NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Electric Vehicle Risk Profiles and Prioritization

Electric Vehicle Task Force White Paper

September 2025

RELIABILITY | RESILIENCE | SECURITY




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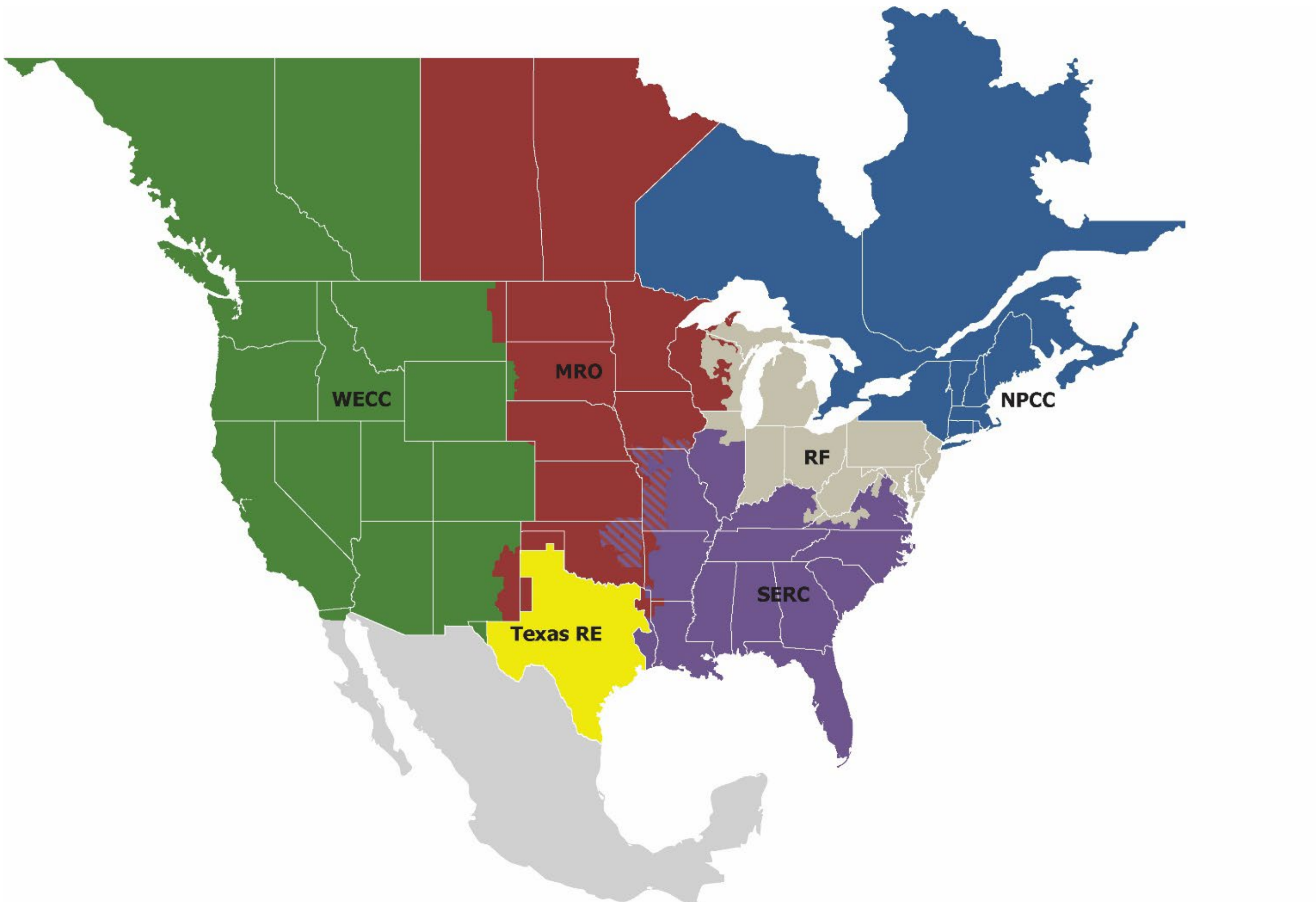
Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of NERC and the six Regional Entities, is a highly reliable, resilient, and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is made up of six Regional Entities as shown on the map and in the corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners/Operators participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	WECC

Statement of Purpose

The NERC Electric Vehicle Task Force (EVTF) was formed to identify, validate, and prioritize specific risk mitigation methods associated with the growing electrification of the motor vehicle sector. Past NERC studies[1] have identified a need to quantify the risks associated with the potential impact that the rise of aggregate electric vehicles (EV) has on the BPS. In addition to identifying, validating, and prioritizing the potential BPS reliability risks related to motor vehicle electrification, this white paper is intended to (where applicable) identify areas where potential security risks require additional follow-up assessment by security professionals. The EVTF used the specific reliability principles[2] as the technical basis for the risks identified in this paper. The paper reviews the following topical areas:

- Resource Adequacy
- Transmission System Stability
- Management of System Constraints
- Energy Policy
- Normal and Emergency Operational Constraints
- Personnel Training
- Physical and Cyber Security

The EVTF reviewed these topical areas of concern as related to rising EV demand and has described and prioritized any risks. Where possible, the EVTF also considered areas where EVs could benefit BPS reliability and included this context with the most applicable identified risk. The EVTF will provide a risk mitigation plan for potential actions to address each of the 20 identified risks. These risks are as follows:

1. Increasing Difficulty to Adequately Forecast EV Characteristics
2. Inability to Represent Modern EV Charging and Discharging Behavior with Current Models
3. Uncertainty of System Needs Under Grid Transformation
4. Speed of Integration Outpacing Utility Ability to Upgrade
5. Lack of Technical and Standards Coordination Between EV Original Equipment Manufacturers (OEM), Utilities, and Electric Vehicle Supply Equipment (EVSE) OEMs
6. Inadequate BPS Studies
7. Lack of Available Charging Profiles
8. Distribution System Requirements Balancing Against BPS Requirements
9. Unclear Charging Requirements, Certifications, and Expectations
10. Lack of Information Share Between Automotive Entities, Utilities, and End-Use customers
11. Unclear Response and Needs of EVs as Part of Emergency Operation Plans
12. The Absence of Guidance and Best Practice in Management of Multi-Layered Choices
13. Lack of Security Standardization
14. Lack of High Bar Cyber Security Posture

[1] See here: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Potential_Bulk_Power_System_Impact_of_Vehicle_Chargers_2024.pdf
[2] Available here: https://www.nerc.com/pa/Stand/Resources/Documents/Reliability_Principles.pdf

15. Lack of Clarity on Authority and Responsibility for Normal or Emergency Operations
16. Lack of Understanding of Hybrid Resource Applicability in Emergency Operation Plans
17. Lack of Operational Practice Development for Wide-Area Management of EV Traffic
18. Inconsistent Nomenclature to Describe Risk
19. Lack of High Bar Physical Security Posture
20. Low Internal Interdepartmental Coordination

Furthermore, this document identifies any Reliability and Security Technical Committee (RSTC) groups that could write additional content to follow up on the work performed in this risk identification paper. These added group recommendations are as follows:

1. Transmission Planners (TP) and Planning Coordinators (PC) are advised to begin a review of their modeling and forecasting processes and to consider improving their ability to adapt to this emerging technology.
2. Transmission Operators (TOP), Reliability Coordinators (RC), and Balancing Authorities (BA) are advised to begin coordination efforts with adjacent TOPs, RCs, and BAs to improve their situational awareness of EV charging needs.
3. TOPs and RCs are advised to adapt their internal processes and procedures to account for the risks identified for normal and emergency conditions. These adaptations should account for current and best practices in EV load treatment, potentially developed under recommendation 4c below.
4. The NERC RSTC is advised to consider assigning the following work items to its subordinate groups:
    a. The NERC Load Modeling Working Group is advised to develop and enhance a generic EV representation to include vehicle-to-grid functionality.
    b. The NERC Resources Subcommittee is advised to develop or enhance its guidance or other technical documentation to describe the considerations for necessary resource characteristics[3] to meet known or expected EV charging profiles.
    c. The NERC Real-Time Operating Subcommittee is advised to develop or enhance its guidance or other technical documentation to describe the necessary coordination efforts when under electrical emergency situations and how to prioritize EV loads during electrical emergencies. This documentation can consider scenarios where EVs are part of the emergency response vehicles.
    d. The NERC Reliability Assessment Subcommittee is advised to develop data gathering procedures or narrative requests to monitor and assess the growing EV charging demand.

[3] E.g., ramping, turnaround, or other qualities of generation resources. Potentially even distribution-connected resources, if appropriate.

Chapter 1: Identification of Risk and Risk Profiles

This chapter explores a structured approach for assessing and prioritizing risks to the BPS related to EV integration into the power grid. Categories of risk are based on the NERC Reliability Principles that are the foundation for the NERC Reliability Standards. This chapter covers the high-level risk profiles with subsequent chapters providing additional details.

Unique EV Charging and Discharging Characteristics

EV charging and discharging behavior has characteristics unique from traditional power system components, particularly other types of energy storage. Key aspects include the speed of charging and discharging, the potential for bi-directional power flow (e.g., vehicle-to-grid (V2G)), the mobility of this storage to travel between points of grid interconnection in order to charge or discharge, and the primary purpose of this energy being for transportation or mobility. These unique characteristics are called out in the paper as appropriate and are detailed in other NERC reports.[4] Furthermore, the EV landscape is integrating more parties that help serve the end user than the traditional distribution or transmission utilities have experienced. This is highlighted in **Figure 1.1** in the various boxes that illustrate the potential for new entities (e.g., the charge point operator or aggregator) to exist across each border in the figure.

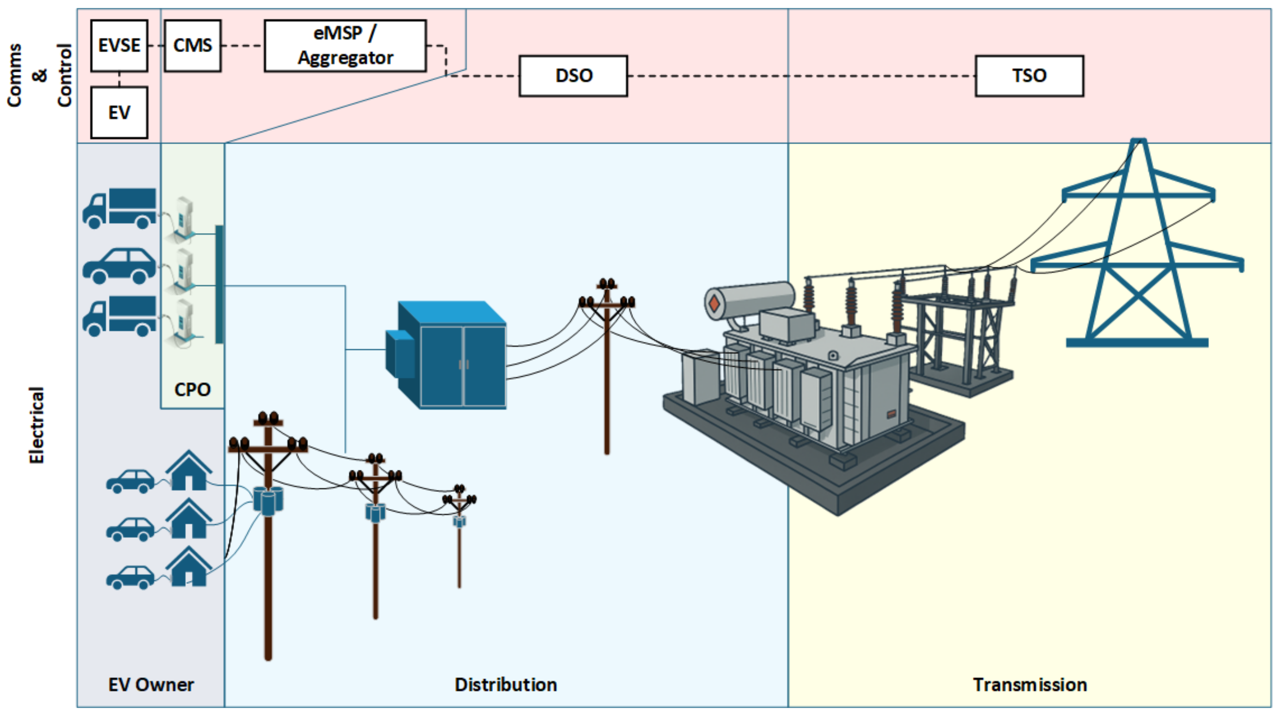


Figure 1.1: EV Integration Through the Distribution System

[4] Available here: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Potential_Bulk_Power_System_Impact_of_Vehicle_Chargers_2024.pdf

NERC Reliability Principles

Each NERC Reliability Standard is developed through the *Standard Process Manual*,[5] which sets the drafting of a standard to align with specific reliability principles[6] such that "each reliability standard shall also be consistent with all of the reliability principles, thereby ensuring that no standard undermines reliability through an unintended consequence." These principles are the following:

- Interconnected bulk power systems shall be planned and operated in a coordinated manner to perform reliably under normal and abnormal conditions as defined in the NERC Standards.
- The frequency and voltage of interconnected bulk power systems shall be controlled within defined limits through the balancing of real and reactive power supply and demand.
- Information necessary for the planning and operation of interconnected bulk power systems shall be made available to those entities responsible for planning and operating the systems reliably.
- Plans for emergency operation and system restoration of interconnected bulk power systems shall be developed, coordinated, maintained, and implemented.
- Facilities for communication, monitoring, and control shall be provided, used, and maintained for the reliability of interconnected bulk power systems.
- Personnel responsible for planning and operating interconnected bulk power systems shall be trained, qualified, and have the responsibility and authority to implement actions.
- The reliability of the interconnected bulk power systems shall be assessed, monitored, and maintained on a wide-area basis.
- bulk power systems shall be protected from malicious physical or cyber attacks.

