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Analytics + IoT = Happy (Utility + Customer)

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ABSTRACT

The Public Utility Regulatory Policies Act (PURPA) changed the utility world in 1978. Power generation was no longer the domain of electric utilities, but was opened to independent power producers. Bigger challenges might be imminent with the falling price of batteries. Individual homes and businesses will add batteries to new and existing solar panels. The biggest disruptor, however, will be the acceleration of electric and hybrid vehicles. Large growth of electric vehicles (EVs) could affect local reliability and increase the cost of delivering electricity to customers. In many areas of the US and the world, one new EV charger can add as much demand as a new residential customer. Fast chargers that recharge EVs in just a few hours can add three times that demand. Analytics and the Internet of Things (IoT) must become partners to create systems that enable the customer and utility to continually communicate their status and options. This will give customers maximum flexibility to charge their EVs without increasing the utility's costs. With a two-way flow of information, the utility will be able to take advantage of excess energy from EVs to maintain grid stability and reduce costs. Additionally, a robust communications system could allow utilities and customers to coordinate demand response, with customers lowering demand to fit the utility's needs. Actions could be as simple as controlling a water heater, but could be as complex as instructing a home thermostat to change set point.

INTRODUCTION

As electric utilities look to the future they are concerned about the possibility of integrating high numbers of electric vehicles (EVs). While EV growth promises electric utilities new revenue sources, the growth itself creates challenges. The quantity of load and its timing is not only an issue for operation of the grid but also maintaining the reliability of the local distribution system.

The near-term response has been to influence consumption patterns through time-of-use (TOU) rates. While TOU rates are helpful, the growth of interconnected devices, the Internet of Things (IoT), offer the possibility of a solution that can be leveraged with analytics to benefit to both the utility and the customer. IoT and analytics coupled with the increasing feasibility of computing resources at the edge could offer a framework that will help the utility contain costs, maintain reliability, and reward customers for their actions.

EVs are only one component of a changing electric utility landscape. Distributed energy resources (DERs), such as commercial wind and solar and rooftop solar, have grown rapidly. In some areas this growth has led to significantly altered load patterns, requiring new grid operating strategies. Demand reductions from demand response (DR) in combination with battery storage appear to be developing as strong alternatives to construction of new plants and facilities. The full value to the utility, and ultimately the customer, will come when the operation of the power system is fully integrated into the same IoT framework with EVs to truly take advantage of every possible economy.

EVS IMPACT ON THE ELECTRIC SYSTEM

Studies have shown that large increases in EV loads can be manageable for the US electric grid on a national basis.[1] While power plants and transmission lines have excess capacity, the same may not be true of the local distribution system. The primary issue is the risk of overloading the local transformers that connect homes and businesses to the power grid. These transformers are the most vulnerable parts of the local distribution system. Most residential transformers are designed to serve between 10 and 50 kW of load, while a single EV with a Level 2 charging system consumes 6.6 kW. A single home fast charger for a Tesla Model S approaches 20 kW.

When adjacent customers served from the same transformer add EVs, the transformer serving them can be overloaded, resulting in damage or degradation. The addition of a 6.6 kW charger can equal the peak demand of three customers in some temperate locales. For areas with high air conditioning or electric heating load, the additional EV load would range from one third to one half of typical customer demand. While the most immediate problem is exceeding the capability of the transformer directly serving the customers, high penetrations of EVs in an area can lead to overloading of higher-level distribution facilities serving multiple locations.

Household load is typically highest in the evening period from 6 p.m through 7 p.m when evening residential load is highest due to cooking coinciding with other household activities. That is also the time most EVs will be returning home and most drivers will routinely plug in their vehicles for recharging. This evening period has the greatest potential for overloading and damaging the local transformer as the household and EV charging load coincide.

