower his consumption by switching off his EVSE's, and he can use the energy stored inside the vehicles as temporary generation to further reduce his demand on the grid.[1]

[1] *At the time of this writing, the usage of generation behind a customer meter in Demand Response programs is hotly debated.*

Ancillary Services - Regulation

The Federal Energy Regulatory Commission defines ancillary services as "Those services necessary to support the transmission of electric power from seller to purchaser".[ii] FERC defines 6 such services, and electric vehicles are suited particularly well for two specifically: regulation and spinning reserves. Regulation is the use of online generating units that are equipped with automatic generation control (AGC) and that can change output quickly (MW/minute) to track the moment-to-moment fluctuations in customer loads and unintended fluctuations in generation.[iii] Essentially, it is the service that is responsible for maintaining the frequency of the grid at 60 Hz. Regulation services can be very profitable for the energy provider, with Regulation Market Clearing Prices (RMCP) averaging around $45/MWh. They can spike dramatically, especially in deregulated energy markets, up to $534/MWh, which was the highest hour-ahead RMCP in 2010 for California ISO

The key component of a regulation generator is its speed in providing power. The amount a resource is allowed to bid into a regulation market is proportional to its ramp rate in megawatts per minute. That is, if you have 200 MW of supply, but can only ramp at 1 MW per minute, you are only allowed to bid 5 MW for a 5 minute dispatch. Since an electric vehicle is simply a battery source, it can supply power almost instantaneously. A CEMS which aggregates EVSE's can quickly take full advantage of the regulation market. It can continuously monitor not only its available EVSE load but also monitor the real-time energy markets, making quick and profitable decisions for the facility owner. A particularly interesting component of the reserves market is that it not only requires regulation to cover the immediate shortfall in supply, but also the immediate shortfall in *demand*. That is, a customer can take advantage of this market simply by using more energy under a certain set of conditions. A recent report by Pike Research estimates "the global revenue for PEVs participating in ancillary services would grow from less than $100,000 in 2011 to more than $18 million by 2017."[iv]

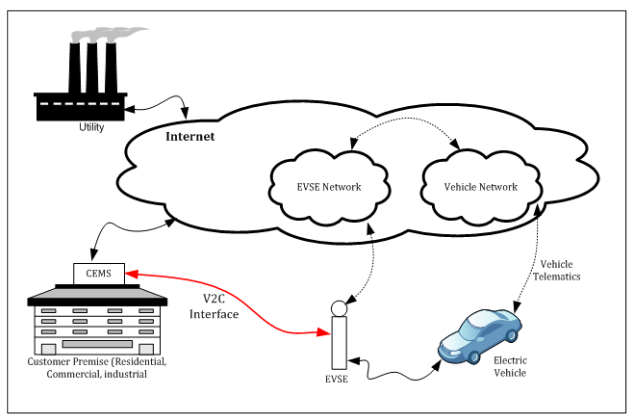
Ancillary Services - Spinning Reserves

Spinning reserves is another generation-based ancillary service, and it provides backup power in the event there is a disruption in supply. Typically they are called upon roughly 20-50 times a year, with load durations ranging from 5 minutes to an hour. While the spinning reserve market is not as lucrative as the regulation market, there are still opportunities for integrated EVSE's to provide value. Through integration to an advanced CEMS, the facility owner can monitor both markets simultaneously and determine which is more profitable for him and beneficial for his tenants. For example, when his tenants first arrive early in the morning, their batteries could possibly be at a low state of charge. He could then decide to only participate in "regulation down", providing service to the grid while simultaneously charging his tenants' batteries. Later in the day, once his tenants' batteries became charged, he could notice an economic incentive to participate in a spinning reserves program. An advanced CEMS could alternatively be programmed to monitor not only the market conditions but also the state of the vehicles, and participate in different areas under pre-configured switch points.