Based on these principles, the EVTF characterized categories of risk into areas that touch on these principles. Generally, these categories are the ability to secure resources to serve load, ensuring stability of the system, training of personnel, and the security of the equipment from physical or cyber intrusion and malicious use.

Risk Identification, Validation, and Prioritization

The NERC RSTC and its subgroups follow the *Framework to Address Known and Emerging Reliability and Security Risks*,[7] which is highlighted in **Figure 1.2**. The scope of this paper is the highlighted (red) section of the figure to identify, validate, and prioritize potential risks to the BPS. The EVTF has a separate white paper (blue) exploring the potential risk mitigations associated with the identified risks in this white paper on its work plan.

[5] Available here: https://www.nerc.com/AboutNERC/RulesOfProcedure/Appendix_3A_SPM_Clean_Mar2019.pdf
[6] Available here: https://www.nerc.com/pa/Stand/Resources/Documents/Reliability_Principles.pdf
[7] This document is available here: https://www.nerc.com/comm/RISC/Related%20Files%20DL/Framework-Address%20Known-Emerging%20Reliabilit-Securit%20%20Risks_ERRATTA_V1.pdf.

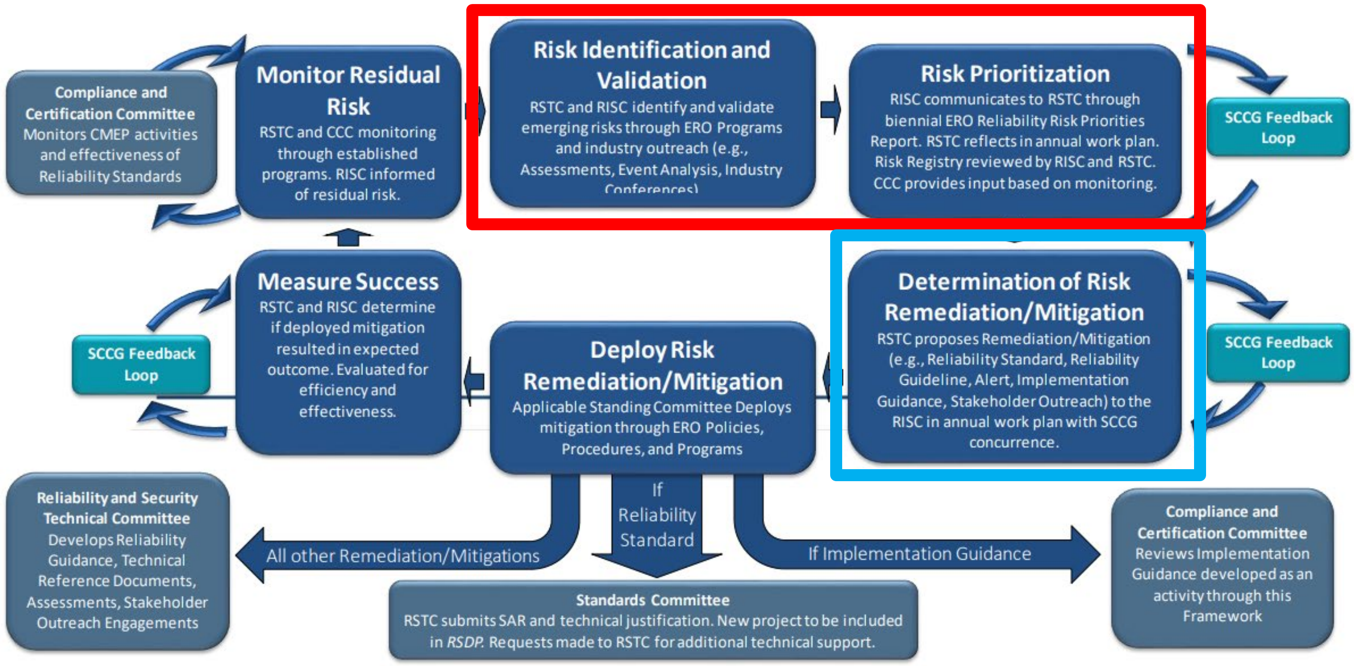
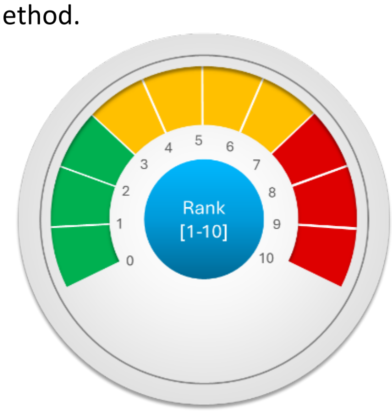


Figure 1.2: NERC Risk Mitigation Procedure[8]

Risk Prioritization and Ranking Figure

As part of the NERC *Framework to Address Known and Emerging Reliability and Security Risks,* the EVTF has assigned a rank and a graphic to summarize the risk into manageable sections. These graphics (with an example found in **Figure 1.3**) help to summarize the weight that the EVTF places on the identified risks. These are helpful to visually represent the priority, a relative ranking among high (red), medium (yellow), and low (green) priority risks, and a brief description of the risk in question. These rankings are recommended by the NERC RSTC and were developed under the risk prioritization method.



Risk Name: [Name]

Risk Description: [2-3 sentence]

Figure 1.3: Example Risk Prioritization Meter

Risk Prioritization Method

After the EVTF identified the relevant BPS risks associated with growing motor vehicle electrification, its members conducted an internal decision matrix. Of the 20 identified risks, each was to be given a priority rank order from 1 to 20. These rankings were then averaged across all responses in the decision matrix and ordered from highest to lowest.

[8] Figure subject to change based on edits to NERC's framework to address known and emerging reliability risk.

Next, these rankings were altered to fit the ranking values of 1 to 10 through a base change. These details are discussed more thoroughly in the **Risk Prioritization** section.

Chapter 2: Resource Adequacy

The EVTF identified risks associated with resource adequacy and has given each of the identified risks a profile that consists of a name, description, and priority. The BPS risk identified in this chapter is associated with the following reliability principles:

- The frequency and voltage of interconnected bulk power systems shall be controlled within defined limits through the balancing of real and reactive power supply and demand.
- Information necessary for the planning and operation of interconnected bulk power systems shall be made available to those entities responsible for planning and operating the systems reliably.

Increasing Difficulty to Adequately Forecast EV Characteristics

Risk Name: Increasing Difficulty to Adequately Forecast EV Characteristics

Risk Description: Transmission planners and operators do not have sufficient fidelity and accuracy for capacity or energy projections.

Resource Planners (RP) require tools, personnel, and information in order to estimate future-year capacity, capabilities, and the location of demand and resources. The lack of available EV charging data prevents RPs from performing these functions for EVs. This risk focuses on challenges where there is a lack of access to EV data, such as locations, maximum capacity, and variability of EV charging. These challenges stem from the strong correlation between EV adoption and the incentives to purchase this type of vehicle. These incentives consist of a variety of factors, such as government direct subsidy, infrastructure availability, and the market price of technology (e.g., the EV battery). These drive the cost to the consumer, in turn driving the demand expectation for future years. However, as with all emerging technologies, the customer's preference also changes the available incentives and creates a feedback loop in this process that makes it challenging to accurately forecast the expected demand and how that demand will exchange energy with the electric system.

The NERC EVTF understands that the accuracy and fidelity of future-year forecasts improves as the EV market matures and that a 100% accurate forecast is not possible due to the inherent nature of forecasting. This means that in the early stages of inclusion, the accuracy of a given projection or forecast can vary and in its most mature form some level of inaccuracy will remain in the forecast. The risk applies to all temporal variants of load forecasts (i.e., long-term load forecast (10–15 years ahead), medium-term load forecast (weeks–years ahead), and short-term operational load forecast (hours–days ahead). The long-term forecast is mostly used for long-term[9] planning purposes, and the inaccuracies in that forecast could eventually result in resource inadequacy if under forecasting EV charging load or stranded generation assets if over forecasting EV charging load at the BPS level. The inaccuracies in the medium-term load forecasts could result in insufficient resource and system planning, especially considering continuing supply chain constraints with material lead time for grid network upgrades taking 18 months up to a 3-year timeframe. Lastly, inaccuracies in the short-term forecast could result in system operational reliability issues, specifically the ability of the power system to balance supply and demand in real time and rapidly respond to unexpected events. As an example, long- (a), medium- (b), and short-term (c) forecasts in the PG&E System are shown in **Figure 2.1**. These forecasts were developed as part of the California Energy Commission's Integrated Energy Policy Report[10] and demonstrate the use of differing forecast representations depending on the end use. Here the long-term (a) forecast has applications for resource adequacy and procurement, the medium-term (b) forecast shows seasonality for intra-year outage planning, and the short-term (c) forecast has application for next-day operational planning. Each is needed for various planning purposes.

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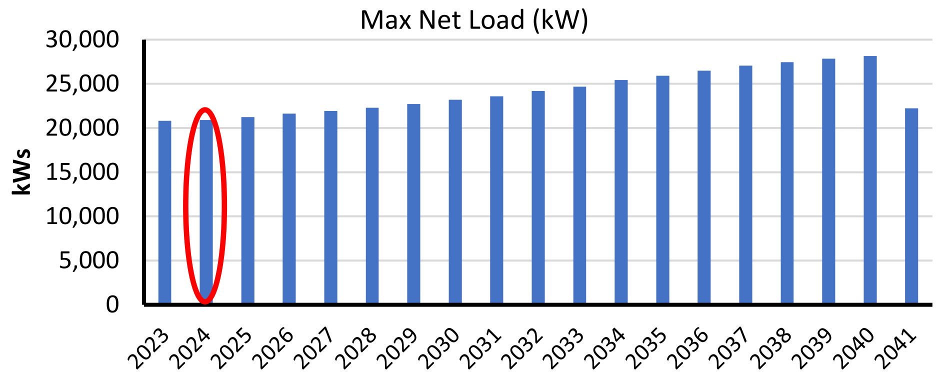
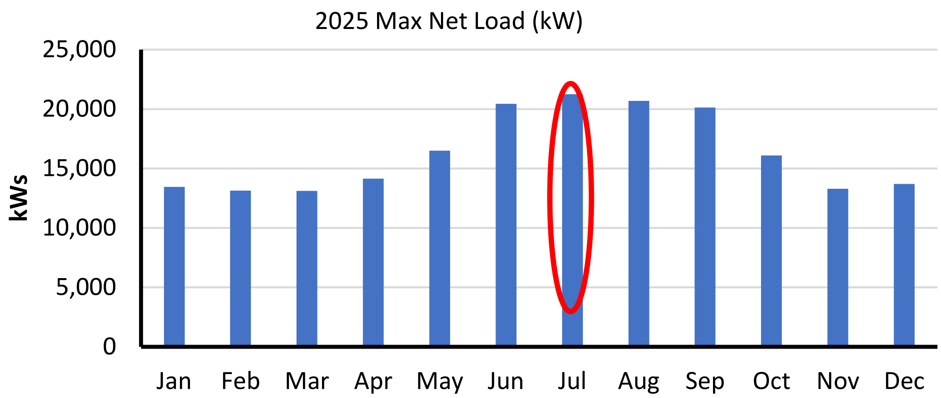
[9] These periods are typically associated with the generation or resource planning activities.