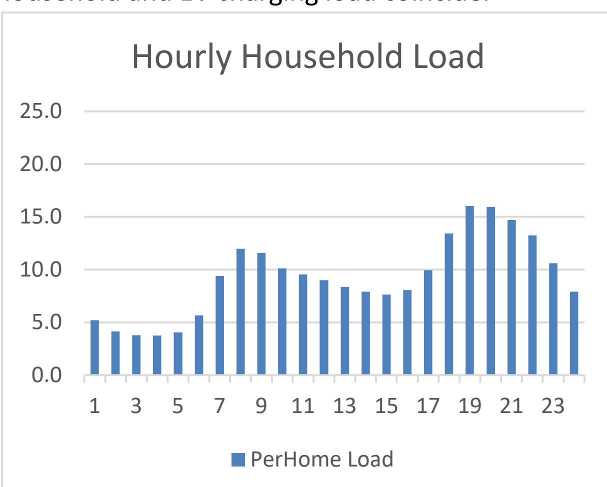

Figure 1

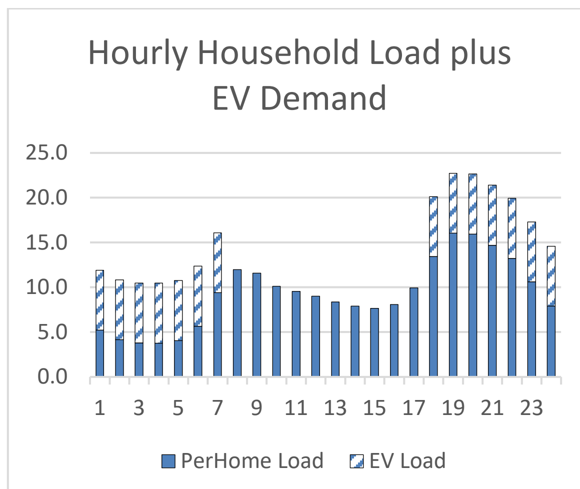

Figure 2

Figure 1 shows the typical loading for a residential customer during a summer or winter peak day. Figure 2 shows the customer load with an additional 6.7 kW added for a Level 2 EV charger starting at 6 p.m. This mirrors the driver plugging in their EV as soon as they arrive home and letting it charge until leaving for work the next morning. The highest household loads typically occur in the evening around 6 or 7 p.m.

TOU RATES TO LESSEN EV CHARGING IMPACTS

TOU rates are one strategy utilities can use to shift EV charging start to later in the evening by offering lower “off-peak” charges. The off-peak period varies by utility depending on load patterns and cost structures. Typically, the off-peak period begins around 9 p.m. and extends to midmorning, but may extend as late as the early afternoon.

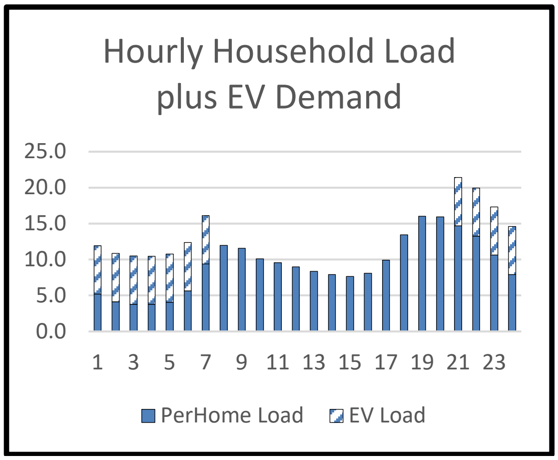

Figure 3

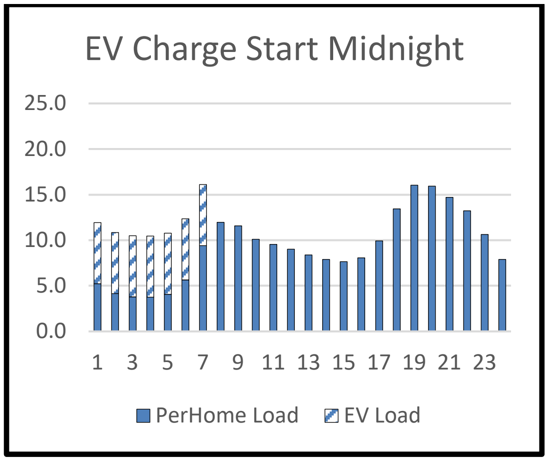

Figure 4

Figure 3 shows the total load when TOU rates shift the charging start to 9 p.m. and being disconnected at 7 a.m. This would shorten the 13 hours of a 6 p.m. to 7 a.m. charging window to 10 hours. This is sufficient charge time for most drivers since 11 hours of charge with a Level 2 charger will add from 100 to 250 miles of range to the vehicle. A Chevrolet Bolt can fully recharge in just over 9 hours with a Level 2 charger.(2) A full recharge for a Tesla S is approximately 11–12 hours, on the edge of the necessary charge window.(3) Most drivers, however, will not need a full recharge and most don’t need a fully charged battery for the next day. Many drivers will also have access to public or office charging stations during the next day.

TOU rates are economic incentives and do not restrict EV owners from charging as they need, it just reduces their savings when they charge during higher-rate periods. The later 9 p.m. start for EV charging still creates a peak larger than household load alone. Moving the start of EV charging later would help reduce the peak. San Diego Gas & Electric offers a multitiered TOU rate that provides an option with later evening periods at slightly lower prices. The company offers a “Super Off-Peak” rate beginning at midnight that is about 24% less that the standard TOU 9–12 p.m. period.(4) Figure 4 shows the charging window shrinking to 7 or 8 hours for EVs that need to be used at 7–8 a.m. the next morning, but is still sufficient for many drivers.

