Electric Vehicle
EVITP
Infrastructure Training Program

Electric Vehicle Charging Equipment

Module #2 Electric Vehicle Charging Equipment - Module Sections

2.1 – Charging Equipment Introduction

2.2 – AC EVSE

2.3 – DC Charging

2.4 – Wireless Charging

2.5 – EVSE Communications and Networks

Seattle, WA - Photo courtesy of Ryan Bradt

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Module 2 – Section 1

2.1 – Charging Equipment Introduction Overview

Section 2.1 introduces the various types of equipment that can be used to charge or supply power to Electric Vehicles (EVs). Charging equipment can supply Alternating Current (AC) to a vehicle which is converted to Direct Current (DC) to charge the battery, or supply DC directly to a vehicle's battery. Charging equipment can transfer power either via direct coupling (cord and plug) or wirelessly (induction).

NW WA Electrical JATC EVSE Lab - Photo courtesy of Ryan Bradt

2.1 – Charging Equipment
Learning objectives

Upon completion of this section, students should be able to…

- Demonstrate awareness of the various terminologies (terms) used throughout the EV industry to describe equipment used to supply energy to EV batteries.
- Understand the development of early EV charging equipment.
- Describe the difference between AC Electric Vehicle Supply Equipment (EVSE) and DC electric vehicle charging equipment.

2.1 – Charging Equipment
EV Charging Equipment Terms!

- **Charging** – supplying power (kW) to an EV battery
- **Charging station** – a piece of equipment that supplies AC or DC to an EV for the purpose of charging the battery.
- **Connector** – a device (plug) connected to the cable from the charging station that connects with the car. (often referred to as a coupler by Standards organization)

Seattle, WA - Photo courtesy of Ryan Bradt

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2.1 – Charging Equipment
EV Charging Equipment Acronyms!

- **EVCS – Electric Vehicle Charging Station**
- **EVSE – Electric Vehicle Supply Equipment**
- **EVSP – Electric Vehicle Service Provider**
- **NRTL – Nationally Recognized Testing Laboratory (e.g., UL & ETL)**
- **SOC – State Of Charge**

Everett, WA - Photo courtesy of Ryan Bradt

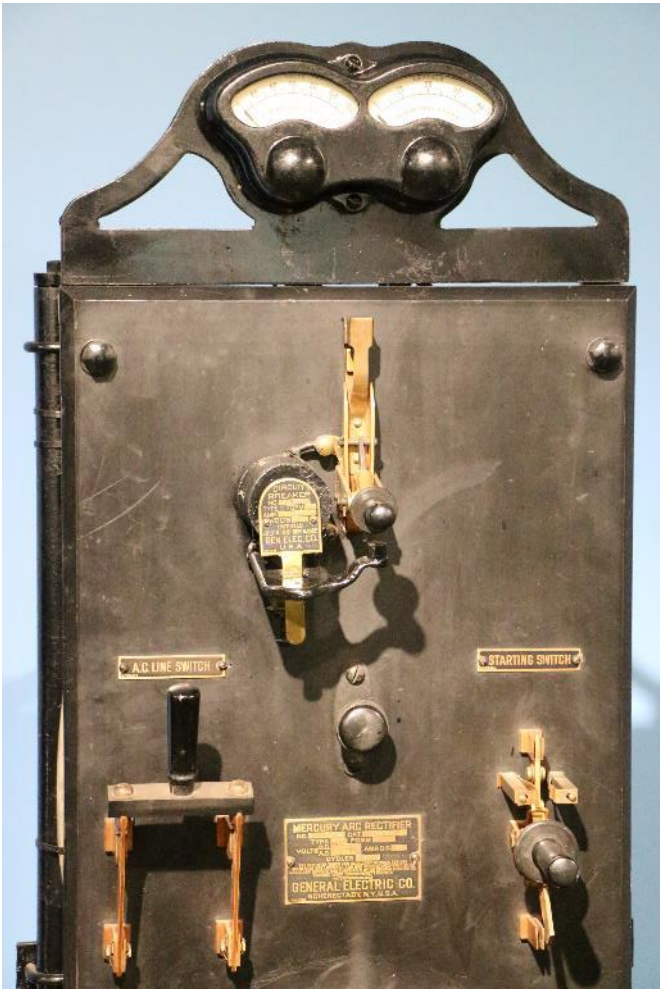
2.1 – Charging Equipment
Historical Perspective

Seattle, WA - Photo courtesy of the Seattle City Light, 1973

- EVs have been available to consumers in some form for as long as Internal Combustion Engine (ICE) vehicles, with EVs came the need to charge.
- Early EV charging was for 12-110VDC batteries requiring an external charger.
- Chargers later moved inside the EV converting AC to DC be used in charging the battery.