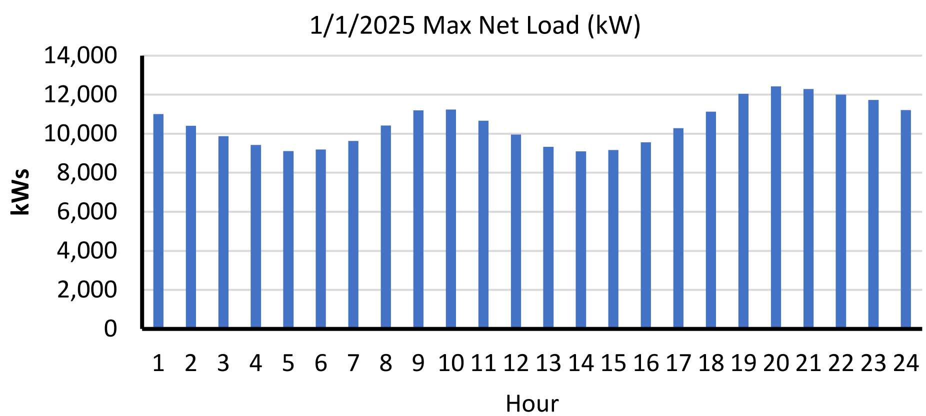
[10] Available here: https://www.energy.ca.gov/data-reports/reports/2023-integrated-energy-policy-report/2023-iepr-workshops-notices-and-2



(a)



(b)



(c)

Figure 2.1: Peak Demand Forecast Example for a) Long-Term Demand, (b) Medium-Term Demand, and (c) Short-Term Demand Forecasts

Furthermore, most forecasts and projections today are focused on sales of vehicles rather than on end-use customer capacity (for charging or discharging). Thus, transferring the sales forecast to a demand forecast is complicated, unclear, and time-consuming for RPs that need to incorporate this transferal of sales into actualized demand into their studies.

Operational Versus Planning Horizon Forecasting

This risk can be broken into the long-term transmission planning horizon (years 1–5), near-term transmission planning horizon (years 6–10), and operational planning horizon (year 0–1). Transmission planners and operators require accurate information for their use, but the types of data needed to conduct these assessments differ. For instance, operational planning assessments (OPA) and real-time assessments (RTA) differ significantly from the information needed to conduct studies set in the future ranging from next-week operational planning assessments to the long-term planning horizon. It is a risk that many utilities have no method to forecast or predict EV behavior due to a lack of experience, data, or tools to accomplish this task. It is highly likely that the mitigations for the operational horizon will look different than for the planning horizon; however, the risk stems from the core challenges of forecasting EV charging or discharging behavior, maximum kW capacity for a variety of EV [light, medium or heavy duty] models, and future EV charging locations.

Lack of Available Charging and Discharging Profiles

Risk Name: Lack of Available Charging Profiles

Risk Description: Insufficient data exists to populate or build charging profiles for EV charging demand.

Resource adequacy is dependent on historical data and projections to fully forecast and identify resource shortfalls in the short-term transmission planning horizon or the long-term transmission planning horizon. This risk is separate from the need for tools, structures, or procedures to forecast risk as discussed above. Procedures that forecast the capacity, capability, and location of these resources are also dependent on historical datasets and performance expectations and are separate from the need for tools, structures, or procedures to forecast risk as discussed above more broadly. For example, hydro resources are dependent on their construction (e.g., run of river or pond sourced), the precipitation of a given weather year, and the necessary water discharge for other industries and consumption. For hydro resources, this means that the many-year recorded hydrological readings of these three conditions allow RPs to use weather sets to forecast hydro output to perform their resource planning function. When such profiles and data are lacking, engineering judgment can supply a generic[11] profile for use in resource planning. But what happens when neither historical data nor generic profiles are available? This means that RPs needing to incorporate EV impacts have neither the historical datasets nor the generic profiles available to describe how, when, and where future EVs will charge or discharge. The EVTF acknowledges that as more EVs come on the road and start charging using the electric power infrastructure, the historical datasets will continue to accumulate, complementing the significant work that has been done by the distribution utilities in creating synthetic profiles from historized EV charging loads. However, how these load profiles diversify and get rolled up to the BPS and how accurately they are forecasted at the BPS is a risk.

Several factors related to charging profiles create risk, as summarized in the following sections:

Types of EV Charging: There are many types of EV charging, each with their own unique charging profiles: home, work, public, and commercial fleet. The breakdown of where people are charging is not well understood and varies by household and type of business. Some charge EVs only at home, while others who live in an apartment may only charge at their workplace; some only use public EV charging; and, finally, some use a combination of all of the above. Assumptions are heavily relied upon.

Level of EV Charging: Not knowing the level of EV charging by type of customer and location can impact load-profile assumptions. Level 1 and Level 2 charging options deliver alternating current (ac) to the vehicle, with maximum power outputs ranging from as little as 2.3 kW and 22 kW, respectively, for Levels 1 and 2, while Fast DC charging feeds direct current (dc) into an EV's battery and unlocks much greater power, up to 400 kW. Even megawatt (1,000 kW)

[11] Through synthesis of known data sources, or projected expectations for new technology types.

and greater charging stations for medium- and heavy-duty EVs are in development. Gathering the level of charging at a location can be accomplished, for example, through permitting, utility programs, or meter infrastructure (e.g., Advanced Metering Infrastructure or AMI).

Diversity of EV Charging - In addition to the wide range in maximum power outputs, diversity[12] plays a major role when it comes to EV charging load profiles. The theory is that not all EVs are charging at the same time. The more EVs or broader geographical area being forecast, the lower the kW maximum capacity assumption per EV; conversely at the household level, EV charging is considered a continuous load by the National Electrical Code, so the maximum kW capacity is tied to the EV's make and model. Utilities can purchase counts by make and model using department of motor vehicles data, but EV locations are not known at the level of detail needed to tie to a utility's distribution grid. Furthermore, there may be patterns of vehicle charging consumption that evolve over time that will change the diversity of EV charging when such information matures and is made available.

Another risk factor with operational short-term forecasting influencing a typical household load profile is creating individual household assumptions for EV charging's maximum kW capacity**,** even with the knowledge that the home or customer has, for example, a Level 2 charger. Relying on EV spec sheets alone to estimate maximum kW capacity may cause oversizing of a transformer. Just because the specs for a particular EV make and model say that it has an 11.5 kW onboard charger does not mean that it will use this full amount of demand. If a smart charger wall connector is in use, it will automatically adjust the amps down to an amount that will not trip the breaker, so the demand will be far less, such as 2–4 kW per EV. This also impacts the load of individual charging profiles that utilities provide within their automated distribution management systems (ADMS). Tracking which homes have upgraded their service, say from 200 to 400 amps, can be useful to know as the home may now have a larger circuit breaker that can charge an EV faster at a higher charging kW level.

Speed of Integration Outpacing Utility Ability to Upgrade

Risk Name: Speed of Integration Outpacing Utility Ability to Upgrade

Risk Description: EV demand is growing at a rate faster than traditional utility procurement can build the resources to serve this demand.

Transportation investment has historically taken several years from the initial project design to the point of energization. This means that for utilities to use historical systems and processes to invest in their grid infrastructure, short-term spikes are harder to plan for and predict than long-term stable growth. EVs are projected to have adoption rates that outpace traditional utility capacity to upgrade facilities. This is because the sheer capacity growth targets would require replacement and upgrades of both distribution and transmission equipment. The supply chain for this equipment on the distribution and transmission grids is already strained with other load growth and applications for other markets. These factors all lead to the conclusion that utilities using traditional methods to upgrade and evaluate their necessary load service will be unable to keep up with the integration speed of EVs.

Furthermore, many high-power charging load applications are dependent on the availability of capacity on the utility infrastructure to connect, but the unavailability of capacity results in detraction or relocation of the load applications as most of the loads will not wait for the upgrades to take place before they are allowed to connect. This dependance on capacity availability also results in uncertainty in the persistence of the load applications contributing to uncertainty and inaccuracies in the load forecasts as well. The NERC EVTF plans to explore options to mitigate this risk that evaluate alterations or alternatives to the traditional methods of utility upgrades in the EVTF work plan. This could include flexible interconnection where the immediate capacity to serve a load is reduced, but once network upgrades are accomplished the entire capacity is able to be served. These solutions further require equipment that

[12] In particular, the diversity factor of the expected load plays a vital role in producing the EV charging load profile. This will change over time and vary seasonally due to the nature of the mobility needs for end-use customers.

limits power import;[13] the increasing control complexity can create errors due to improperly installed or defective equipment. Further compounding this risk is population movement potentially taking these sizable loads across various electrical networks.

The utility's traditional methods can handle population growth over time, but mass movement[14] can create situations of localized congestion until network upgrades are available. While not entirely an EV consideration, populations that move their vehicles across electric systems may create new seasonal profiles[15] (e.g., travel to visit family for Thanksgiving or other holidays) above what an area can serve. Utilities that are facing these challenges are already strained, and factoring the size of new EV charging demands into this growth is yet another challenge. Compounding this effort is the potential congestion of EV adoption on a local, state, or regional level (as seen from the BPS) that will lead to differences in realized grid conditions, supply chain constraints, and the utility's ability to meet the new demands on its system. Furthermore, the policy changes at the federal level in 2025 can further increase the variability of EV adoption at the local or state level. Because of these complicating factors, utilities will likely have differing structures and abilities to implement changes to their practices and policies based on their business size and practices.[16] The EVTF anticipates that some utilities may have a harder time in adjusting their practices and policies to account for shifts or alterations to the concepts above.

Uncertainty of System Needs Under Grid Transformation

Risk Name: Uncertainty of System Needs under Grid Transformation

Risk Description: Future year transmission Systems are not well articulated. It is uncertain if the future system can meet new end-users.

Resource adequacy analysis (in the form of integrated resource plans and holistic planning) involves resource and demand projections. The third major component is the availability and strength of the transmission system. This system is known to be evolving alongside other advances or transformations in the grid, which complicates the analysis of this component. Unless the transmission system's performance and needs are known for this future-year system, it is difficult to accurately identify the ability of the transmission system to meet end-use customer demands. The risk is exacerbated by the limited integration in the planning processes of the transmission and distribution systems. Furthermore, the lack of understanding of the long- and medium-term variations in the EV charging demand makes it difficult to map the forecasts to the system needs. The mobile nature of the charging load also adds to the uncertainty in load forecasting (e.g. as the demographics of one area change from an EV-adopting population to a non-EV-adopting population or vice-versa due to factors such as new developments or gentrification), meaning that the resulting residential charging load also shifts as demographics shift. A similar variation may also occur because of transportation seasonality (e.g., COVID-19, winter travel, holiday seasons, snowbirds) now starting to interact with the demand seasonality as well.

[13] For example, the UL 3141 standard defines the Power Control Systems used in distribution networks to limit consumption of the end-use devices. Available here: https://www.shopulstandards.com/ProductDetail.aspx?productId=UL3141_2_O_20241009

[14] Variations in the U.S. Census data show significant population movement. Available here: https://www.census.gov/data.html

[15] Example seasonal traffic shifts can be seen here: https://tdot.public.ms2soft.com/tcds/tsearch.asp?loc=Tdot&mod=TCDS. Organizations like the American Automobile Association (AAA) also have data that demonstrates these seasonal motor vehicle shifts. Some datasets are also purchasable for consumer end use.

[16] For example, engagement across many stakeholders depends on solid relationship development between the utility and their stakeholders. Effectiveness of any change or alteration to traditional utility means to update or upgrade its applications, systems, or customer programs to the evolving EV landscape depends on these business practices.