ANALYTICS TO DETERMINE CHARGE NEEDS

While TOU rates are a good start, more flexibility is possible in EV charging when we consider the following:

- Most EVs do not need a full charge every night, as they likely arrive at home with some level of charge in their batteries.
- Most EVs don’t need a full charge for the next day’s driving.

- The time to attain 80% charge is proportionately less than moving from 80% to 100% charge.
- Many drivers will have access to charging away from home the next day.

EV charging times can be calculated each night knowing battery charge level, driving needs for the next day, and the availability of away-from-home charging stations. Many EVs now provide convenient access to all or part of this information through mobile phone apps such as Ford's MyFord Mobile and Tesla's TesLab.

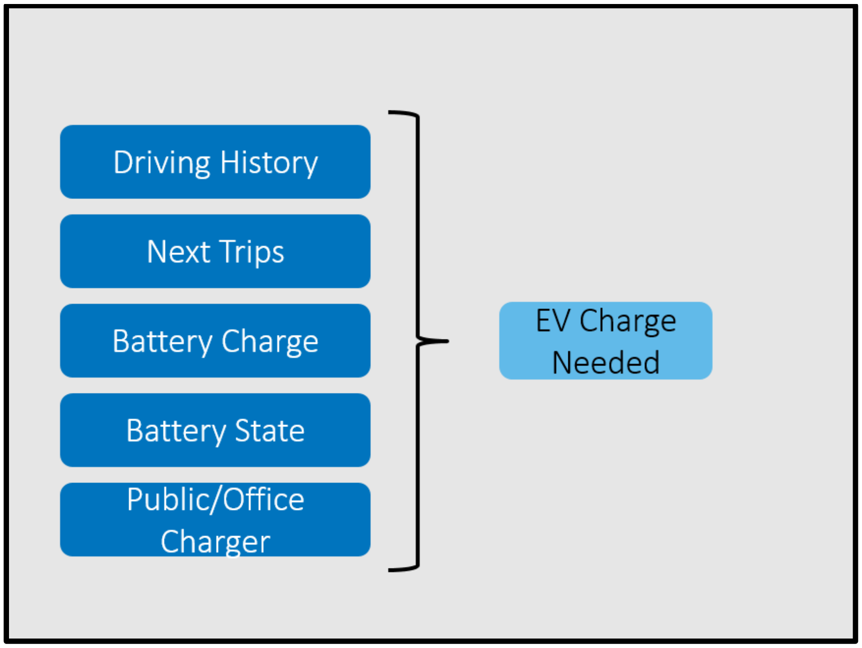

Figure 5

HOURLY ENERGY FORECASTING INCREASES THE FLEXIBILITY OF EV CHARGING

During most evenings, household loads are not near maximum levels and transformer overloading is not a concern. During those times, there may be no concern for the distribution system loading for when EVs are charging. Integrating the EV charging information with an hourly forecast of household loads identifies the need in advance to influence or control daily EV charging. Integrating Automated Meter Infrastructure (AMI) and forecast temperature data on a real-time basis allows for continuous update of the forecast.

Coupling the forecast of customer load with the energy needs of the EV can be used to calculate a charging schedule. EV information could be transferred to a central location, coupled with a load forecast, a charge schedule calculated, and the results transferred back to a charging controller for the EV. Alternatively, temperature data could be transferred to computing on the edge. An IoT system already exists for many utilities with two-way communication between AMI meters and central data collection and control.

By itself, the process offers no incentive for the customer to change their behavior. The process must be integrated with an IoT system for the utility to evaluate the relative economics and communicate with the customer. In the ultimate scenario, such a system could operate automatically based on predefined decision rules for the customer and utility.

