



# Electric Vehicles Intro, Grid Impact, and Vehicle 2 Everything

An Online Continuing Education Course for Engineers

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**Credit: 2 Hours / 2 PDH / 2 CPD**

# Electric Vehicles Intro, Grid Impact, and Vehicle 2 Everything

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## Introduction

From a climate change and emissions control perspective, the power sector was the most pollutant. However, because of the renewable penetration and closure of several coal power plants, the power sector is no longer the emissions leader. Currently, the transportation sector is leading the emissions Pac. As a result, nations are electrifying the transportation sectors, and others are banning internal combustion engines (ICE) to reduce emissions from the transportation sector.

The power sector, mainly electric utilities, has a major role to play in the electrification process. With respect to electrification, the focus is not solely on small passenger vehicles. On the contrary, electrification addresses any and every method of transportation, i.e., small, medium, and large vehicles, boats, port-related equipment, skateboards, scooters, bicycles, etc. There are numerous challenges facing utilities, such as speeding the electric vehicle interconnection process, minimizing the grid impact, promptly providing the required grid enhancements, etc. There are also several opportunities for customers with electric vehicles to earn by participating in various programs such as Vehicle 2 Home (V2H), Vehicle 2 Grid (V2G), Vehicle 2 Everything (V2X), etc., and opportunities to even earn further via non-wire alternatives programs.

Electric vehicles (EVs) are not a new phenomenon. Customer adoption is what changed recently, mainly driven by:

- Climate change and customers' willingness to support the environment by acquiring an EV
- Lucrative incentives and tax-breaks
- Major transformation in the EV field, where EVs no longer resemble the ones in the picture below



On the contrary, there is a wide selection of very attractive EVs, as seen in the picture below.



EVs will be mainly charged at homes or various businesses. As a result, they will be connected to the distribution system and not the transmission system (a very large penetration of EVs will eventually impact the transmission systems at various locations). As a result, it is essential to start the discussion by describing various distribution systems.

## The Distribution System

The key components of the distribution systems are:

- The inception: distribution systems start at the distribution substation, mainly at the substation bus, which is connected to the secondary side of the substation step-down transformer (that steps down the transmission, i.e., 138 or 345 kV or sub-transmission voltage, i.e., 69 kV to distribution voltage, i.e., 5 - 35 kV class).
- Unlike power plants and transmission substations, distribution substations are near the load center to minimize the voltage drop that is proportional to the circuit length.
- The end: distribution systems typically end at the small distribution overhead (OH) or underground (UG) transformer that is located very close to a customer's residence/business or at the customer's electric meter.
- The distribution voltage is typically below 69 kV, mainly 5-35 kV class; on a global scale, the 15-kV class is the most common voltage.
- It is common for utilities to have several distribution medium voltages. The main reason for the different voltages is that decades ago, numerous separate utilities were operating at different medium voltages. After the consolidation of several small utilities, it was cost-

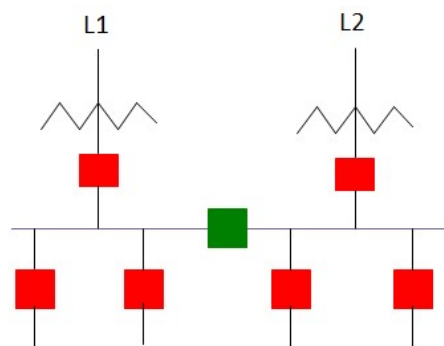
effective to maintain some of the various voltages, else there was a need to convert circuits/cables/equipment to an agreed-upon voltage. Load density (measured in megawatts per square mile) is another common reason. Heavily loaded areas may be supplied via higher medium voltage (the higher the voltage, the higher the ratings, and the lower the losses).

Transmission and distribution substations are similar except for the following exceptions:

- Transmission breakers/disconnect switches and other disconnecting equipment have higher capabilities, i.e., the higher short circuit interrupting capabilities.
- Pumping plants that are used to circulate oil for underground transmission cables are utilized at some transmission substations and not distribution substations.
- Transmission stations typically do not have transformers unless it is a switching substation; however, distribution stations always have transformers.