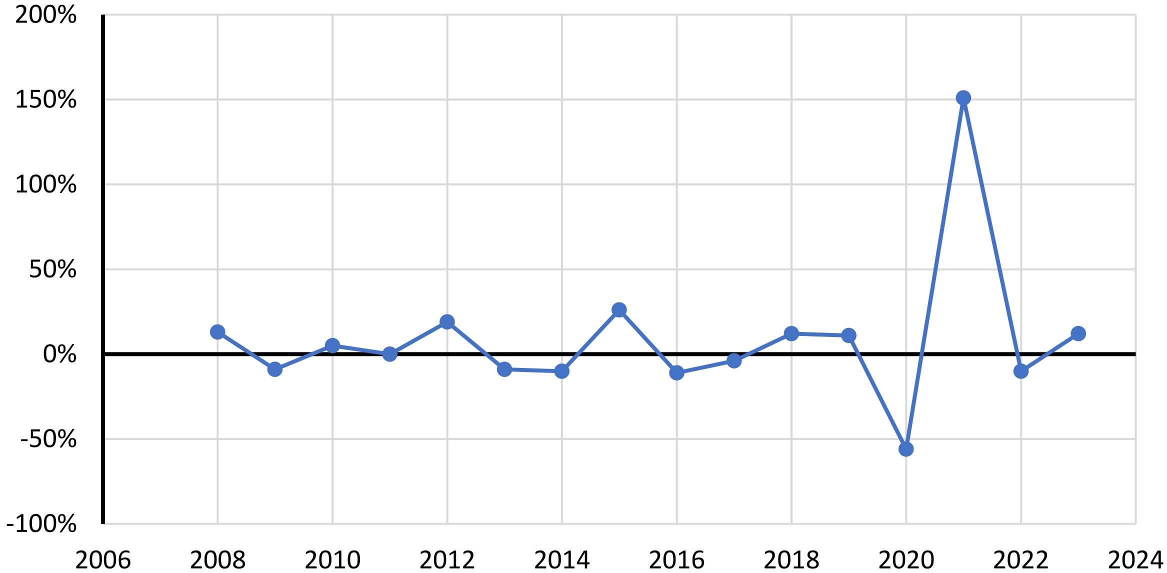


Figure 2.2: Annual Traffic Count Growth on a Portion of Interstate I-75 in Anderson, Tennessee[17]

[17] https://tdot.public.ms2soft.com/tcds/tsearch.asp?loc=Tdot&mod=TCDS

Chapter 3: Transmission System Stability

The EVTF identified risks associated with transmission system stability and has given each of the identified risks a profile that consists of a name, description, and priority. The BPS risk identified in this chapter is associated with the following reliability principles:

- Interconnected bulk power systems shall be planned and operated in a coordinated manner to perform reliably under normal and abnormal conditions as defined in the NERC Standards.
- Information necessary for the planning and operation of interconnected bulk power systems shall be made available to those entities responsible for planning and operating the systems reliably.
- The reliability of the interconnected bulk power systems shall be assessed, monitored, and maintained on a wide-area basis.

Inability to Represent Modern EV Charging and Discharging Behavior with Current Models

Risk Name: Inability to Represent Modern EV Charging and Discharging Behavior with Current Models

Risk Description: The transient response of EVs is unable to be represented in available models for use by Transmission Planners.

As past NERC studies[18] have shown, the reliability of the BPS can be compromised by how EVs charge under voltage depressions or resource loss. This impacts the ability of the BPS to maintain transmission system stability under common system disturbances. In particular, the transmission system needs to avoid instances of cascading, instability, and uncontrolled separation. TPs evaluate transmission stability by performing near- and long-term assessments of the BPS and evaluate corrective actions where risk is identified. TOPs address this risk by performing their operational planning analyses and real-time assessments. These studies collectively need a way to represent modern EV charging characteristics in the steady-state, transient, and short-circuit domains. The common study domain[19] in which these evaluations occur is positive sequence. The latest model-year data that has influenced the positive-sequence EV model representation is from the 2017 EV model year. Software and charging infrastructure has rapidly evolved since its 2017 state, and the model further simplifies EV charging on the distribution system to have simultaneous action at the modeled load bus[20] in the transmission simulation. The EVTF has identified that these base assumptions and antiquated charging logic are unable to represent modern EV charging architecture. This indicates that models need to be developed for TPs and TOPs to be able to represent modern EV charging and discharging behavior.

One major example is the method to model the behavior of the EV under exporting mode, particularly the behavior seen from heavy- or medium-duty EV fleets. The addition of EV charging depots with high MW charging capabilities may pose a potential stability risk, so the representation of these assets in transmission studies is necessary to identify how these assets will perform in simulation. As an example, the return to service parameter from aggregate EVs can affect the success of load-shed programs for underfrequency conditions. Should aggregate EVs return to service at full charging on entering service, the underfrequency condition may be exacerbated and destabilize the system. Clear representation of this transient behavior is thus essential to the success of these automated programs as inaccurate models can lead to study conclusions that are not realistic, leading to potential reliability gaps.

A significant risk factor stems from the difficulty in accurately modeling emerging technologies within a rapidly evolving technological landscape. As users adopt new technologies, they inevitably request and drive the

[18] https://nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Potential_Bulk_Power_System_Impact_of_Vehicle_Chargers_2024.pdf

[19] Other study domains, like electromagnetic transient studies, exist. However, they are not common for evaluating the impact of distribution-connected equipment in transmission level stability.

[20] This is typically the "centroid" of the distribution feeder for a given load represented in the transmission cases.

development of additional features. Transmission planners must therefore possess a robust understanding and representation of how these new features or functions will impact the electrical response of EVs to ensure proper modeling. Available positive sequence models focus on the active power and reactive power consumption of aggregate devices (see **Figure 3.2**). As of this report, there are known alterations to this model that should be implemented to better reflect the way EVs exchange current with the grid.

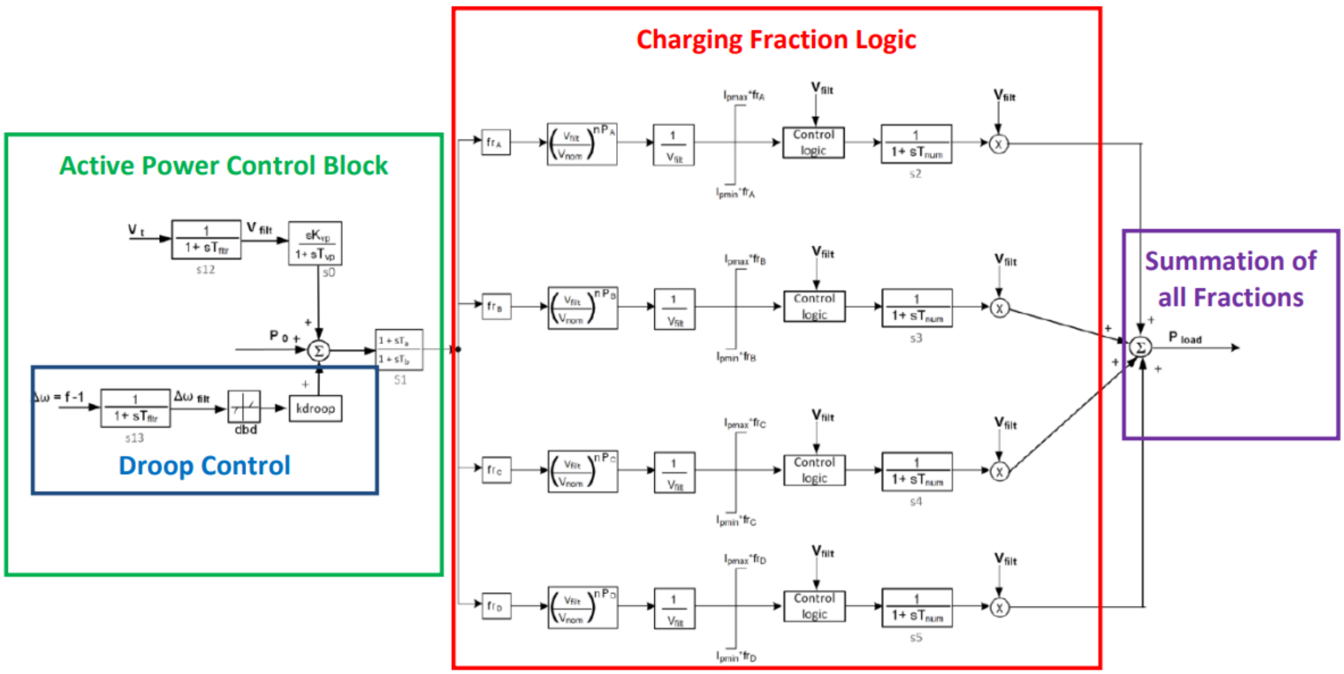


Figure 3.1: Block Diagram of Aggregate EV Model Active Power Logic (Source: General Electric)

For the reasons discussed above, there is an inherent iterative process that may change the electrical characteristics to meet new uses. This process can lead to models lagging their ability to represent emerging technologies. Over time, however, models are expected to reach maturity, and ensuring that the proper models are readily available to TPs will help mitigate this risk.

Inadequate BPS Studies

Risk Name: Inadequate BPS Studies

Risk Description: Currently, minimal studies have explicitly incorporated EV charging behavior and evaluated the BPS response.

A separate but necessary step in evaluating transmission system stability is the performance of BPS studies including EV charging or discharging. BPS studies vary between the operational horizon (5 minutes) to the long-term planning horizon (10 years). Today, most of the risk is in how to effectively study EV growth in the planning horizon (1–10 years). However, as EV penetrations rise in given areas, TOPs will also need to be able to adequately represent charging behavior in their operational assessments to ensure that transmission system stability is maintained under credible contingencies. The EVTF has identified that there is a risk for TPs and TOPs to exclude EVs from their studies as penetrations of EVs arise. While the penetration remains low, the majority of this risk will fall on mitigations identified in the planning horizon so that operators have the right tools and capabilities to operate the transmission system that integrates EV charging and discharging behavior. The following issues should be addressed as part of this risk:

- Parameterization of the EV model
- Validation of EV performance

- Aggregation and model techniques to reflect EV charging and discharging
- Performance targets to meet EV load needs
- Capacity and capability of EVs to supply Essential Reliability Services

The recent inverter-based resource (IBR) work has created opportunities to ensure that emerging technology can be included in stability models after years of effort to highlight the risks associated with growing BPS-connected IBRs. The EVTF recommends that planners review and include EV performance in their studies at a more rapid pace than that of which has occurred with IBRs. It is best for planners to stay proactive in this area to study the potential future grid and provide prudent mitigations to identified risk. To do so, guidance on how to predict what is coming and what is appropriate to study should be developed. New technology may require studies that differ from those necessary in the past. This may even cause a need to re-evaluate criteria to identify poor performance in a study framework. Adequate studies will include a framework to adapt to modern technology and to the changing resource mix.

Lack of Technical and Standards Coordination Between EV OEMs, Utilities, and EVSE OEMs

Risk Name: Lack of Technical and Standards Coordination Between EV OEMs, Utilities, and EVSE OEMs

Risk Description: No significant communication exists to coordinate the standards and technical requirements among affected stakeholders.

Transmission stability is highly benefited by collaboration among EVSE OEMs, EV manufacturers, and utility entities to establish performance criteria and engineering standards regarding grid-friendly EV charging methods. For example, communication standards for how devices exchange information can be housed separately from the performance requirements needed to ensure distribution worker or customer safety. As these standard setting organizations are focused on their own areas, sometimes they may create silos of equipment or performance standards. In the area of EVs, there is not a strong collaboration evident between the standards bodies that organize the EVSE OEMs, EV manufacturers, and utility entities. Without clear collaboration and communication on the technical standards, there can be errors in the correct application of specific standards necessary to interconnect EVs to the electric grid. NERC has seen this in its *San Fernando Disturbance Report*[21] where distribution-level interconnection standards were implemented for BPS-connected resources. The pertinent standards bodies to ensure technical collaboration for EV integration are the Society of Automotive Engineers, Institute of Electrical and Electronics Engineers (IEEE), Underwriter Solutions (UL), and International Electrotechnical Commission (IEC). The lack of collaboration itself is not as strong a risk as the misapplication of equipment standards; however, implementation of strong collaboration brings a major benefit to all industries that clearly articulate the information and performance requirements to safely integrate technology.