2.1 – Charging Equipment Historical Perspective

- The 1911 Baker Electric came with 12 six-volt batteries that produced 72 volts DC.
- The General Electric Arc rectifier was used to charge the batteries.



Photos taken at the American Car Museum Tacoma, WA
Courtesy of Ryan Bradt

2.1 – Charging Equipment
What is EVSE?

- EVSE provides a safe connection from the electrical source to the plug connected to the EV.
- EVSE provides several safety features including: ground fault circuit interruption (GFCI), ground verification, and safety lock-out de-energizing when the cable is not properly connected to the EV.
- EVSE detects hardware faults, disconnecting power and preventing vehicle and battery damage.

Wenatchee, WA - Photo courtesy of Ryan Bradt

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2.1 – Charging Equipment
EVSE VS DC Charging

- EVSE is a protocol and equipment for providing AC to a converter onboard the EV.

Leavenworth, WA - Photo courtesy of Ryan Bradt

- DC Charging equipment provides DC directly to an EV's battery management system (BMS).

Tulalip, WA - Photo courtesy of Ryan Bradt

2.1 – Charging Equipment - Questions?

Stevens Pass Ski Resort, WA - Photo courtesy of Ryan Bradt

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Module 2 – Section 3

2.2 – AC EVSE Overview

Section 2.2 reviews electric vehicle supply equipment (EVSE) that supplies alternating current (AC) to electric vehicles. In the US EVSE has been standardized by the Society for Automotive Engineers (SAE) J1772 Standard. The SAE standards specify the plug configuration, safety features, and maximum AC voltage and current for EVSE. Charge times for EVs varies greatly based on the capacity of equipment both internal and external to the vehicles. This section will introduce these variables allowing proper sizing for the end user.

NW WA Electrical JATC EVSE Lab - Photo courtesy of Ryan Bradt

2.2 – AC EVSE
Learning Objectives

Upon completion of this section, students should be able to…

- Explain the importance of the EVSE safety features required by the SAE standards and how they function.
- Classify the levels of EVSE specified by AC voltage and current levels.
- Diagram the pin configuration of the J1772 Standard and explain the purpose of the pins in the charging of an EV.
- Define the variables that determine the required charge time for an EV.

2.2 – AC EVSE
EVSE AC output, Level 1 & 2

AC Level 1

- 120V AC, 1-phase
- 12-16 amps – continuous
- 1.44 – 1.92kW

Photo courtesy of Ryan Bradt

AC Level 2

- 208/240V AC, 1-phase
- Up to 80 amps – continuous
- Up to 19.2kW

Renton, WA - Photo courtesy of Ryan Bradt

2.2 – AC EVSE
SAE J1772 connector standard

- SAE International (Society of Automotive Engineers) is a standards developing organization focused on the transport industry.
- The SAE J1172-2009 connector configuration is standard equipment in the U.S. market.