## Substation Design

Several substation designs are adopted by utilities worldwide. The straight bus design below is very common as it is the simplest and cheapest design. There are several straight bus configurations/variations. Below is a very common design. Many utilities have been converting their straight bus designs to more reliable designs, i.e., ring bus, double ring bus, double breaker, and breaker and a half (the more reliable the design, the more expensive the design will be). It is expected that many utilities will build transmission, switching, and distribution substations to accommodate the large, forecasted EV load.



## Distribution Line Design Reliability

The reliability of the distribution circuit design varies whether the line is constructed underground or overhead. There are several differences between transmission and distribution circuits. The voltage variance is the biggest difference. There is another major difference between the two systems: the attached equipment. The large adoption of EVs indirectly forces utilities to improve the grid's reliability and resiliency; otherwise, customers may not be able to charge their EVs, and transportation will come to a halt.

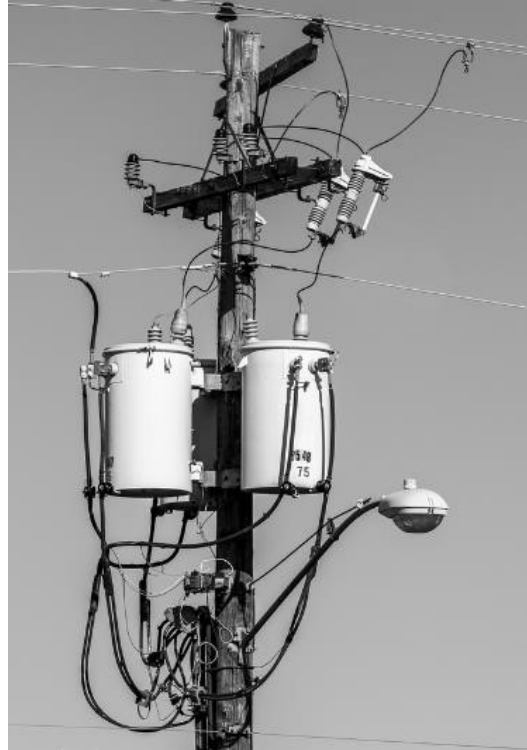


An important question the reader should think about is whether EVs can and will improve the system's reliability or hinder system reliability.

The reliability of the distribution system varies whether the design is underground (UG) or overhead (OH). From a reliability scoring/reputation perspective, several indices are commonly utilized to measure/quantify system reliability.

- SAIFI (System Average Interruption Frequency Index) is the number of customer interruptions divided by the total number of customers served. The goal is to limit the number of customers interrupted annually.
- CAIDI (Customer Average Interruption Duration Index) is the total number of minutes customers were interrupted divided by the total number of customers affected. As seen, SAIFI calculates the total customer interruption, and CAIDI calculates the outage duration. Utilities exert tremendous efforts and investments to reduce both indices. Radial feeders are the least reliable distribution circuit design. By design, radial feeders do not connect to other circuits (think of them as a one-way street); thus, radial feeders have a direct correlation to CAIDI, i.e., when a radial feeder trips, the CAIDI number rises since customers do not have access to an alternate supply.

- OH transformer(s): Utilities have thousands of transformers scattered throughout their territory to supply small and large customers. Poles can have single, double, or three-phase transformers attached. OH transformers will be the major impacted utility asset as a result of the EV adoption.



- Capacitors: Depending on the utility's power factor requirement and need for reactive power support, capacitors may be utilized heavily. Capacitors are reactive power generators measured in VARs (utility-scale MVAR). EVs require power to charge properly. Reactive power is mainly supplied by power plants and transmission and distribution capacitors. EVs will play a major role in the reactive market in the future.



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capacitors,

- Reclosers: Reclosers are used to automatically reclose a circuit after a fault. They resemble a breaker that is installed on a line. They can reclose multiple times automatically upon sensing faults.