[21] Available here: https://www.nerc.com/pa/rrm/ea/Documents/San_Fernando_Disturbance_Report.pdf

Chapter 4: Constraint Management and Policy Overlap

The EVTF identified risks associated with the management of constraints and state/federal energy policy and has given each of the identified risks a profile that consists of a name, description, and priority. The BPS risk identified in this chapter is associated with the following reliability principles:

- Facilities for communication, monitoring, and control shall be provided, used, and maintained for the reliability of interconnected bulk power systems
- The reliability of the interconnected bulk power systems shall be assessed, monitored, and maintained on a wide-area basis.

Unclear Charging Requirements, Certifications, and Expectations

Risk Name: Unclear Charging Requirements, Certifications, and Expectations

Risk Description: A lack of coordinated requirements, certifications, and equipment expectations leads to potential lack of technology to meet all stakeholder needs.

Like utilities' uncertainty on EV charging or discharging behavior, it is unclear to the automotive industry what criteria utilities will require when building a proposition to implement charging or discharging behavior. Furthermore, the end-use customer's preferences and constraints on their own usage (charging or discharging) may have an impact on the ability of specific managed charging programs to accomplish their stated objectives. EV manufacturers are balancing all these concerns without a clear direction from policymakers, utilities, or consumers for which capabilities should be in the design philosophy and which standards should be implemented to accomplish those capabilities. Should the policy abruptly change, there is also a scenario where the divestment of infrastructure or bankruptcies of certain companies can lead to a lack of needed support to identify clear charging requirements, certifications, or expectations in this area.

The BPS, given sufficient capacity in an aggregate manner, would be impacted by the aggregate way EVs and their supply equipment charge or discharge. The lack of guidance and expectation in how this is accomplished between the supply equipment and the various utility programs can pose a risk to the BPS. For example, utilities can expect variation in the return to service characteristic of a given distribution system. This is because not all portions of the distribution system experience the exact same voltage and each customer recovers in slightly different ways due to variation in their equipment. To the transmission system serving this recovering distribution system, each customer's recovery is "randomized" and is expected to ramp to its final value. Should this ramp become too steep, automated responses at the transmission system may not have enough time to mitigate the local load ramp. Further, if all customers were restored at the same time, this may not allow enough time for transmission elements to accommodate this added load. Unclear charging requirements and expectations for EVs and their supply equipment create a scenario where this risk can thrive.

Further exacerbating this uncertainty is the lack of a standardized certification process for this equipment. Currently, the conformity to agreed-upon expectations happens when the equipment is certified; however, the process of an acceptable path to certification can differ between the automotive and utility sectors. Automotive manufacturers have developed their equipment with a known self-certification process whereby the testing data and certifications are performed by the manufacturer. The utility industry does not commonly perform these certifications. Rather, utilities commonly rely on third-party certifications through the National Laboratories, research and development agencies, or standalone certification bodies like Underwriter Solutions.[22] Naturally, when EVs interface with the utility industry, the differences between the certifications provide a source of uncertainty on which, if any, certifications are common to the two procedures and are usable for both sectors. Lack of certification is not desirable by either

[22] Previously known as Underwriter Laboratories. They hold the UL certification and its stamps on equipment.

sector; however, the lack of clarity on the accepted certifications for widespread adoption provides an uncertainty in addition to the lack of a model representation. That is, even if utilities were able to model the equipment, there is no certainty that this equipment responds to the parameters they chose.[23]

The EVTF identifies that this risk generates uncertainty for both the automotive and utility sectors, leading to the potential for errors to be introduced in the representation of these devices for near- and long-term studies. This risk is inherently transitory until an authority is able to set clear requirements, certifications, and expectations unless the authority shifts its decision frequently so that all sectors maintain a transitory nature to meet frequently changing decisions.

Distribution System Requirements Balancing Against BPS Requirements

Risk Name: Distribution system Requirements Balancing Against BPS Requirements

Risk Description: The needs of the transmission system are not always considered when integrating into the distribution system and vice versa.

End-use customers connect through the distribution system before connecting to the transmission system. Some customers are served at transmission voltages before the end-use customer facilities distribute the energy to their devices; however, the end-use customer generally connects through a distribution system. This would include end-use customers adopting EVs and installing supply equipment to charge or discharge their vehicles. As such, the distribution system is expected to see impacts before the BPS; however, the needs of both systems should be accounted for in any large-scale solution. While the BPS desires ride-through of resources to ensure continuity of service to customers, the distribution system may desire cessation of injection to ensure that a fault is fully isolated from the system and no longer a danger to equipment or personnel. Furthermore, “break before make” programs and other distribution safety requirements will typically dictate the interface between the end-use customer and the distribution system. However, at a sufficient level of aggregation, some of these practices may induce conditions on the BPS where instability, cascading, or uncontrolled separation will occur. The root cause of this risk is the lack of communication and balancing of BPS needs to ensure a reliable delivery of energy through the transmission system and the needs of the distribution system. In some areas, this may mean that the distribution system supports the transmission system through enabled equipment capabilities[24] (e.g., frequency response) while others have the distribution system disconnecting from the transmission system and re-energizing through specific return to service procedures.

While the number of customers taking transmission level electric service is lower than the distribution counterparts, the transmission level capacities are also typically much larger. For EVs, class 6 to class 8 trucking depots could reach 10s of MWs per installation. These charging solutions for heavy-duty vehicles also create a potential need to coordinate against the BPS requirements as the end-use load can now directly impact the BPS requirements. While this risk focused on the distribution system requirements balancing against BPS requirements, the same concern exists for the transmission customer’s needs (e.g., determining how often this load can be interrupted to clear faults) against BPS requirements.

Furthermore, where the end-use customer connects through the distribution system, this risk can lead to a need to utilize the distribution system infrastructure to serve the end-use customer to a greater extent than historically operated (e.g., by using flexible interconnections). This increase in capacity use degrades the margins of historical operation, pitting system planning designs against operational reliability objectives. While not entirely an EV-specific

[23] Which can lead to assumption-based modeling that can mask reliability issues on the BPS.
[24] Past NERC studies have shown that EVs can support Interconnection Primary Frequency Response. https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Potential_Bulk_Power_System_Impact_of_Vehicle_Chargers_2024.pdf

risk, the way end-use EV customers are anticipated to operate demonstrates that the distribution system's needs and the transmission system's needs should be weighed and appropriately addressed to mitigate this risk.

The Absence of Guidance and Best Practice in Management of Multi-Layered Choices

Risk Name: The Absence of Guidance and Best Practice in Management of Multi-Layered Choices

Risk Description: A lack of guidance exists on how to prioritize the electrical or transportation uses for EV customers for both utilities and automotive manufacturers.

Utilities have historically seen the customer as a monolithic consumption device. In more recent years, these customers have integrated generation resources or other smart devices to enhance their interactions to the grid. These options and choices turn what once was a monolithic assumption into a multi-layered combination of choices a given customer may employ for various reasons. Both utilities and automotive manufacturers are finding it difficult to identify the precise set of needs a customer would desire in an EV. On the automotive side, the customer purchasing this vehicle for transportation needs may value certain features over others. The utilities may not differentiate between EV models, styles, or features but will want to determine what the impact is on their ability to deliver energy to the customer. Best practices and guidance for representing these interactions are not standardized. No NERC reliability guidelines on this topic exist, the guidance that does exist[25] is not based on received data but engineering judgment, and the estimation techniques to identify transformer needs have yet to be developed. Thus, there exists no standardized, tested, or provided guidance to utilities on how particular customers will adopt the technology and what the electrical consumption needs are.

Additional complications arise with the variation in EV policy at the state and federal levels. The initial EV adoption policy aimed for significant emission reductions in the transportation sector. New policies and alterations to this policy have altered the expected adoption of EVs in the aggregate and further affect customer choice to purchase the technology. Like in the case above, no particular guidance or best practice exists in how to accommodate this additional factor to customer choice. Changes in energy policy at both the state and federal levels can significantly influence which technologies are available to consumers and how they choose to adopt them. While the uncertain policies further exacerbate[26] the risk posed by the lack of guidance or best practices in this area, the EVTF separated this concept into two distinct pieces. Risk associated with uncertain policies are covered by the **Unclear Charging Requirements, Certifications, and Expectations** risk section as part of the higher-level risk than the lack of guidance surrounding changing energy policies in this section.

In summary, this BPS risk is a lack of guidance in a changing and complex set of choices available to customers of EV technology. As such, the EVTF assigned a low priority to this risk as it does not immediately affect the operation of the BPS but may create "unfriendly" future-year scenarios if not clarified.

[25] NERC's Load Modeling Working Group has developed an initial parameterization for transmission planners to begin proactive risk identification. These parameters were not developed under test data and will need refinement. This document is available here: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/EV_Modeling_Technical_Reference_Report.pdf

[26] There are ways to minimize this aspect of the lack of guidance through utility participation and influence of the development in policy. These are to be discussed in the second EVTF whitepaper that will identify potential risk mitigation strategies.

Chapter 5: Operation Under Normal and Abnormal Conditions

The EVTF identified risks for the operation of the BPS under normal and abnormal conditions and has given each of the identified risks a profile that consists of a name, description, and priority. The BPS risk identified in this chapter is associated with the following reliability principles:

- Interconnected bulk power systems should be planned and operated in a coordinated manner to perform reliably under normal and abnormal conditions as defined in the NERC Standards.
- Plans for emergency operation and system restoration of interconnected bulk power systems shall be developed, coordinated, maintained, and implemented.
- Personnel responsible for planning and operating interconnected bulk power systems shall be trained, qualified, and have the responsibility and authority to implement actions.
- The reliability of the interconnected bulk power systems shall be assessed, monitored, and maintained on a wide-area basis.

Unclear Response and Needs of EVs as Part of Emergency Operation Plans

Risk Name: Unclear Response and Needs of EVs as Part of Emergency Operation Plans

Risk Description: Transmission Operators are not sure how EVs will operate during normal and emergency conditions. It is unclear how EVs will participate in response to electrical or environmental disasters.

TOPs must maintain the BPS within its limits by following normal and emergency plans. Extreme weather events, however, test the resilience of the electric grid and other infrastructure, potentially leading to widespread power loss. The growing adoption of EVs adds a new layer of complexity for TOPs when preparing emergency plans. TOPs need to consider how people might use EVs during extreme weather—either as a source of backup power (Vehicle-to-Grid, V2G) or in ways that could strain the grid before a disaster hits. This means anticipating increased electricity demand from EV charging, especially when trying to reroute power to avoid damage from weather fronts or at-risk substations. These EV-related factors are crucial and must be included in TOP emergency plans[22] for managing rare but severe events.

While not as catastrophic as the above, other electric emergencies may exist (e.g., energy emergencies or transmission congestion) where EVs may play a role in the TOP's emergency plans. In particular, the response and coordination of EVs for emergency operation plans can directly impact the success of those plans. To improve grid resilience, establishing clear authority to prevent blackouts during emergencies is paramount. This authority allows for the effective implementation of blackstart plans, where EVs can act as valuable resources, stabilizing local sections of the electric system and minimizing the duration and severity of outages. .

Because EVs come in various sizes and capabilities (light-, medium-, or heavy-duty), they will likely serve different purposes within these plans. Consequently, TOPs will probably classify and prioritize different EV types and their uses based on their electrical impact and the constraints of the energy or transmission system.

Hybrid Resources Are Not Well Understood for Their Applicability in Emergency Operation Plans

Risk Name: Hybrid Resources Are Not Well Understood for Their Applicability in Emergency Operations Plans

Risk Description: EVs can operate as a load or a resource; it is not clearly understood how these devices affect manual or automatic schemes to maintain BPS reliability.

Previous NERC papers[27] have discussed the performance of hybrid generation facilities, meaning that multiple sources of power are expected to serve the stated purpose of that generation asset. These have largely dealt with a primary source of energy (e.g., solar PV) coupled with a storage device (e.g., chemical battery storage) at the same electrical location on the BPS. This is dissimilar to the hybrid load and generation asset that EVs and other stationary storage devices play when connected to the electric system. Previous papers identified the hybrid nature as supporting the delivery of power and diversifying energy sources to expand the capability of the generation asset. Here, the EVTF is discussing the role of a device capable of drawing and producing current while under emergency operation conditions.