J1772 coupler and Nissan Leaf port - Photo courtesy of Ryan Bradt

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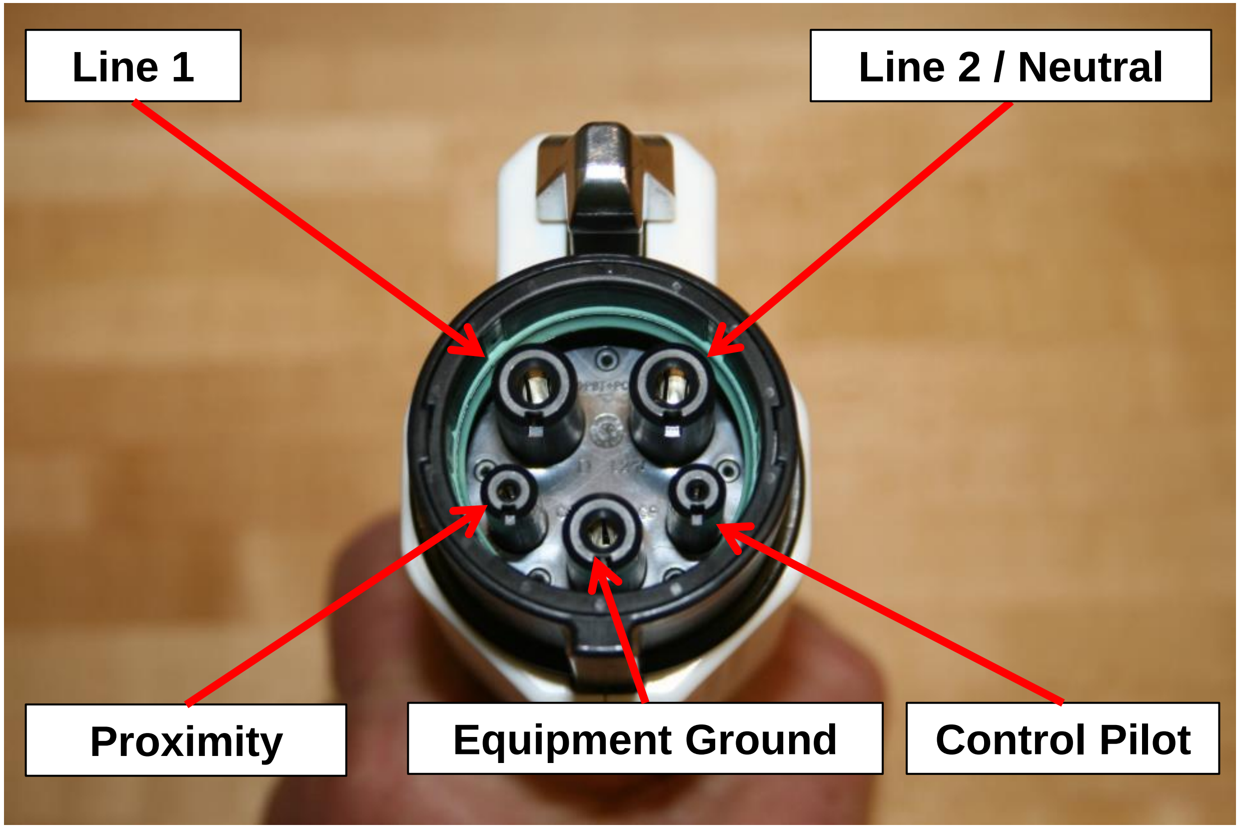
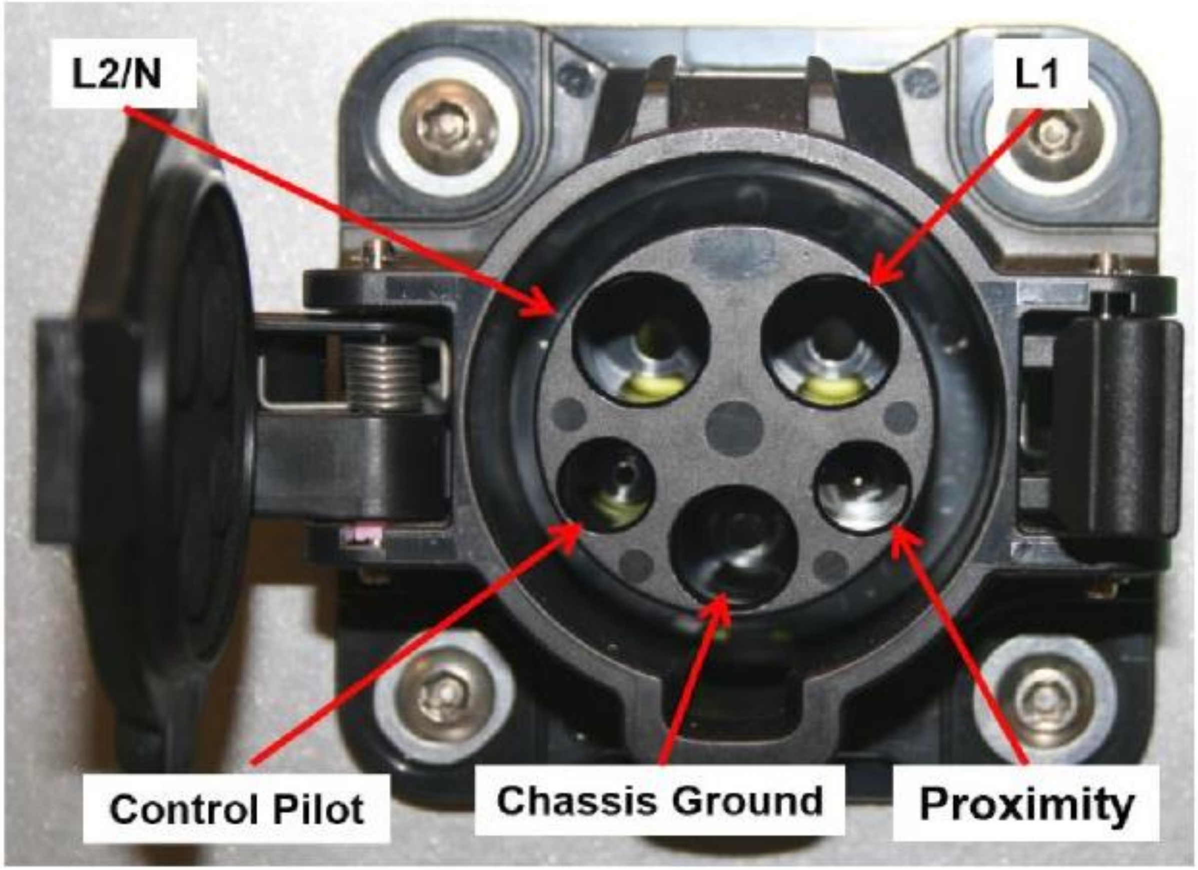
2.2 – AC EVSE
SAE J1772 Coupler Configuration