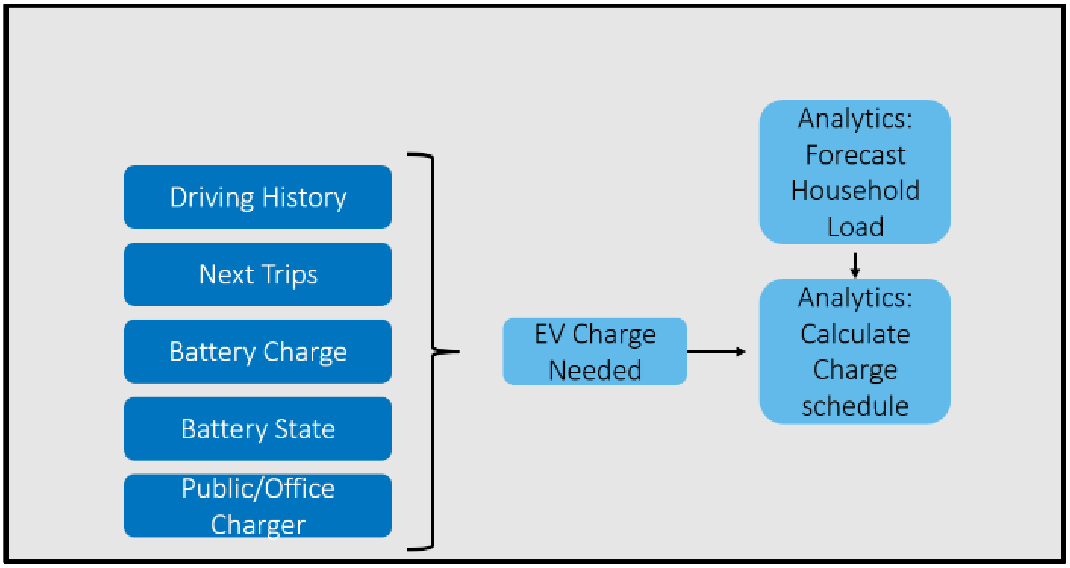

Figure 6

EVS CAN BENEFIT THE UTILITY

We generally only think of EVs taking energy from the grid, but EVs can also be structured to provide power back to the grid. They can provide energy from their batteries to provide power during periods where grid managers occasionally need small amounts of power for short periods of time to maintain grid frequency and stability. Nissan and Enel conducted a year-long study in Denmark that demonstrated that utilities can use parked electric vehicles to deliver power back into the grid and in return provide owners with compensation.[(5)]

A trial program next year in the UK by Nissan and energy supplier Ovo Energy will offer "vehicle to grid services" to buyers of the new Leaf. Ovo will automatically trade electricity from the car battery to the grid, managing the vehicle's charge level through a special interconnected charger installed at home. The concept goes beyond emergency grid support to supply from the car battery during high-cost periods and recharging during lower cost periods. The cost differential between charging and discharging periods provide the basis for compensation to the EV owner.[(5)]

INTEGRATE THE ENTIRE GRID USING IOT AND ANALYTICS

EVs are only one component that modern electric utilities would like to manage or influence in their hour-to-hour operations. Utilities would like to be able to influence or control all electricity-consuming devices on their power system that have some discretion in scheduling. Each increment of control allows the utility to operate more efficiently and have more control over the grid reliability and security.

The grid itself has changed, with more sensors and meters interconnected by better communications systems. Many utilities now have two-way communication with the customer site through the AMI. Analytics applied to real-time customer information through home automation systems, coupled with extensive grid data, can provide the optimal strategy for generation and customer control to minimize cost and maintain reliability. Utility savings and payments to the customers for modifying their loads can also be calculated in real time. Response by the customer equipment can be automatic based on their decision rules or information provided for a response confirmation.

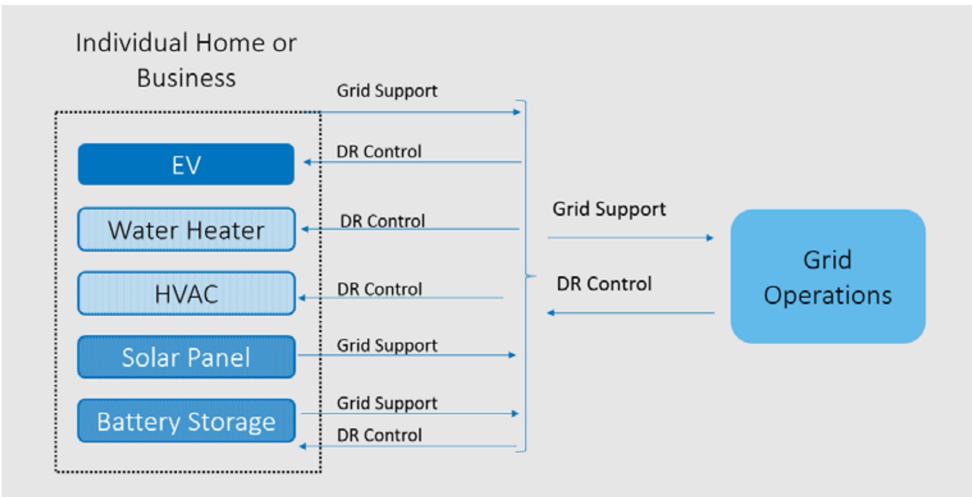

Figure 7

Water heaters and HVAC are still the biggest targets for demand response (DR) control as they were with early demand-side management (DSM) programs. While the customer devices may be the same, the strategy for use may be different. By interfacing with home automation devices, the utility could request preheating or precooling of the residence to be able to lower temperature setpoints later and have a longer period of reduction. Utilities with “duck curve” load patterns can charge EV and other batteries during the midday to increase load and use some of that charge in the late afternoon and evening as the rate of load increases.