In both the transmission-connected or distribution-connected sense, EVs may play a role in the success of automated programs such as the underfrequency load shedding (UFLS) or undervoltage load shedding (UVLS) programs that stabilize the BPS as part of emergencies. The role an EV plays while drawing current (i.e., acting as a load) would necessitate the shedding of non-critical loads in this automated role. However, while producing current, EVs are supporting the grid and should not be shed as part of these programs. The history of UFLS and UVLS program design is a largely static study[28] where a specific set of load assumptions, albeit conservative in nature, are identified to target the amount of load shedding required to stabilize a frequency or voltage decline. When distributed energy resources (DER) are affected by the shedding of load under UFLS or UVLS, it affects the ability for the UFLS and UVLS program to operate effectively. As EVs are DERs while generating current back to the grid, the SPIDERWG's previous review of these programs[29] validates the risk if not captured appropriately.

Furthermore, there is an aspect of this risk that varies depending on the planned or unplanned nature of an outage. For instance, the implementation of emergency programs like the public safety power shutoffs[30] carries with it the intentional disconnection of portions of the electric system that can include the EV and the EVSE. When the planned disconnection is re-energizing, the automatic response of the EVs and the EVSEs will occur when the electrical terminals experience a healthy voltage and frequency. This is true of any hybrid (i.e., load and generation) asset connected to the transmission or distribution system. This may not be well understood, studied, or planned for in the emergency protocols by the TOP or RC.

EV applicability and response in an emergency operating plan is a risk to the success of the emergency operation plan where unclear applicability and response is in question. Due to the critical nature for emergency response plans to maintain BPS stability, EVs and other hybrid resources should be well understood. Utilities should develop operating manuals and improve their situational awareness for these active devices on the automatic or manual decision-making that occurs during electrical emergencies.

[27] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_BESS_Hybrid_Performance_Modeling_Studies.pdf
[28] For emergency actions that require prior study, this risk is further complicated and related to the risks in **Chapter 2** and **Chapter 3**.
[29]
https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Recommended_Approaches_for_UFLS_Program_Design_with_Increasing_Penetrations_of_DERs.pdf
https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper-DER_UVLS_Impact.pdf
[30] https://www.epa.gov/waterresilience/public-safety-power-shutoff-standard-operating-procedure-template

Authority and Responsibility Are Not Clear for Normal and Abnormal Conditions

Risk Name: Authority and Responsibility Are Not Clear for Normal and Abnormal Conditions

Risk Description: With many entities involved in EV operations, a clear governance structure on implementing changes to settings is necessary. It currently is not clear how this occurs.

In contrast to the lack of understanding of the automatic or manual response for hybrid resources, there is a risk associated with the authority and responsibility of these assets that are not clear under normal and abnormal conditions. For instance, if a setting change or charging management change is required, who is the governing authority and how does the end device know that the governing authority is requiring this change? The answer to this question lies in how the asset is configured for automatic or manual operation, and EVs are no exception. Given the many hands, there needs to be clear identification in the authority to take such actions for both normal and abnormal operating conditions.

Given the many different governing entities, there could be a conflicting command sent to the device. For instance, one program may require the EV to cease charging during a disturbance, while another entity may require riding through the disturbance in question. A lack of clarity in this structure poses a risk that specific assets are not performing as expected and could exacerbate a developing emergency or lead to an emergency situation. The treatment of EVs and EVSEs in these structures should be predicated by a thorough understanding of their operating preferences and performance; however, a clear governing authority of the control of these devices should be enacted for all utility and end-use cases. Furthermore, when dealing with stacked incentives and programs, there is a risk to not counting or double counting the availability of specific service. The growing prominence of V2G technology, which allows electric vehicles to provide power back to the grid, is creating opportunities for a new suite of services. This trend is being reinforced by the proactive work of DER managing entities,[27] which are implementing and advocating for advanced solutions like managed charging and V2X schemes. V2X is a broader concept encompassing V2G and other "Vehicle to Everything" applications, such as providing backup power to homes or buildings. In a hypothetical example scenario of these schemes, Utility A could issue an event call 24 hours in advance for 4 to 6 p.m. the next day and send that message to the DER managing entities via a platform. The aggregators would in turn send a control signal to all their customers' systems to prepare for and respond to the event. At the moment, most of the aggregator program focus has been on behind-the-meter (BTM) solar plus storage, but some states have similar programs for smart thermostats, and these are expected to expand to include EVs and EVSEs. In these examples, it becomes a concern to make sure that, if an EV is registered as a resource in an aggregator's program but also in a demand-response program, then it should not be counted twice[31] as utilities will rely on this asset to perform under these programs. Revisions and improvements to these programs are ongoing, and it is important that these programs have the clear authority and structure as they are implemented for use by utilities.

[31] There are ongoing mitigations for the general double counting of assets; mitigations will be discussed in the next EVTF product.

Lack of Operational Practice Development for Wide Area Management of EV Traffic

Risk Name: Lack of Operational Practice Development for Wide Area Management of EV Traffic

Risk Description: EV charging demands over a wide area require Reliability Coordinators and Balancing Authorities to improve their monitoring functions for heavy use of EV transportation.

A related risk to the operational practices is the development of wide-area management of EV traffic throughout an RC's footprint. The unique relationship of the RC (and the BA) to handle wide geographic footprints makes this risk separate from the local interactions from the other operational risks described in this chapter. There could arise situations where the wide-area view of the RC or BA requires pre-positioning of the system to account for predictable use of EVs across their footprint. The RC or BA should ensure that for events like large sporting events, driving-focused holidays, or other events that could use the interstate road infrastructure (and thus the charging infrastructure in those areas) are understood for their wide-area management. Furthermore, where these vehicles and their electric equipment are used to fulfill the Essential Reliability Services (ERS) obligations for the reliable operation of the BPS, there needs to be a coordination structure between the RCs and BAs that utilize these EVs for such services. There are automatic services that are seeking to improve the monitoring of the distribution system[32] and leverage the service through automatic software (e.g., systems that integrate the Energy Management System, Generation Management System, Distributed Energy Management System, and Advanced Distribution Monitoring System platforms). Entities should leverage the required monitoring and management systems to account for EV movement and maintain wide-area situational awareness. A lack of this situational awareness could result in a need for operators to engage in emergency operational practices.

[32] See broader efforts in between the transmission system operator and the distribution system operator available here: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/TandDCoordinationDocument_draft_White_Paper.pdf

Chapter 6: Personnel Training

The EVTF identified risks associated with transmission personnel training and has given each of the identified risks a profile that consists of a name, description, and priority. The BPS risk identified in this chapter is associated with the following reliability principles:

- Facilities for communication, monitoring, and control shall be provided, used, and maintained for the reliability of interconnected bulk power systems.
- Personnel responsible for planning and operating interconnected bulk power systems shall be trained, qualified, and have the responsibility and authority to implement actions.

Inconsistent Nomenclature to Describe Risk

Risk Name: Inconsistent Nomenclature to Describe Risk

Risk Description: The taxonomy of sharing information is not consistent between utilities and the automotive sector.

There are a variety of standard bodies, terminologies, and methods to describe what "risk" is to an entity. For some engineers, risk is defined by the likelihood of a violation occurring multiplied by the severity of the violation. For others, risk is defined by the inability to reach certain targets rather than the exceedance of limits. When the automotive sector speaks to the utility sector, there arise inconsistent, incomplete, or nonexistent ways to describe risk between the two sectors. The EVTF has developed its nomenclature document[33] to describe the joining of the electric system to the EV's supply equipment. However, the inability to communicate the needs, requirements, and policy impacts across these sectors sits at the core of this paper. If the sectors cannot agree on a way to communicate the risk and the ways to meet these risks, it is only a matter of time until miscommunication prevents the entities responsible for planning or operating the BPS from being able to accomplish their objectives and vice-versa for the automotive sector to rely on the reliable delivery of electricity for their transportation use.

Lack of Information Sharing Between Automotive Entities, Utilities, and End-Use Customers

Risk Name: Lack of Information Sharing Between Automotive Entities, Utilities, and End-use Customers

Risk Description: Data silos between entities reduce the effective integration of EV technology and can pose reliability risk or lost reliability benefit.

With the many entities that house or deal with the end-use customers for EVs, many data silos exist between the end-use customer, automotive entities, and utility entities. Further complicating this matter, there are third-party DER managing entities that could aggregate the response of the EVs and EVSEs. This can complicate the number and type of entities that maintain specific data related to the use, capacity, or other information that could be shared and used for planning and operations purposes. Where this information is necessary to perform BPS planning and operations, appropriate entities should provide this information to the successful planning and operation of the BPS. Some information that is helpful to transmission planning and operation may be owned by the DER managing entity[34] (i.e., third-party aggregator in this example), which complicates access to some data. In particular, the capability for vehicle-to-grid or other V2X capacities should be appropriately communicated to the TP so they can properly perform their studies. Similarly, to accurately model the overall impact of EVs on the transmission grid, TPs need to understand key consumption details, such as how EVs shift between drawing power (sink state) and potentially supplying power (source state).

[33] Available at the EVTF website here: https://www.nerc.com/comm/RSTC/Pages/EVTF.aspx

[34] This concern and risk are not just related to EVs but part of a larger silo that comes from sharing of information across third party platforms. Some recent examples include data sharing for power system equipment and power electronic device design and operation.

Furthermore, the entities that plan and operate the BPS need to disseminate ongoing BPS information to end-use customers for their choices. For some information, systems and practices already exist to share from the utilities to end-use customers in a public setting, like end-use customer conservation alerts, that can assist in the mitigation of BPS conditions. EVs and EVSEs are now impacting the information that needs to be sent to the utility and received from the utility.

As an example, the enter-service characteristics from aggregate EVs are highly important for the utility to monitor and account for in their plans. The way the utility hears about this information, whether directly from the end-use customer, an automotive entity, a regulatory body, or an aggregating entity, is less important than that the information sharing flows to the appropriate bodies. Likewise, the information flowing from the utility to the automotive sector, whether through regulatory bodies or public forums, is less important than the utility sharing upgrade and infrastructure improvements needed to serve the EVs and EVSEs in its area. Clear and actionable information sharing structures should be established so that all parties receive their information as appropriate for the planning and operation of the BPS while integrating EVs and EVSE.

Low Internal Interdepartmental Coordination

Risk Name: Low Internal Interdepartmental Coordination

Risk Description: Internal department inefficient data share and collaboration can reduce the ability to leverage EV capabilities or create instances where operators rely on unrealized capacity.

In addition to the risk of poor information sharing between entities external to the utility and the utility, there is a need for the same improvement across silos within a utility. This risk is not unique to EVs or EVSEs, but the rapid growth of EVs strains the risk of programs or departments not sharing appropriate information in the utility. For example, the EVTF has identified that long-term planners may not discuss their plans directly with operational planners and has further agreed that RPs seldom share their expected resource procurements with transmission stability or long-term planning. These silos of work not being shared among traditional or modern utilities is only exacerbated by the EVs' transformative nature and the methods utilities are using to serve this end-use device.

As an example, if the charging depot, public charger, or at-home charger is planned to be served via a flexible interconnection agreement, multiple utility departments are impacted by this choice as, opposed to say, a rigid load service agreement that may require infrastructure improvements. Poor communication between the service planning department (responsible for distribution) and upstream departments like TPs, RPs, and protection engineers can lead to significant problems, including unnecessary transmission infrastructure improvements. Conversely, this could result in an underestimation of infrastructure needs, leaving both distribution and transmission with inadequate resources to meet demand. Further complicating this example, the agreement may have all the implementation aspects solved and accounted for, but the TOP or authority to utilize this capacity and capability is unaware of this program,[35] preventing this program from functioning to its intended use.

[35] This is true for automatic or manual systems.

Chapter 7: Physical and Cyber Security

The EVTF identified risks associated with transmission personnel training and has given each of the identified risks a profile that consists of a name, description, and priority. The BPS risk identified in this chapter is associated with the following reliability principle:

- bulk power systems shall be protected from malicious physical or cyber attacks.

Lack of High Bar Cyber Security Posture

Risk Name: Lack of High Bar Cyber Security Posture

Risk Description: Current gaps in cyber security practices lead to unpatched vulnerabilities. Exploitation of these vulnerabilities can propagate if not prevented by implementing proper cyber security measures.

