1898 & CO
PART OF BURNS & McDONNELL

WHITE PAPER

Electrification's Impacts on System Planning

By Frederic Dubois

Growing adoption of electric vehicles and solar photovoltaic systems is adding new wrinkles to how electrical systems are planned and operated. Beyond load growth and the increasingly fragmented nature of what needs to connect to the grid, utilities need to consider changes in load volatility, utilization factors and ratepayer impacts.

Replacing internal combustion engines with electric motors shifts the economics from the gasoline industry to electron providers. However, electric vehicles (EVs) are meant to move around and tap the power grid (with as much demand as multiple average households) wherever they charge when the battery gets low. Depending on how prevalent EVs are in an area, this could become the equivalent of entire neighborhoods popping up and going away at various points across the grid, worsening the utilization factor for the assets that must be deployed to serve the local peak load.

Similarly, the deployment of solar photovoltaic (PV) systems presents both benefits and threats to utilities. The farther power generation is from a load, the more electrons are lost to heat as they move along miles of transmission and distribution assets. Electrical proximity between generators and loads, such as rooftop PV serving a residential load, alleviates the burden on power delivery assets that would otherwise have to bridge centralized generation and load sinks. Conversely, the natural intermittency of solar irradiance due to cloud coverage can translate into power quality issues for the electrical neighborhood. Generation-to-load mismatch may cause reverse power flow, which has protection coordination implications, and revenue erosion, which conflicts with the conventional utility business model.

Engineering to Accommodate Net Load Volatility

PV and EV adoption levels are not yet high enough to cause widespread issues that cannot be managed with conventional technology and methods. The long-term adoption forecast varies drastically from region to region and even from circuit to circuit. The inclination of a population to adopt these technologies is influenced by socioeconomic factors, incentives, utility programs and global supply chain delays. This line of sight directly impacts the load growth estimation, by circuit and systemwide, which is an important consideration for long-term budgetary decisions for generation, distribution and transmission capacity, and grid flexibility planning.

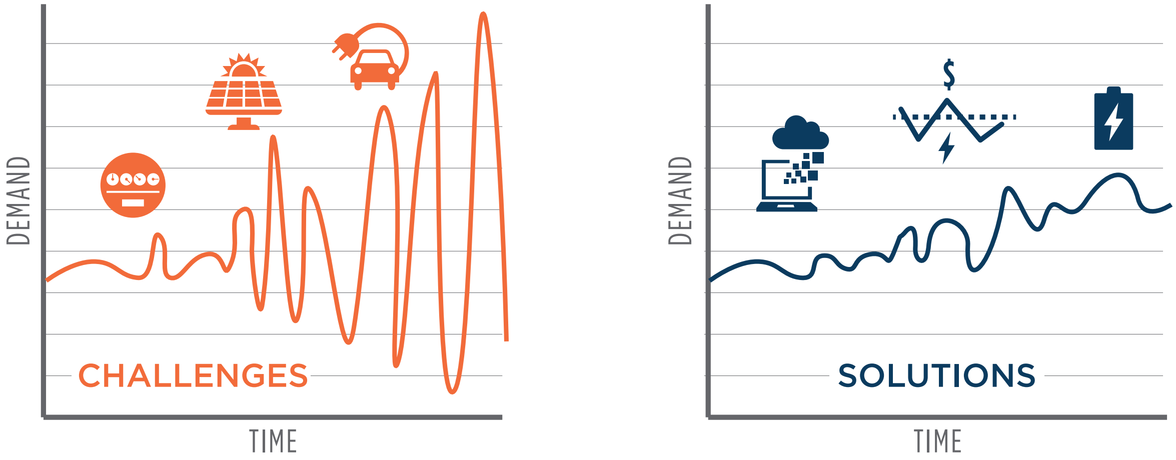

***Figure 1:** Demand increases over time, becoming more erratic because of factors like the unpredictable impact of renewables and EVs. This directly affects all aspects of power from generation through transmission and distribution. Creating grid flexibility through edge computing, demand response programs and energy storage can help compensate for the challenges and smooth the demand curve.*

If the anticipation of EV load and PV deployment is aggressive enough, those factors can impact macro investment decisions such as generation mix and capacity, as well as transmission line sizing and the need for parallel paths — large-scale projects requiring years of planning and execution. It can also affect more granular system planning, such as distribution asset capacity sizing and distribution operating voltage standards.

The utilization factor of any asset is the ratio of its average loading to its capacity. Asset capacity requirements are derived as a multiplier of the peak loading an asset is expected to handle over the forecastable future. The aggregated impact of EV and PV on the net load can wreck the expected utilization factor, resulting in underutilization of the asset base.