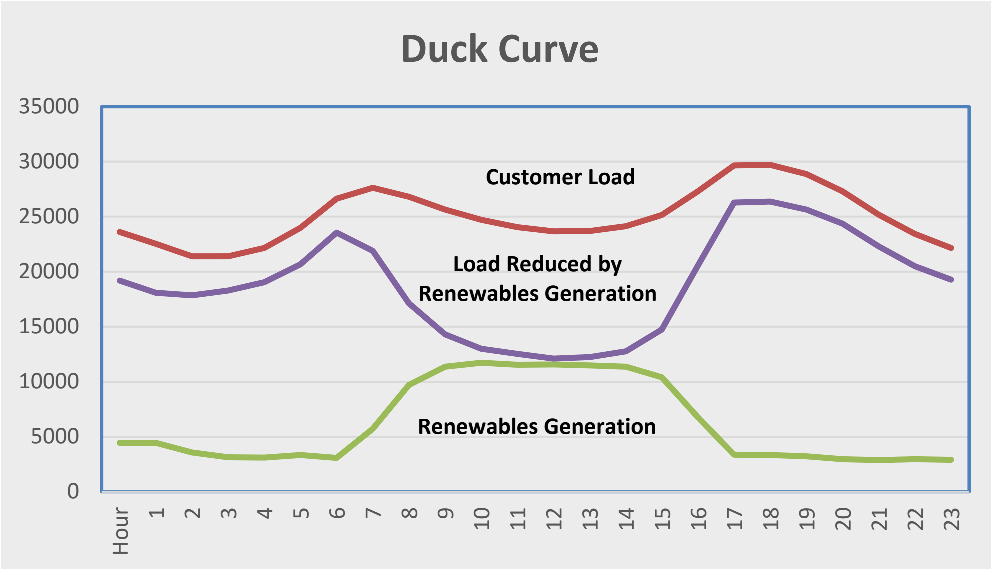

Figure 8

PREDICTING LOAD CHANGES ON THE DISTRIBUTION SYSTEM WILL BECOME MORE IMPORTANT

The growth of EVs coupled with solar, battery storage, and household DR will increase the sensitivity of the distribution system and elevate the need for distribution-level load forecasting. For segments without metering, the forecast must be developed for loads on the edge and accumulated back to the level of interest.

Probabilistic load forecasting will be valuable to understand the load levels possible beyond the range of recently observed temperatures. Coupling EV charging data with a probabilistic customer load forecast provides a range of loads possible on a local transformer. In turn that information can be summed by phase and location on the distribution system to estimate severe loading by phase on distribution lines, switches, and higher-voltage transformers.

CONCLUSION

The landscape for electric utilities has changed dramatically in the past 20 years, as commercial solar and wind generation have grown dramatically, residential and small commercial solar have become viable, and electric vehicles have become more desirable. Falling battery prices have made grid-level battery storage economically viable and are being added not only for stability and voltage support but to provide short-term resources. Battery storage, paired with demand response, is being considered in some cases in lieu of building new generating units or overhauling old units. Grid operations have changed in response to the new mix of resources and load patterns.

Analytics and communications resources have already been expanded to connect sensors, switches, and other devices on the grid. Going forward, the reliable and economic operation of the power system will require IoT expansion to include EVs and home automation systems. Only when coordinated together can the utility recognize the efficiencies possible to provide maximum cost savings for the utility and allow the customer to receive the maximum reward for their participation.

Analytics will be required to evaluate the needs of the driver and forecasting to assure that actions to benefit the grid don't create stability and reliability issues on distribution. Probabilistic forecasting at the lowest levels of the distribution will be necessary for assuring that reliable service will be available under extreme weather conditions.

An integral part of the analytics and IOT will be hourly energy forecasting. An energy forecast of customer load is the first step in planning for energy sources, and scheduling loads and demand response. Energy forecasting is necessary to determine EV and battery loading discharge patterns and not affect the reliability and security of local distribution facilities. A probabilistic forecasting component will be necessary to evaluate the likelihood of severe loading as EVs area added to local distribution.

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