2.2 – AC EVSE
SAE J1772 Port Configuration



2.2 – AC EVSE
SAE J1772 Proximity

- The proximity connection point is used to communicate between the EV and the EVSE to insure proper connection of the EVSE to the EV.
- When the EVSE detects the proper resistance value at the proximity point is allows contactor closure.
- This safety feature assures no energy is present at the EVSE coupler without proper connection to the EV.

Photo courtesy of Ryan Bradt

2.2 – AC EVSE
SAE J1772 Pilot Signal

- The voltage present pilot terminal defines the state of the EVSE
- The J1772 pilot uses a 1kHz +12V to -12V square wave signal
- The EVSE changes state according to the voltage present

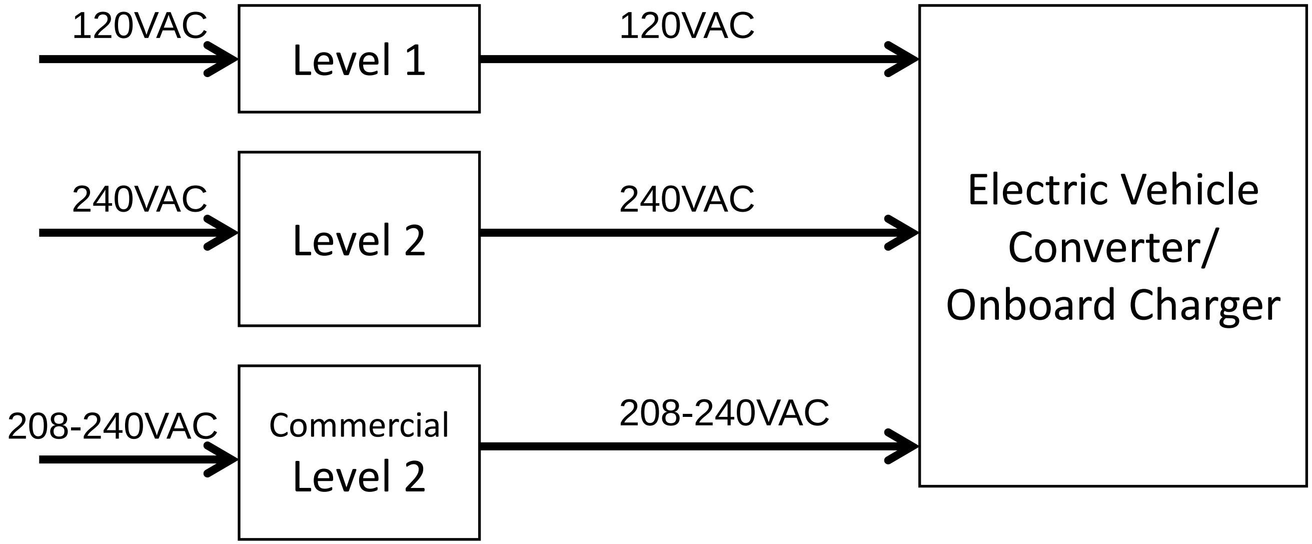
State	Pilot High	Pilot Low	Frequency	EV Resistance	Description
A	+12V	N/A	DC	N/A	Not Connected
B	+9V	-12V	1kHz	2.74k	EV Connected (Ready)
C	+6V	-12V	1kHz	882	EV Charge
D	+3V	-12V	1kHz	246	EV Charge Vent. Required
E	+0V	+0V	N/A		Error
F	N/A	-12V	N/A		Unknown/Error

Photo courtesy of Ryan Bradt

2.2 – AC EVSE
SAE J1772 Charging time variables

Two factors determine the maximum power (kW) that can be delivered to a EVs battery from EVSE.