Because EVs and EVSEs, as potential parts of DER aggregations, will use smart-grid technologies, mobile applications, and back-end networking systems, the following attack vectors are likely common:

- Bi-directional charging between EVSE and grid
- New attack vectors for the U.S. electric grid, such as a compromised smart meter or home network
- Compromising a charging station's software
- Exploiting vulnerabilities in charging station's Application Program Interface
- Control of the EVSE cyber-physical system through the internet, potentially offering a foothold on internal enterprise networks

EVSE providers, grid operators, vehicle manufacturers, and government agencies must understand that cyber attacks targeting EVSE chargers can create both localized and widespread impacts. The local impacts include the following:

- Theft of personally identifiable information (PII) and financial information
- Failure to charge vehicle
- Damage to batteries or other EV components[36]
- Compromise of EVSE life-safety systems
- Loss of EVSE service availability

While the local impacts are important, the bulk system could experience a compromise that can cascade into a larger-0scale, widespread impact to the usage of EVs and EVSEs. Some of these wider impacts include the following items:

- Loss of customer data, such as personally identifiable information and financial information
- Harvesting of PII and financial information
- Shutdown of entire EVSE charging network
- Exposure of upstream and partner IT networks
- Misconfiguration of EVSE, creating damaging or dangerous conditions and resulting in more potential exploitable vulnerabilities
- Loss of consumer confidence in EVSE ecosystem

[36] This includes the impact to the equipment as well as the impact to public safety for certain chemical compositions of the EV battery.

- BPS instability caused by malicious operation of the EVSE charging network

Not all the above local or widespread impacts will affect the BPS equally; however, all of these compromises can lead to operational technology (OT) network breaches and the use of the OT network for devices to propagate instability, uncontrolled separation, or cascading on the BPS. To protect against these potential impacts, there are two ways to view the necessary cybersecurity protections. The first view focuses on the protection of the device or asset against a coordinated, malicious attack on that single asset, device, or grouping of devices at a local point. The authority structure here is straightforward for the owner of the device but will require coordination with vendors and other entities to mitigate against the intrusion. The second view is focused to ensuring that the remainder of the system and network is isolated from the compromised system to halt propagation of the malicious access into other networks that could potentially contain critical energy infrastructure. The requirements for containment and a successful security response plan are highly important to ensure that the compromise is contained.

However, there are known complications[37] that demonstrate a lack of a high bar of cyber security posture, as validated by National Laboratories for gaps[38] and recommended solutions[39] to improve on the EV cyber security posture. Common system hardening, network protection, and monitoring conditions include the following:

- Unused, enabled network ports in use.
- Debugging ports are not removed prior to deployment.
- Default or system accounts, using common credentials, prevent accountability for malicious activities.
- The use of common credentials prevents system administrators from revoking access when personnel leave the organization or no longer require access.
- EVSE networks do not always support encryption across necessary data modalities, such as at rest or in transit.
- Intrusion detection systems (IDS) are not installed at key network locations (e.g., IT/OT demilitarized zones and cloud firewalls).
- Lack of proper network segmentation in enterprise systems and EVSE networks.
- Regular vulnerability scanning and patching of backend/cloud infrastructure is not performed by EVSE owners/operators.

The EVTF has found that the lack of a high bar of cyber security poses a meaningful risk to the operation of the BPS should a coordinated attack targeting EVs or EVSEs occur. This validates the potential risk found in the scenario analysis that NERC published in *Potential Bulk Power System Impact of Electric Vehicle Chargers*.[40] Improving the cyber security of the EV industry hinges on strengthening defenses against cyber intrusion. However, the constantly evolving and diverse nature of attack vectors[41] poses a significant challenge to the ability of EVs, EVSE, and utility companies to successfully defend against breaches. This cyber security risk varies considerably across organizations and may necessitate vendor support and broader collaborative efforts to ensure that EVs and EVSE are adequately protected from malicious exploitation. Securing these assets is crucial to prevent them from being used to cause instability, uncontrolled separation, or cascading failures within the BPS.

[37] Furthermore, other organizations have identified specific security gaps associated with EVs and EVSEs. ANSI has performed such analysis here: https://ansi.org/standards-news/all-news/2023/06/6-15-23-ansi-publishes-roadmap-of-standards-and-codes-for-electric-vehicles-at-scale

[38] https://www.sandia.gov/research/publications/details/cybersecurity-for-electric-vehicle-charging-infrastructure-2022-07-01/

[39] https://www.researchgate.net/publication/344888849_Recommended_Cybersecurity_Practices_for_EV_Charging_Systems

[40] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_Potential_Bulk_Power_System_Impact_of_Vehicle_Chargers_2024.pdf

[41] For example, zero day vulnerabilities will challenge even a very mature cyber security posture.

Lack of High Bar Physical Security Posture

Risk Name: Lack of High Bar Physical Security Posture

Risk Description: Current gaps in physical security practices lead to potential vulnerabilities. Exploitation of these vulnerabilities can lead to broad outages if not prevented by implementing physical access or security measures.

Like the previous risk, the lack of a high bar of physical security posture for EVs and EVSEs is a potential security risk to the BPS. While physical access to the end-use device may not be clearly tied to BPS compromise, the physical access of the networking devices found in an EV or EVSE can be leveraged to gain lateral or vertical movement for OT networks. Furthermore, physical security control and site control improve the appropriate use of the EV charging stalls while preventing against copper theft or other hardware theft. In contrast to the cyber threat, the entity in charge of implementing physical security controls (e.g., guards, gates, or barriers) is fairly straightforward: The owner of the geographic location needs to implement proper security controls. These controls help to ensure proper physical access to the devices, where the lack of such controls can lead to the following:

- Failure to log or generate an alarm when internal compartments are accessed.
- Unencrypted storage theft allows attackers to steal credentials for use in accessing EVSE or partner systems, networks, and cloud services.
- Spacious internal compartments allow placement of malicious hardware to obtain PII or financial information.
- Attackers can modify or damage internal power electronics and safety systems.
- Insufficient physical measures to deter and identify intrusions.

While related to cyber security posture, the vulnerabilities for physical compromise are much different than those found in cyber security. However, the threat posed by malicious use of these assets can be propagated by physical access of these devices. As such, the EVTF still identified the lack of a high bar of physical security as a risk.

Lack of Security Standardization

Risk Name: Lack of Security Standardization

Risk Description: Current security practices and standards are not standardized in a manner to clearly identify the necessary EV security standards to protect the assets.

The American National Standards Institute (ANSI) has provided a gap analysis of identified security problems, their failure modes, and a roadmap[42] to ensure that security standards are standardized in a manner that can clearly how to identify prevailing security standards and incorporate them into the electric ecosystem. The lack of standardization can lead to confusing security requirements where potential gaps in security or overlaps can in turn lead to compromised assets given a motivated and meticulous actor. While this is tied to the general lack of standardization risks, the specific prevailing security standard, if one even exists,[43] should be clear for utilities to help plan their incident response protocols should a compromise occur. Complicating this particular risk is that changing international relationships may create situations where some network supplier equipment is unable to be selected due to the changing federal identification of evolving security threats. Clarity on expectations and security standardization will reduce the likelihood of this risk impacting the BPS.

[42] See here: https://ansi.org/standards-news/all-news/2023/06/6-15-23-ansi-publishes-roadmap-of-standards-and-codes-for-electric-vehicles-at-scale

[43] Many security entities do not develop standards but evolving guidelines to match the changing threat landscape. As such, identifying a prevailing security standard is harder than identifying the prevailing security framework to address particular risks.

Chapter 8: Conclusion

This white paper sought to identify, validate, and prioritize specific BPS risk raised with the rise of motor vehicle electrification for light-, medium-, and heavy-duty vehicles.

Interoperability, Standardization, and Maturity Changes

New technologies, in their early stages, can rapidly advance through significant innovations. However, as a technology matures, standardizing features, operational methods, and data can help utilities predict growth and plan for the increasing demands of related electrical assets, such as those related to EVs. The ultimate goal for utilities might be to establish industry-wide standards, essentially creating a "generic" version[40] of these new technologies like EVs. However, this approach could stifle innovation, preventing the development of new and improved ways to address both customer and utility needs. Therefore, collaboration among all stakeholders[41] is crucial to find a balance between the benefits of standardization and the importance of fostering continuous innovation.

To illustrate this point, a common nomenclature of labeling equipment components can improve the efficiency and effectiveness of utilities and end-use customer communication and improve the ability to act on the results with the data. Certain IEEE[44] or SAE standards already exist[45] to enable the automated transfer of communicated information in a common information format as in **Figure 8.1**. While these are open streams of communication necessary to operate, imposing strict standardization can limit the innovation of the EV, EVSE, or other manufacturer to improve the effectiveness and efficiencies of these systems.

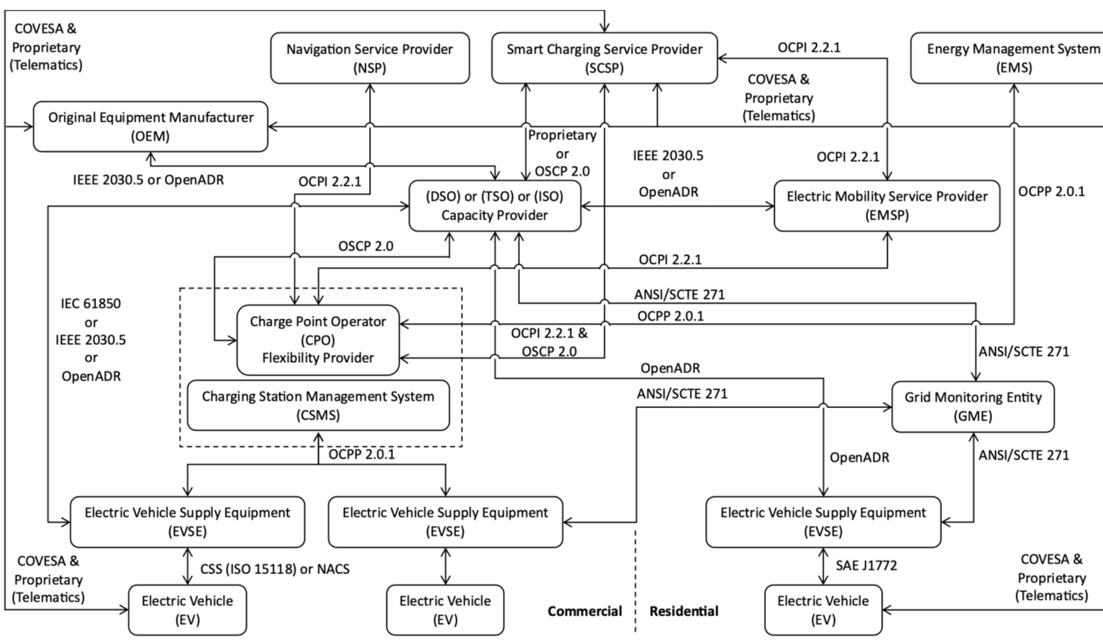


Figure 8.1: Protocol Mapping of EV Communications [Source: Brown Wolf Consulting][46]

If a TOP needs to use standardized data and interfaces to operate its aggregated EV assets, NERC might include the use of these standards in the operator's certification. As standards evolve, so should the personnel training necessary

[44] For example, IEEE 1547 contains specific clauses on interoperability for distributed energy resources. Available here: https://ieeexplore.ieee.org/document/8332112

[45] Furthermore, other entities are developing process to promote interoperability and coordination. One such international effort is available here: https://task53.org/

[46] Taken from *Realizing Infrastructure Convergence of Broadband, Energy, and Transportation* that analyzed trends for transportation electrification in the coming decade. This work is available here: https://www.brownwolfconsulting.com/post/the-coming-convergence-of-broadband-energy-and-transportation

to ensure that the communication architecture is able to handle the use cases of the utilities. Any standardization on data and interfaces for obtaining or sharing that data should include provisions to improve grid visibility to the edge of the utility network, which leads to promoting interoperability. This means that the communications buses, data sharing mechanisms, control architecture, and monitoring devices should be capable of handling the data transfer as seen in **Figure 8.2**. While the TOP is not depicted in **Figure 8.2** its input and communication through the distribution system operator (DSO in the figure) should also be included. Based on the improvements and technological maturity, the EVTF recommends that the risks identified in this paper be re-evaluated once the technology matures and standardization of equipment is clearer.