As an example, assume the capacity design standards call for a distribution transformer to be rated at 33% above its forecasted peak load, and both EV and PV penetration are at 30% of peak load (see Figure 2). In this scenario, the distribution transformer would have to be rated to accommodate loading 8% higher than it would have before being subject to electrification impacts. This may not seem significant, but that is a large enough difference to force the deployment of a 50-kVA unit where a 37.5-kVA unit would have sufficed, at an additional cost of about $2,500. Repeat the same exercise across the thousands of distribution assets subject to the impacts of electrification, and the financial impact of electrification on system planning becomes a significant line item in the budget. Since these are capital assets, the ratepayers are likely to be the ones bearing the burden as these cost increases will be democratized in tariff increases.

Sharing the Bounty and the Burden

In terms of individual premises, interconnection analyses increase in complexity since planning engineers must account for the aggregated impact of existing and planned EV chargers and PV sites. The complexity starts with maintaining an accurate electrical model that reflects the system as built, tracking planned distribution grid upgrades, and keeping up with approved and expected interconnection requests. Keeping the electrical model validated in anticipation of future EV and PV deployment is fundamental to producing accurate engineering studies, because any concerns are due to the aggregated impact of distributed generation and load increase, not just what happens on individual premises.

Territories subject to significant EV and PV deployment may include more flexibility technologies in their integrated resource planning, such as community energy storage. These would be sized and located at optimal nodes on the power distribution grid for the purpose of reducing peak loading, supplementing PV generation intermittency, balancing phase loading, or avoiding reverse power flow — or a combination of such purposes. The introduction of edge intelligence for collaboration and control out at the edge may offer new avenues for utilities to consider where local control of smart inverters, and the orchestration of EV charging and other loads, could be coupled with dynamic price signals as a form of advanced demand response during periods of local capacity constraints.

Residential customers with EV chargers might see their electric bills increase between 10% and 50%, depending on their typical electricity usage, driving habits and conventional residential tariffs. Utilities might implement time-of-use (TOU)

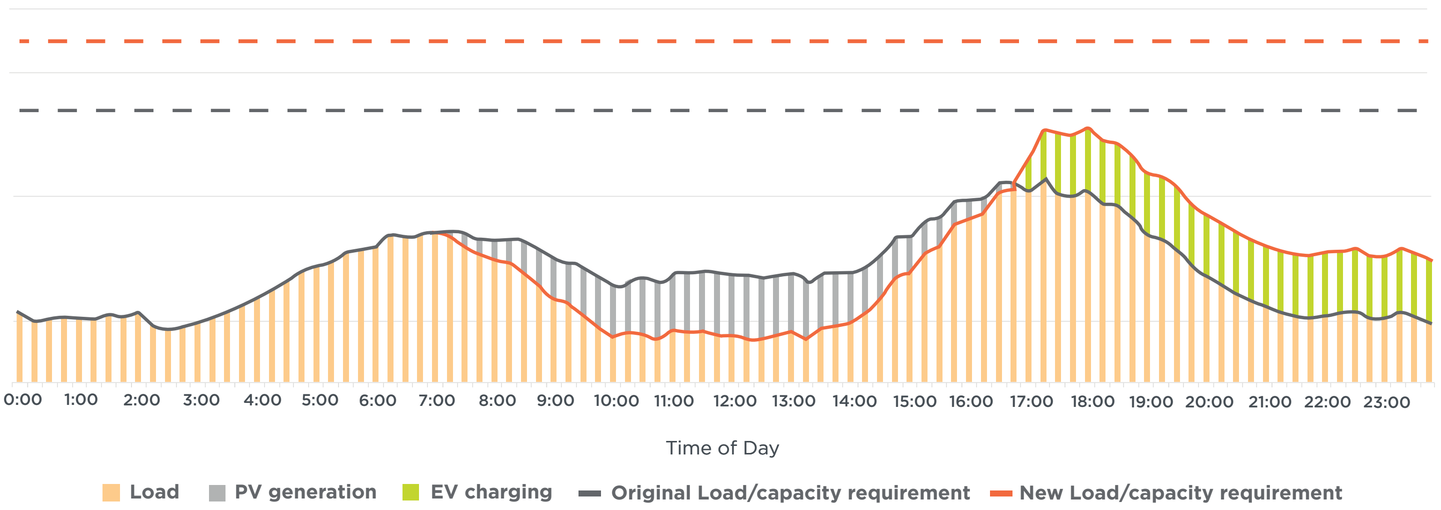

***Figure 2:** EV charging and PV generation impact on utilization factor.*

rates to encourage EV charging during lighter system loading hours. This effectively would convert this new revenue into an incentive for behavioral load shifting to reduce the peak loading on their power distribution assets (see Figure 3).

Conversely, every kilowatt-hour generated by a customer's PV system for individual use is a kilowatt-hour that cannot be billed by the utility and often is not even metered. This reality is introducing societal complexities, because residential rates are based on the net consumption seen by the meter. Considering that utilities are mandated to maintain the power distribution grid for all customers, and the tariffs in most cases are derived from allowing a marginal profit on top of their capitalizable assets, this effectively means PV owners' bills are subsidized by non-PV owners. This has in turn led to the idea of billing new capacity charges for PV owners, which also carries its share of controversy.

