

Managing Plug-In Electric Vehicle (PEV) Charging Profile Utilizing Online Distribution Transformer Monitoring

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The adoption rate of plug-in electric (PEV) has been growing in recent years thanks to the improvements in technology, regulatory benefits and other market conditions.





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Electric Vehicles are recognized as a key role in the United States transportation future as it already is in other parts of the world. Since 2008 the Department of Energy has invested in technology to reduce the costs of producing electric vehicle batteries by more than 85%. This coupled with the increasing cost and dependency on global petroleum imports is accelerating the adoption of plug-in electric vehicles (PEVs). Additionally, while it is accepted the bulk power grid must be modernized to support clean

Electric Vehicles are recognized as a key role in the United States transportation future as it already is in other parts of the world. This is driven by a need for the more efficient use of energy that reduces impacts to environment. The adoption rate of plug-in electric (PEV) has been growing in recent years from the improvements in technology, regulatory benefits and other market conditions. Specifically, the Department of Energy (DOE) Vehicle and Technology Office has been investing in the improvement of specific areas [1]:

- Reducing the cost, volume, and weight of batteries by developing cells and modules, improving lithium-ion electro-chemistries, and investigating new materials;
- Improving electric traction drive systems by reducing the cost, decreasing the weight and size, improving the performance, and increasing the efficiency of power electronics and electric motors.

These investments have driven down the estimated vehicle lithium-ion battery cost by nearly 87% since 2008 [2]. The reduced cost along with Federal, State and Utility tax credits with other incentives makes PEVs financially accessible for majority of light vehicles users. The rising cost of oil per barrel because of domestic regulatory policies aimed to reduce fossil fuels, coupled with trade sanctions that are increasing the cost of foreign oil imports creates the ideal market conditions to increase PEV consumer sales.

energy initiatives, most of the investment is going into transmission infrastructure improvements. This leaves a technical problem at the distribution system level on how to maintain system reliability and manage the increased electrical demand from PEV adoption. The use of smart infrastructure solutions based on industrial IoT technology can manage electric vehicle charging based on real time capacity of distribution transformers and circuits. This paper aims to discuss the use case and technology available to accomplish this coordination.

The electric grid and distribution system is recognized as a key conduit for enabling PEVs and the benefits to energy efficiency goals. The challenge is to determine how the system is going to be impacted by the wider adoption and increased population of PEVs. Modeling suggests that the grid already has generation capacity to meet this demand [3]. While generation capacity improvements have been largely flat for the past decade, the modest gains still are able to keep pace with PEV forecasted adoption rates by 2030 [3]. The true challenge is going to be how the distribution system and fixed assets can handle additional load.

Uncontrolled charging occurs when the PEV charges as soon as its plugged in. It is simple to implement and maintain. The problem with this methodology as it relates to distribution system is this demand becomes additive to the peak load profile that already exists. The average residential feeder in the US will have a peak between hours 16 and 20 of each day [3]. Uncontrolled charging only adds to this load and starts to encroach on the equipment ratings of distribution transformers and other circuit components.