1. The voltage/amperage supplied to the EVSE determines the power output that the EVSE can deliver to vehicle.
2. The vehicle's converter has a maximum power capacity.



2.2 – AC EVSE
SAE J1772 Charging time variables

- EVSE are available with different levels of power delivery
- The EVs power acceptance rate should be considered when making purchasing decisions.

EVSE kW capacity	Voltage	Amperage	Branch Circuit Required
1.4kW	120V	11.66A	15A
3.3kW	208V	15.86A	20A
7.2kW	208V	34.61A	40A
7.2kW	240V	30A	40A
19.2kW	240V	80A	80A (MAX per SAE)

2.2 – Charging Equipment
Factors affecting EV charge time

Several factors determine the time necessary to fully charge an EV including:

- The capacity of the EV battery
- The State Of Charge (SOC) of the EV battery
- The power acceptance rate of the EV
- The available power delivery of the charging equipment

Example:

An EV with a 60 kWh battery capacity has a 50% SOC. How long will take to fully charge the battery utilizing a 7.2 kW EVSE?

30 kWh / 7.2kW = <u>4.2 hours</u>

What if the EVs onboard converter had maximum a conversion of 6600W or 3300W?

30 kWh / 6.6kw = <u>4.5 hours</u>

30 kWh / 3.3 kw = <u>9+ hours</u>

2.2 – AC EVSE Manufacturers – ClipperCreek (sample)

CLIPPERCREEK
RELIABLE. POWERFUL. MADE IN AMERICA.

Photos courtesy of ClipperCreek

2.2 – AC EVSE – Questions?

Puget Sound Electrical JATC, Renton, WA - Photo courtesy of Ryan Bradt

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Module 2 – Section 3

2.3 – DC Charging Overview

Section 2.3 DC charging reviews the advantages of DCQC vs supplying EVs with alternating current (AC). Direct Current (DC) Fast Chargers also known as DC Quick Chargers (DCQC) are capable of charging Electric Vehicles (EVs) quickly with an output range between 50 – 400kW.

Everett, WA - Photo courtesy of Ryan Bradt

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2.3 – DC Charging
Learning objectives

Upon completion of this section, students should be able to…

- Describe the various types and sizes of DC charging equipment available in the marketplace.
- Define the safety feature of DC charging equipment.
- Identify the difference between the various DC charging equipment connector configurations.
- Understand the AC voltage and current requirements of DC charging equipment for proper service load calculations.
- Be aware of the load created by electrical vehicle charging equipment on a buildings service and serving utilities.

2.3 – DC Charging Introduction

DC Chargers…

- offer considerably more power than the current generation of AC Chargers (EVSE).
- are not limited by capacity of the vehicle’s converter to rectify AC to DC.
- are capable of charging many of todays EVs in 30 minutes or less!
- require a large three phase supply of 200 - 400A at 208 or 480V

Seattle, WA - Photo courtesy of Ryan Bradt

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2.3 – DC Charging Standards

Three competing standards in the U.S.

- CHAdeMO
- J1772 CCS (combination)
- Tesla Supercharging - Proprietary
- Many others worldwide

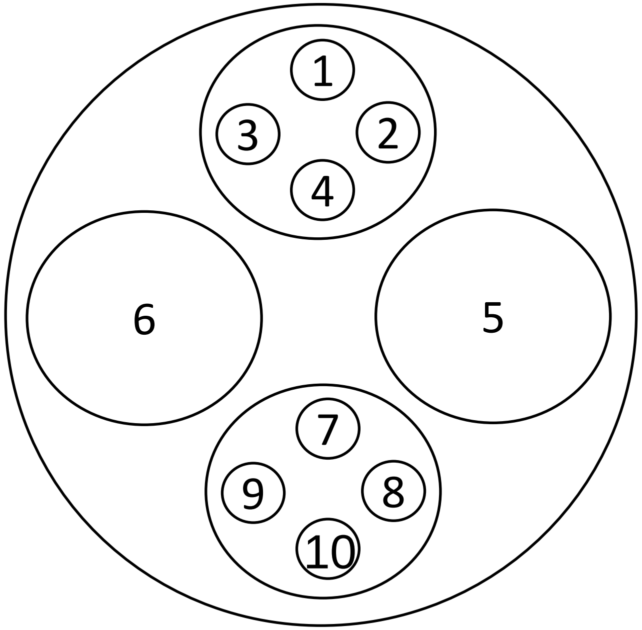
Anaheim, CA - Photo courtesy of Ryan Bradt