Answering the Call With Data-Driven Solutions

The challenges that power utility engineers are facing call for the application of data science to advance analytical solutions. One of the most pressing issues for utilities is producing investment estimates — that can be justified to the commission or other governing body — so the utilities are prepared to accommodate electrification. A data-driven approach starts with EV and PV adoption forecasts by circuit, derived from socioeconomic trend analyses. It then translates this into the impact on loading performance across transmission and distribution power delivery asset and generation capacity requirements. Ultimately it leads to bundling and prioritizing specific projects systemwide, resulting in a data-driven budget request and prioritization of asset replacements or capacity expansion.

The load migration effect caused by the large load footprint of EVs charging in electrical proximity — and the load estimation error introduced by hidden load from local PV generation — means grid operators must gain more visibility into and control of the power distribution grid than ever. Analytics increasingly rely on near-real-time feedback and more accurate near-term net load forecast across the power distribution asset base, letting grid operations work with more context to target demand response actions, inspect and replace overloaded devices to avoid equipment failure, and repurpose larger distribution transformers that are underutilized.

These analytics use cases rely on orchestrating and serving data from multiple systems of record to bring into the same context the electric model, premise-level and feeder device-level measurements, events and switch status, and near-term weather forecasts. This might justify the implementation of a common information model or data platform to produce intelligent information, coordinated across various departments, to meet their specific data-driven needs while keeping the results aligned with a broader picture. Additionally, the granularity of deploying these analytics on the distribution grid calls for data fidelity beyond what can be provided through a conventional validation, estimation and editing (VEE) approach to clean up the data. This need for higher fidelity may be met by applying advanced validation methods to leverage advanced metering infrastructure and supervisory control and data acquisition (SCADA) measurements, events and control to confirm or correct meter-transformer association, asset phasing and impedance across the system.

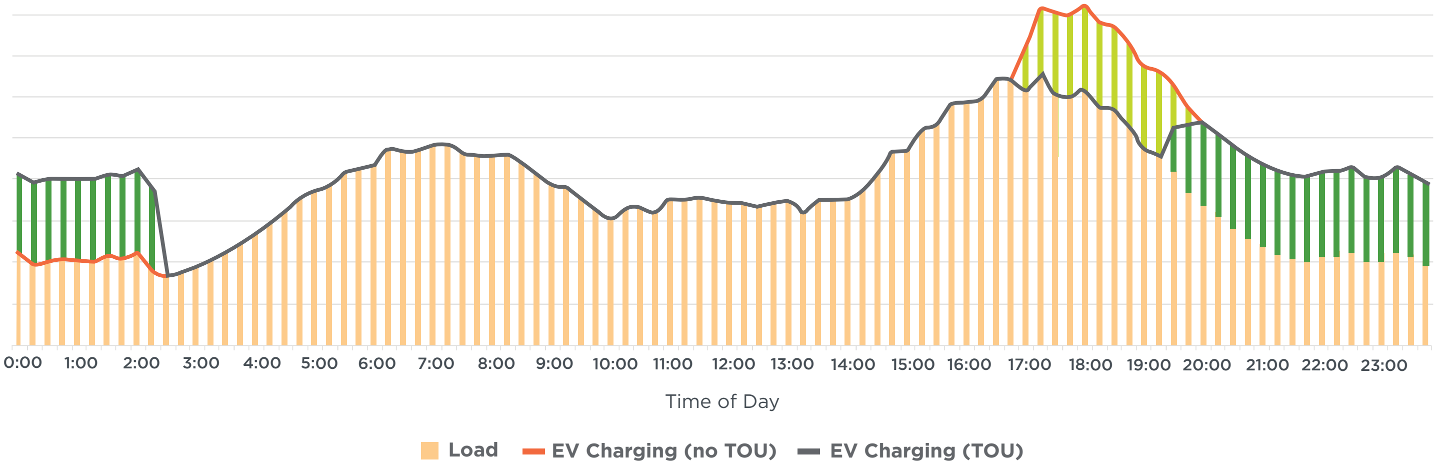

Figure 3: *EV charging and PV generation impact on load profile.*

Conclusion

Electrification could become one of the great success stories of the 21st century, but the devil is in the details as society moves forward. The electric grid was designed for legacy technologies that are rapidly being sidelined. System planners will need to confront the greater complexities introduced through EV charging and PV deployments, predicting and modeling behaviors to maintain the necessary level of aggregate expectations guiding utility decision-making in the decades to come. This will be critical to avoiding overbuilding and delivering cost-effective service.

About 1898 & Co.

1898 & Co. is a business, technology and cybersecurity consulting firm serving the industries that keep our world in motion. As part of Burns & McDonnell, our consultants leverage global experience in critical infrastructure assets to innovate practical solutions grounded in your operational realities. For more information, visit **1898andCo.com**.