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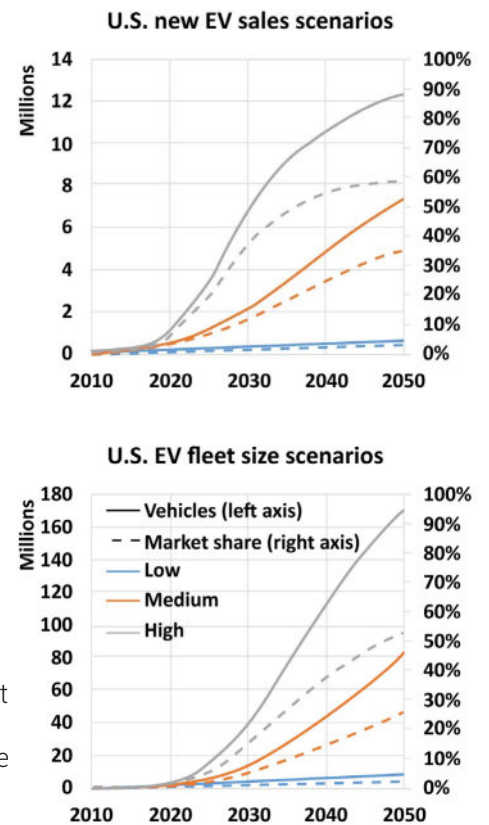
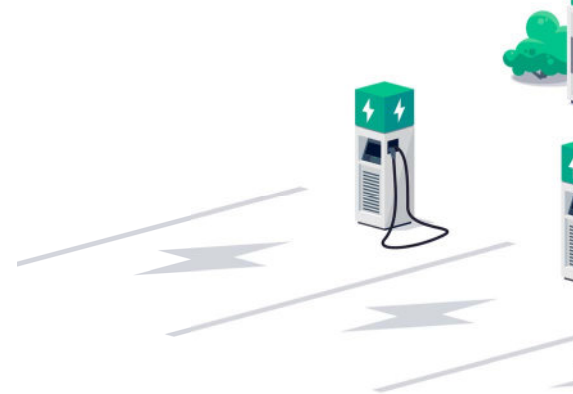
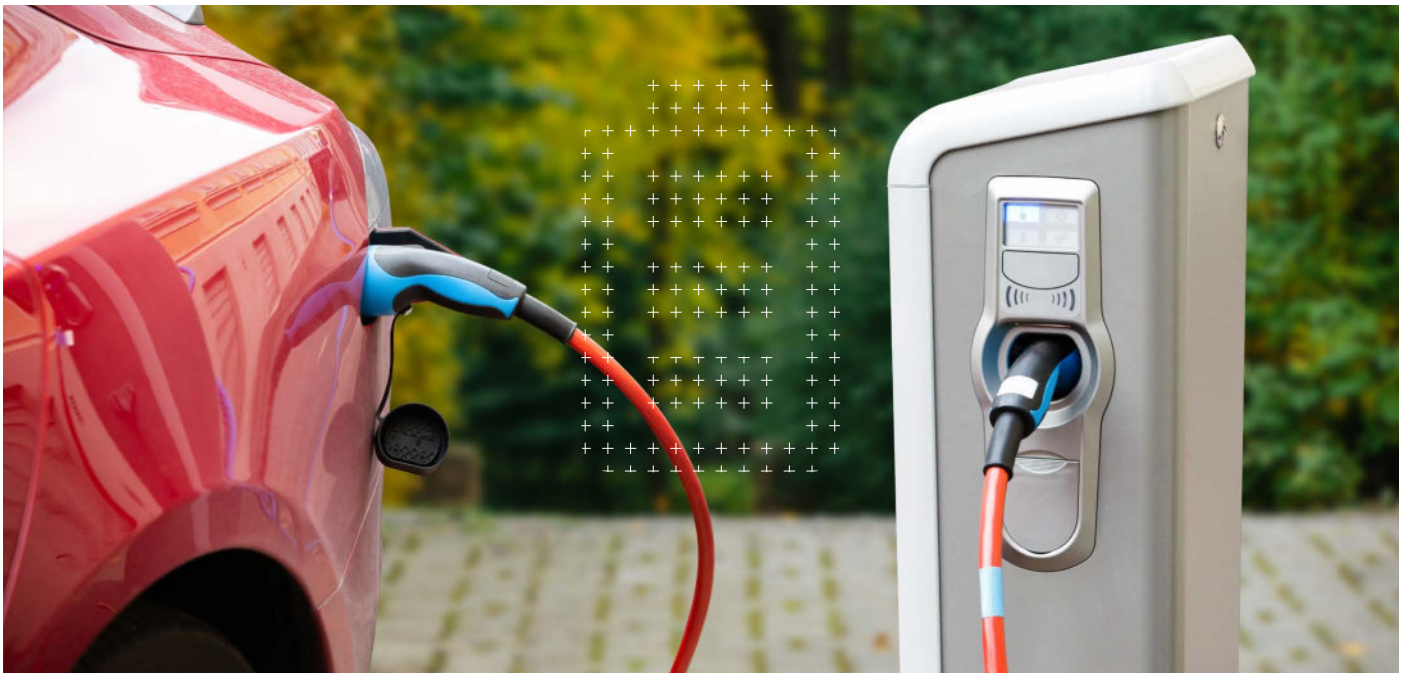


Figure 1. Low, medium, and high PEV market penetration scenarios, shown both as annual sales (at left) and total PEV fleet size (i.e., cumulative vehicles in service, at right). Solid lines correspond to number of vehicles (left axes) and dotted lines correspond to sales shares (right axes) [3].



In other parts of the world this can cause voltage quality issues, but this is less of a concern in the US because utilities actively regulate distribution voltages by means of tap changing transformers, line regulators and



switched capacitor banks to follow load changes [4]. The increased load however can impact coordination studies of protective equipment causing unplanned outages and further accelerate the aging and failure of grid assets.