2.3 – DC Charging CHAdeMO

- CHAdeMO is the name of a DC charging standard developed by JARI (Japan Automobile Research Institute) and TEPCO (Tokyo Electric Power Company)
- Delivers up to 62.5 kW of high voltage DC at 500VDC, up to 125A
- CHAdeMO is an abbreviation of "CHArge de MOve“

Renton, WA - Photo courtesy of Ryan Bradt

2.3 – DC Charging CHAdeMo coupler configuration



Pin #	Function
1	Reference ground
2	Control EV Relay (1 of 2)
3	not assigned
4	Ready to Charge
5	DC Negative
6	DC Positive
7	Proximity Detection
8	Communication +
9	Communication -
10	Control EV Relay (2 of 2)

2.3 – DC Charging CHAdeMo standard

- CHAdeMo 1.0 standard up to 62.5 kW at 500VDC, up to 125A
- CHAdeMo 2.0 standard up to 400 kW at 1000V VDC, up to 400A

Leavenworth, WA - Photo courtesy of Ryan Bradt

2.3 – DC Charging CCS (combination)

- The SAE Combined Charging System (CCS) connector contains a type 1 J1772 connector, to allow for AC Level 1 and 2, and a DC connection.
- CCS Standard 1.0 allows for the following specifications: 500VDC, 200A, 80kW max.
- CCS Standard 2.0 increased the allowed equipment specifications: 1000VDC, 500A, and 350kW max.

Renton, WA - Photo courtesy of Ryan Bradt

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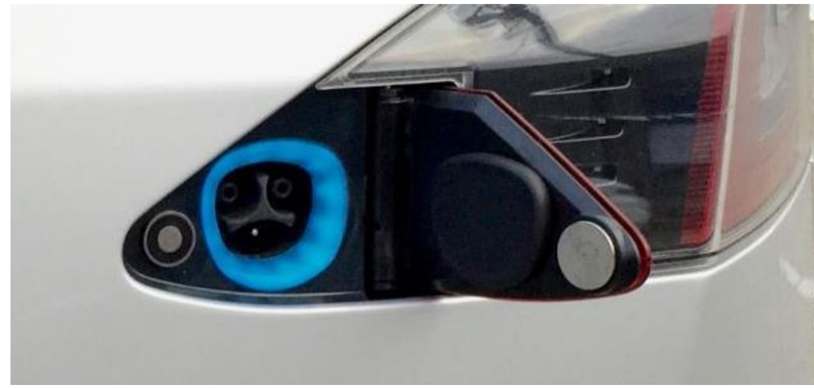
2.3 – DC Charging Tesla

- Tesla Superchargers utilize a proprietary connector only compatible with Tesla EVs.
- Current Superchargers can provide a maximum of 120 kW per EV.
- As of 2018, Tesla operates 7,320 superchargers in 1,063 stations worldwide including 443 stations in the U.S. and 31 in Canada.



Photos courtesy of Ryan Bradt

2.3 – DC Charging
Charging Cable Technology – High-Power Charging(HPC)

- Charging currents up to 200A have been technically possible with conventional cables and connectors.
- Higher currents (up to 500A) is being demanded by the industry. A conventional cable and connector at these current levels would overheat or extremely large cable and connectors would be required.
- Solutions:
  - Liquid cooled cables – circulating a coolant through the cable
  - Passive cable cooling - using ambient air and fan
  - Active cable cooling - using a refrigeration compressor

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2.3 – DC Charging
Load on electrical service

- AC and DC charging of EVs requires a significant amount of power.
- EV charging equipment may represent the largest load on a buildings electrical service.
- EVSE level 1 = 1.4kW – 1.9kW
- EVSE level 2 = up to 19.2kW
- DC fast charger CCS Standard 2.0 = 350kW
- DC fast charger CHAdeMo Standard 2.0 = 400kW.

Mount Vernon, WA - Photo courtesy of Ryan Bradt

2.3 – DC Charging Manufacturers – ABB

ABB

Photos courtesy of ABB

2.3 – DC Charging Manufacturers – BTC

BTCPower

Photos courtesy of BTC

2.3 – DC Charging Manufacturers – Efacec

Photos courtesy of efaces

efacec Empowering the future

2.3 – DC Charging Manufacturers – Delta

Photos courtesy of Delta

2.3 – DC Charging Questions?