3. CUSTOMER REQUIREMENTS FOR EVSE TO CEMS INTEGRATION

The EIS Alliance has created a set of use cases that defines the data set required for effective communication between an EVSE and a CEMS. As shown in Figure 4, while there are various methods of obtaining the necessary information required to perform vehicle to building (V2B) services, the Alliance decided to focus on a direct link between the CEMS and the EVSE. It is also important to note that the Alliance has purposefully chosen to not select or define a physical medium and protocol for this interaction. The intent is to create a common platform on which open physical-layer standards can be implemented.

Figure 4: Interfaces for Electric Vehicles[v]



3.1. EV Owner Requirements

Vehicle owners are obviously a critical component to the success of a facility-managed EV charging program. Even if it proves to be highly profitable for owner, there are still numerous opportunities to push away potential users. A vehicle is considered by many to be a private and expensive piece of personal property. While early PEV adopters might be more willing and patient with building operators, if widespread adoption is expected there will have to be a paradigm shift in the way people think about their vehicles. In order to ensure widespread user acceptance, an EV charging program must be as simple and user-friendly as possible. A CEMS-integrated EVSE can be thoroughly leveraged here. A building owner can utilize his security system to automatically allow an employee entering a parking structure using his badge to also be allowed to charge, eliminating the need for additional authentication at the EVSE. The CEMS can then serve up a charger user interface to the employee to enable them to monitor and manage their charge session, as well as receive any important notifications that are deemed necessary by the building operator. This allows the user to maintain a sense of ownership while letting the building owner utilize his vehicle as an energy resource.

This notification system is perhaps the most important feature a facility manager can implement, as it provides the fundamental basis for communication that is necessary for the long-term success of a tenant charging program. A facility will typically not have enough charging stations to service its entire tenant base. Therefore, it is likely that when a tenant arrives he will not immediately have a charging station available to him. Also, receiving a full charge at 19.2 kW (SAE Level 2) would typically only take 1-2 hours for an average passenger vehicle. Ideally, the facility will have to manage this “charger queue” with a minimum of human intervention. Information such as present state of charge, estimated charge completion time, and next person in queue must be communicated seamlessly to tenants, and they must have a mechanism for providing feedback and input as required. For instance, while the EVSE will certainly know when charging is complete and when the vehicle has been unplugged, it will not know when the vehicle has been physically moved, allowing the next user in the queue access to the EVSE. We can certainly theorize technological solutions involving cameras or weight sensors, but for the practical near term, the owner will simply need a simple and secure mechanism for informing the next user in line.

Vehicle owners who agree to participate in V2B services must understand that accurate and timely information is required from them in order not only for the facility owner to optimize his usage of the vehicle but to ensure the owner is receiving adequate service as well. For instance, if a vehicle owner previously agrees to enroll his vehicle for a demand response program, he must provide an accurate representation of when he plans on leaving the facility and the expected state of this battery in order for him to arrive home safely. This information is vital in order for the CEMS to conduct an accurate calculation of what it is able to provide the grid for an upcoming event. The vehicle owner also must understand that his vehicle might not be available to use during that time period, and if he insists on unplugging his vehicle there could not only be financial penalties for doing so, but there could very well be a very low charge in his batteries. The Alliance has addressed this problem by including a parameter that allows the owner to specify the minimum state of charge that his batteries are never allowed to go under. This allows the owner to set his own level of risk/reward for his participation in the facility manager’s program.

3.2. Facility Owner Requirements

The facility manager has the unenviable task of managing the additional electrical load while providing service to his tenants. Again, proper communication is crucial. Facility managers, in coordination with vehicle owners, need to establish fixed parameters under which the facility is allowed to use the vehicle as an energy resource. These need to be reviewed periodically by both parties in order to maintain a positive relationship. Additionally, inter-day modifications to these parameters will need to be communicated in a timely and efficient matter. For example, say a tenant generally agrees to allow the facility to use his vehicle for regulation services, as long as his vehicle has 70% battery charge at 5PM. If the vehicle owner has a need to leave the facility at 3PM, he must communicate that information to the facility manager, preferably before he arrives that day. Integrated CEMS can push this information to email or messaging servers automatically, eliminating the need for the vehicle owner to find the facility manager individually. Also, once a CEMS has this new participation information, it can automatically modify its market participation strategy in real-time.