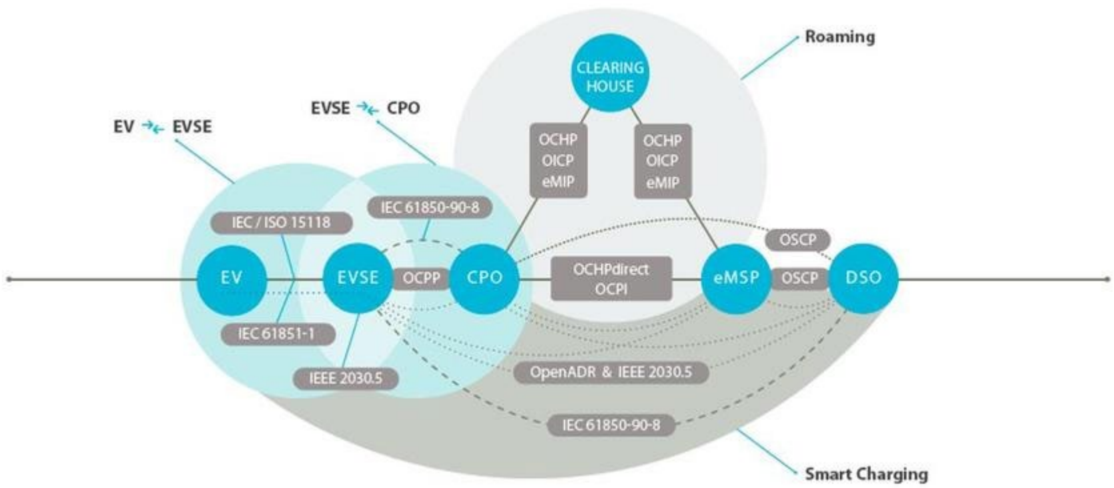


Figure 8.2: EV Related Protocols Between Entities [Source: ElaadNL][47]

As a sample for how the current protocols can interface with a multitude of stakeholders, see **Figure 8.3**. These stakeholders may be the same ones that own or operate the electrical infrastructure as shown in the green box in **Figure 8.3** as those in the communications portion of the figure. However, the likely scenario today is that each of these boxes outlines a separate, distinct entity in the communications and network architecture for transmission utilities to interface with EVs in the aggregate.

[47] ElaadNL's EV Related Protocol Study, from which this image is reproduced, is available here: https://www.researchgate.net/publication/317265159_EV_Related_Protocol_Study. Klapwijk, Paul & Driessen, Lonneke. (2017). EV Related Protocol Study.

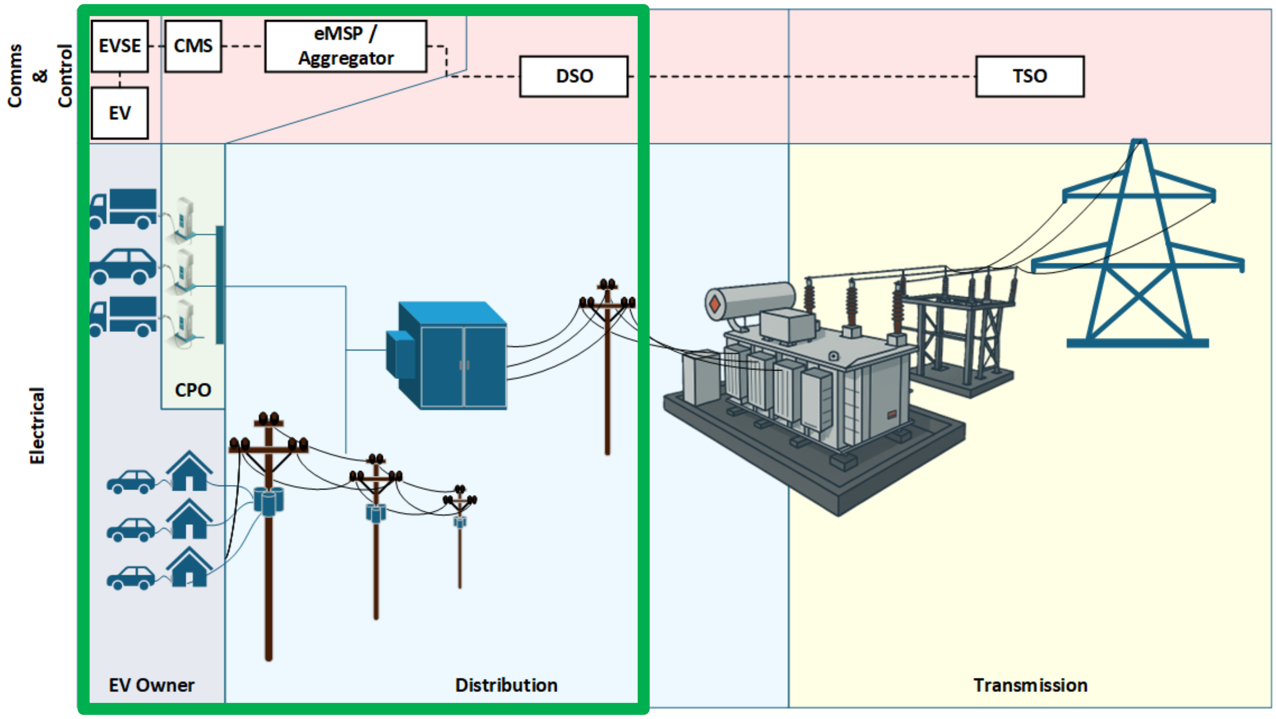


Figure 8.3: EV Integration with Various Downstream Entities Highlighted

Continued Societal Adaption to New Technology

As with many emerging technologies, the risks associated with their use are not always evident in the beginning of technological adoption and only become evident as the adoption of the technology increases. As an example, users of older vehicles understood that certain vehicles would stall on higher-grade hills. These drivers did not need to take their vehicles to mechanics in order to innately understand the risk posed by higher-grade hills. Today, many EV owners require specialized technicians to diagnose and fix issues caused by use of EVs over time; however, as cultural literacy of EVs increases, there are likely to be more drivers who can be expected to make changes to their vehicle to fix identified issues.[48] Given the electrical ties, this could mean that EV drivers may be able to respond to utility calls for demand reduction or to otherwise change their device to suit grid conditions. As such, the conclusions in this paper may need a review once the broader public is able to adopt EV technology and the collective knowledge of EV technology increases. Furthermore, charging standards continue to evolve and new charging levels (e.g., charging at a rate of 1 MW or higher) could warrant further review of the kinds of risks with the iterative improvements for this technology.

Risk Prioritization

The risks posted by rising EVs were prioritized according to the following list of most to least significant risks to mitigate:

1. Increasing Difficulty to Adequately Forecast EV Characteristics
2. Inability to Represent Modern EV Charging and Discharging Behavior with Current Models
3. Uncertainty of System Needs Under Grid Transformation
4. Speed of Integration Outpacing Utility Ability to Upgrade
5. Lack of Technical and Standards Coordination Between EV OEMs, Utilities, and EVSE OEMs

[48] This universal is based on the generic technology adoption curve that generational knowledge transfers can improve on the readiness of any given individual to adapt to their technological needs. There are istances today where the complicated nature and specialized tooling of internal combustion engines is comparable to the "newness" of EV internal components.

6. Inadequate BPS Studies
7. Lack of Available Charging Profiles
8. Distribution System Requirements Balancing Against BPS Requirements
9. Unclear Charging Requirements, Certifications, and Expectations
10. Lack of Information Sharing Between Automotive Entities, Utilities, and End-Use customers
11. Unclear Response and Needs of EVs as Part of Emergency Operation Plans
12. The Absence of Guidance and Best Practice in Management of Multi-Layered Choices
13. Lack of Security Standardization
14. Lack of High Bar Cyber Security Posture
15. Authority and Responsibility Are Not Clear For Normal or Emergency Operations
16. Hybrid Resources Are Not Well Understood for Their Applicability in Emergency Operation Plans
17. Lack of Operational Practice Development for Wide-Area Management of EV Traffic
18. Inconsistent Nomenclature to Describe Risk
19. Lack of High Bar Physical Security Posture
20. Low Internal Interdepartmental Coordination

The EVTF took into account the time, duration, impact, and likelihood of the specific risks above and broke the risks into high, medium, and low priority according to a weighted decision matrix method as described in the **Risk Prioritization Method** section. These breakdowns are found in **Table 8.1**.

Table 8.1: High-, Medium-, and Low-Priority Risk Ranking

Risk Name	Raw Weight	Translated Weight [Rank]
High-Priority Risks		
Increasing Difficulty to Adequately Forecast EV Characteristics	17.53	10 [Rank 10]
Inability to Represent Modern EV Charging and Discharging Behavior with Current Models	15.95	9.09 [Rank 9]
Uncertainty of System Needs Under Grid Transformation	15.74	8.97 [Rank 9]
Speed of Integration Outpacing Utility Ability to Upgrade	15.32	8.74 [Rank 9]
Lack of Technical and Standards Coordination Between EV OEMs, Utilities, and EVSE OEMs	15	8.56 [Rank 9]
Inadequate BPS Studies	14.89	8.49 [Rank 8]
Lack of Available Charging Profiles	14.89	8.49 [Rank 8]
Medium-Priority Risks		
Distribution System Requirements Balancing Against BPS Requirements	11.21	6.39 [Rank 6]
Unclear Charging Requirements, Certifications, and Expectations	11.16	6.37 [Rank 6]
Lack of Information Sharing between Automotive Entities, Utilities, and End-Use Customers	9.63	5.49 [Rank 5]
Unclear Response and Needs of EVs as part of Emergency Operation Plans	9	5.13 [Rank 5]
The Absence of Guidance and Best Practice in Managing Multi-Layered Choices	8.37	4.77 [Rank 5]
Lack of Security Standardization	8.32	4.75 [Rank 5]
Lack of High Bar Cyber Security Posture	8.26	4.71 [Rank 5]
Authority and Responsibility Are Not Clear for Normal or Emergency Operations	7.58	4.32 [Rank 4]

Table 8.1: High-, Medium-, and Low-Priority Risk Ranking		
Risk Name	**Raw Weight**	**Translated Weight [Rank]**
Hybrid Resources Not Well Understood for Their Applicability in Emergency Operation Plans	6.63	3.78 [Rank 4]
Lack of Operational Practice Development for Wide-Area Management of EV Traffic	6.26	3.57 [Rank 4]
Inconsistent Nomenclature to Describe Risk	6.21	3.54 [Rank 4]
Low Priority Risks		
Lack of High Bar Physical Security Posture	4.58	2.61 [Rank 3]
Low Internal Interdepartmental Coordination	3.47	1.98 [Rank 2]

Recommendations

Based on the prioritization and ranking, the EVTF would recommend that the following actions be taken to help mitigate the identified and prioritized risks. Furthermore, the EVTF will write a potential risk mitigation plan for each of the 20 identified risks per their scope to provide recommendations to mitigate these risks.

1. TPs and PCs are advised to begin a review of their modeling and forecasting processes and consider improving their ability to adapt to this emerging technology.
2. TOPs, RCs, and BAs are advised to begin coordination efforts with adjacent TOPs, RCs, and BAs to improve their situational awareness of EV charging needs.
3. TOPs and RCs are advised to adapt their internal processes and procedures to account for the risks identified for normal and emergency conditions.
4. The NERC RSTC is advised to consider assigning the following work items to its subordinate groups:
    a. The NERC Load Modeling Working Group is advised to develop and enhance a generic EV representation(s) to include V2G functionality.
    b. The NERC Resources Subcommittee is advised to develop or enhance its guidance or other technical documentation to describe the considerations for necessary resource characteristics[49] to meet known or expected EV charging profiles.
    c. The NERC Real-Time Operating Subcommittee is advised to develop or enhance its guidance or other technical documentation to describe the necessary coordination efforts when under electrical emergency situations and how to prioritize EV loads during electrical emergencies. This documentation can consider scenarios where EVs are included among the emergency response vehicles.
    d. The NERC Reliability Assessment Subcommittee is advised to develop data gathering procedures to monitor and assess the growing EV charging demand.

[49] E.g., ramping, turnaround, or other qualities of generation resources. Potentially even distribution-connected resources, if appropriate.