Seattle, WA - Photo courtesy of Ryan Bradt

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Module 2 – Section 4

2.4 – Wireless Charging Overview

Section 2.4 Wireless charging introduces the concept of wireless charging of electric vehicles (EVs) utilizing the principal of induction. In the wireless charging of an EV, energy is transferred between coils often mounted beneath the EV and another set mounted near the bottom of the vehicle.

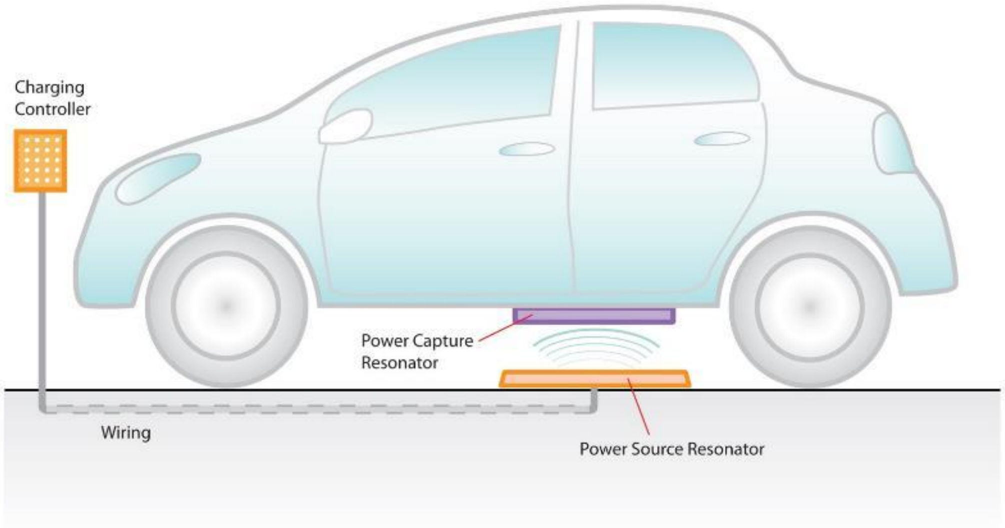

Photo source: electric-vehiclenews.com

2.4 – Wireless Charging Learning Objectives

Upon completion of this section, students should be able to…

- Understand the difference between wireless EV charging and traditional coupled (conductive) charging.
- Define the key components of wireless EV charging equipment and purpose.
- Explain the benefits and drawbacks of wireless charging.
- Recognize wireless charging as an up-and-coming technology still in development.

2.4 – Wireless Charging
What is wireless charging?

- Wireless charging also known as inductive or cordless charging uses an electromagnetic field to transfer energy to an EV.
- Two induction coils are used with one creating a field within a charging base, and a second field in proximity combine to form a transformer.