It is therefore imperative that the facility manager have access to a centralized interface in which to manage the way his EVSEs interact with the rest of his building subsystems. The CEMS is a logical supplier of this interface, as it has the ability to aggregate the standard operational metrics such as the amount of energy available, as well as pulling data from a customer resource management system to consume user-defined metrics such as the amount of energy needed in the vehicle when the tenant leaves for the day.

3.3. Fleet Management

Electric vehicles are particularly interesting to fleet owners, as fleet usage fits nicely with the operating characteristics of an electric vehicle. A consistent and predictable route mitigates any notion of range anxiety. What’s more, vehicles can be tailored to run a specific route; that is, if a fleet manager has vehicles that always run 40 mile routes, a 45 mile battery could be installed, thus lowering overall cost. High utilization enhances the low operating cost of an EV, and maintenance is estimated to be roughly half the cost of a gas-powered vehicle.[vi] Additionally, fleet managers who connect their EVSEs to an intelligent CEMS will be able to fully utilize electric markets in their favor, lowering their purchase price of electricity.

In numerous instances, a fleet owner will play the role of both the vehicle owner and the facility owner. This puts him in a unique position to maximize his profits from not only his normal business operations, but also from the value he can provide to the utility grid. A CEMS that is already configured to consume energy market prices can also interface with the customer's fleet management application. The CEMS can then make hour, day, or even week-ahead decisions on how to maximize the use of every individual vehicle.

4. TIMELINE AND PROPOSAL FOR BACNET INCLUSION

Due to its prevalence and history as a robust open standard for the building automation and control industry, the Alliance has decided to pursue the ASHRAE SSPC135 BACnet committee as its first instantiation of the EVSE data model. The Alliance has already submitted a proposal to the committee and it has been approved of the task of submitting aSPC201-compliant data model to the January 2012 BACnet meeting.

5. CONCLUSIONS

Accelerate Development of SAE Standards

The SAE Communications Task Force is developing use cases and standards around the information required to support plug-in electric vehicles. SAE project J2836-3 specifically addresses the information required for reverse power flow. This is clearly a critical component to implementing V2B services. J2836-3 is expected to be released 3 – 4 years from now, although pilot projects are expected to start in 1 – 1.5 years. Any effort that could accelerate the development of the J2836 set of standards will be highly beneficial to the V2B and V2G industry.

Promote Open Standards for CEMS Integration

Proprietary standards tend to increase complexity for the customer, and serve as technological barriers for widespread market adoption. The communications infrastructure supporting V2B services need to reside on an open and interoperable platform. Stakeholders need to collaborate on standards in order to provide the maximum value for their customers.

Biography

Nick McLellan is employed with Johnson Controls and works to support emerging technologies in the energy and sustainability space. His areas are focus is around defining open standards of communication between buildings, end devices, and the utility grid. He is currently involved in the OpenADR Alliance, an industry organization tasked to develop the next version of the OpenADR communications standard. He holds a Bachelor of Science in Mechanical Engineering from the University of Wisconsin-Milwaukee.

References

[i] Center for Automotive Research, *Deployment Rollout Estimate of Electric Vehicles 2011-2015:* http://www.cargroup.org/pdfs/deployment.pdf
[ii] FERC Guide to Market Oversight – Glossary: http://www.ferc.gov/market-oversight/guide/glossary.asp
[iii]Hirst, Eric and Kirby, Brendan, "Ancillary Services, A Call for Fair Prices." December 1999. Accessed at: http://cwec.ucdavis.edu/rpsintegration/library/Ancillary%20services%20prices%20Dec99%20Hirst%20Kirby.pdf
[iv] Pike Research, *Vehicle to Grid Technologies:* http://www.pikeresearch.com/research/vehicle-to-grid-technologies
[v] EIS Alliance, *EIS Alliance EVSE to Customer Management System (V2C)*: http://www.eisalliance.org/documents.html
[vi] Electrification Coalition, *Fleet Electrification Roadmap:* http://www.electrificationcoalition.org/sites/default/files/EC-Fleet-Roadmap-screen.pdf