One approach to offset the increased PEV charging demand is to upgrade transformers and other assets to accommodate the higher load. This is sometimes mandated with extremely fast charging systems. The deferral of distribution system upgrades can have strong financial benefits to utilities. The key is shifting the charging profile based on time of need, not when the PEV is plugged in. Time of use (TOU) rates is a financial mechanism used by many utilities to change customer energy consumption behavior. Delayed charging during off peak TOU rate times does not ensure charging is properly staggered to prevent creating a second peak and can only deliver 80% of operating cost savings as a managed charging system [5]. The better approach is to manage the charging of PEVs based on system constraints with a smart infrastructure solution that gives utility direct control of charging. This benefits utilities by allowing deferral of distribution system upgrades, reduction in unplanned outages, and better information on distribution system operating conditions to assess future planning.

The use of smart infrastructure solutions based on industrial IoT technology can manage electric vehicle charging based on real time capacity of distribution transformers and circuits.

Calculation Outputs (Currents)

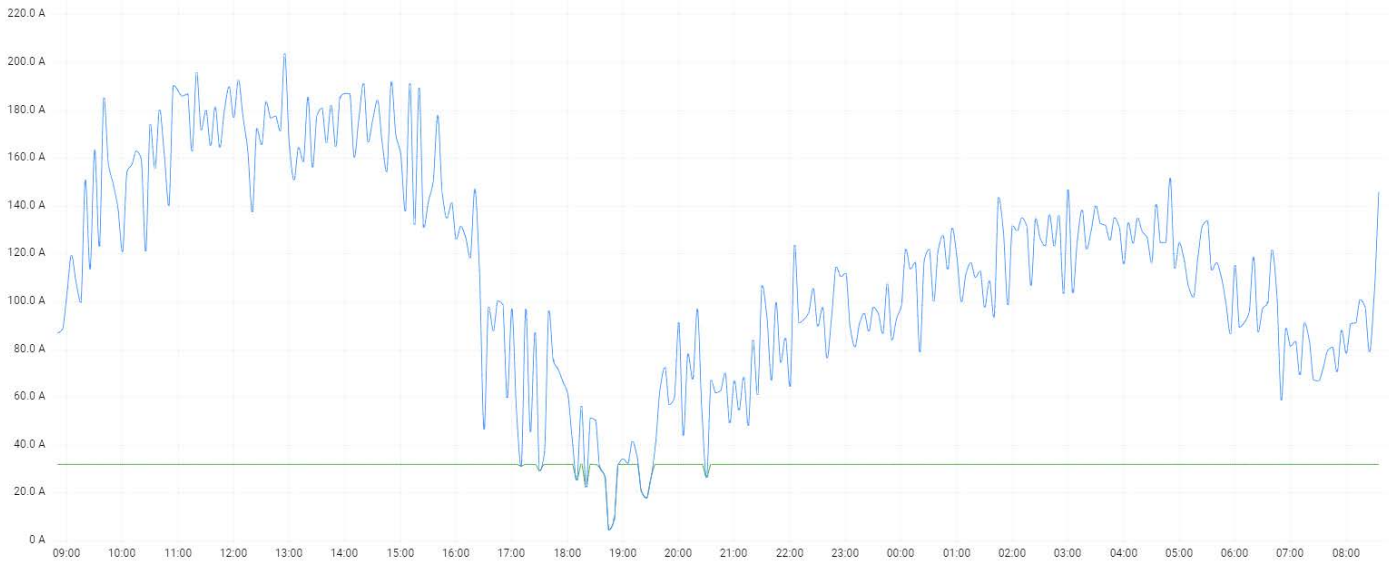


Figure 2. Circuit and transformer capacity analytic

A smart infrastructure solution combines software, sensors and communications to deliver a scalable and agile platform for improving connectivity to grid edge assets. To manage PEV charging, a utility-grade IoT architecture can be utilized to bring distribution transformer capacity information to an application running on a cloud service. This solution will integrate data from distribution transformer monitors, energy metering (AMI) data and the PEV chargers to run advanced analytics to determine circuit and transformer capacity. The analytic can replace live transformer monitoring data with historical load profiles to supplement areas without fully deployed monitoring. Meteorologic data is also integrated to support a forecast model on load fluctuations due to ambient temperature changes.

At the end of the analytic, if the available capacity is less than the PEV chargers connected to the distribution transformer, the remaining capacity (if any) is shared among the connected chargers that are currently in session. The charging limits are sent to the PEV chargers to manage the additional load put on distribution system. This can be seen in above diagram where the



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blue line represents circuit capacity for PEV charging and green line is the limit imposed on charger(s). When the capacity drops below limit, a new limit is issued to charger to prevent adding additional load onto system. The digital transformation of the bulk power industry is going to change the way the electric grid is operated and managed. The data and tools available with Smart Infrastructure Solutions will improve grid efficiency, defer equipment upgrades, and provide better information for system planning. These new solutions will all have a positive impact on the options available for utility asset managers to make better informed decisions.

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