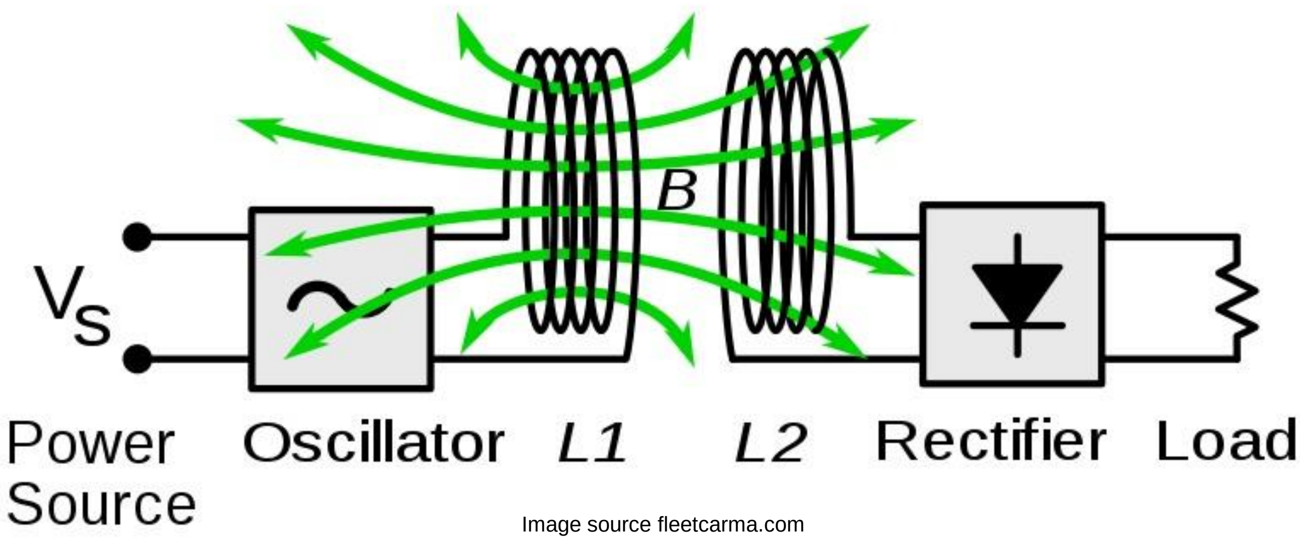

Image source fleetcarma.com

2.4 – Wireless Charging Equipment components

Wireless charging requires the following key components

- EV mounted coil (Power Capture)
- Ground mounted surface or imbedded power source coil (Power Source)
- Charging controller

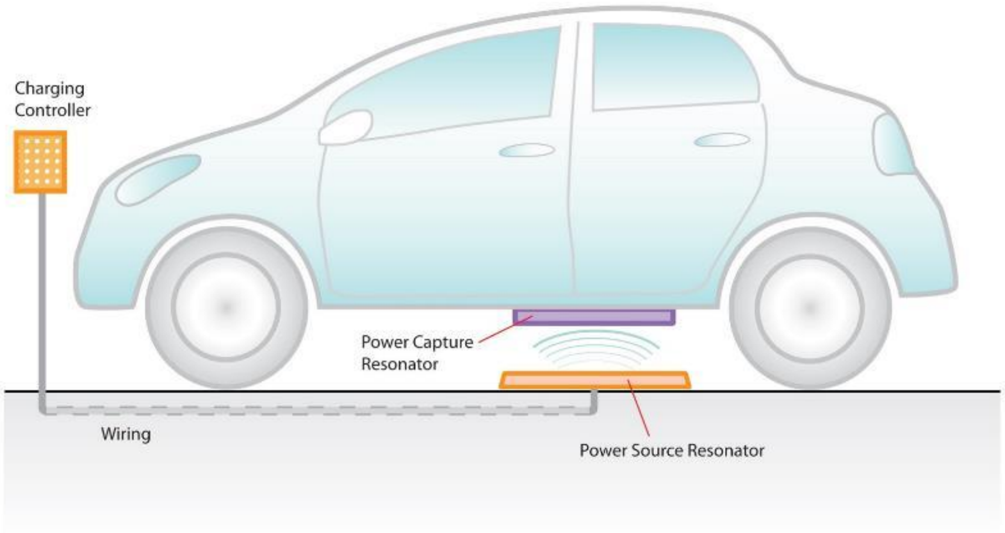

Photo source: electric-vehiclenews.com

2.4 – Wireless Charging
Wireless charging pros and cons

Advantages

- Protected connection – no corrosion
- Durability with no required contact points to break down with connection cycles.
- Reduction in electrical faults with no exposed contact points
- Convenience and safety with with no cables
- Aesthetic quality
- Higher reliability

Disadvantages

- More expensive
- Availability - few EVs in the market are currently wireless charging ready, requiring conversion
- Efficiency losses from inductive charging is around 5% greater than direct coupled EVSE
- Compatibility standards are still being developed.
- Health effects require more study

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2.4 – Wireless Charging
Wireless charging standard development

Photo source: Plugless Power media kit

- The SAE has released a new wireless charging specification **J2954 Recommended Practice (RP)**
- **The recommended practice includes specifications for:**
  - **Up to 11kW wireless charging**
  - **Magnetic triangulation for vehicle alignment**
  - **Coupled with communication to allow for payment without physical interaction**
  - **Ground clearance up to 250mm (10 inches)**

2.4 – Wireless Charging
Wireless charging equipment manufacturers

Currently there are only a handful of companies manufacturing wireless charging equipment for EVs.

- WiTricity / Qualcomm Halo
- Plugless power
- HEVO

PLUGLESS

WiTricity®

Photo source: Plugless Power media kit

2.4 – Wireless Charging Questions?

2.5 – Network and EVSE Communications Learning Objectives

Upon completion of this section, students should be able to…

1. Explain what an EV network does for consumers and entities supporting public EV charging equipment.
2. Understand the various methods by which charging networks generate revenue. (CC processing, network cards, keypad, and pay-by-phone.)
3. Identify the charging networks commonly available around the US and Canada.
4. Explain the methods utilized by networked EV charging equipment for communication.