

# **EV Charging Project**

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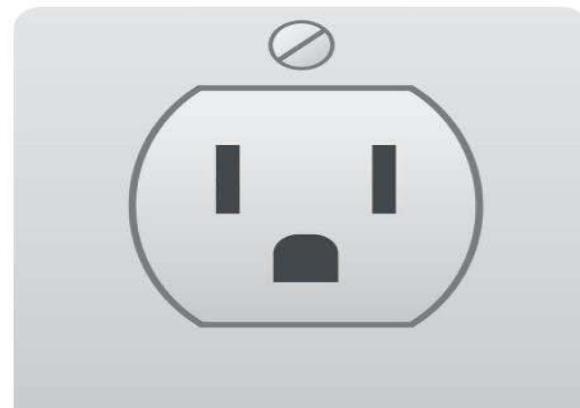
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# Agenda

- Introduction
  - Problem Description
-

# How does EV charging work?

- There are three main types of EV charging: Level 1, Level 2, and DC fast charging (Level 3). Levels 1 and 2 convert AC to DC using an on-board converter in the EV.
- With DC fast charging, the conversion from AC to DC happens **in the charging station, not in the EV**. This allows stations to supply more power, charging vehicles faster.



Level 1



Level 2



Level 3



[https://www.chargepoint.com/files/Quick\\_Guide\\_to\\_Fast\\_Charging.pdf](https://www.chargepoint.com/files/Quick_Guide_to_Fast_Charging.pdf)

# Charging Modes

- There are different charging levels defined by Standard SAE J 1772.

	Level 1	Level 2	Fast charge
Voltage	120 V	208 or 240 V	200 to 450 V
Current type	AC	AC	DC
Useful power	1.4 kW	7.2 kW	50 kW
Maximum output	1.9 kW	19.2 kW	150 kW
Charging time <sup>a</sup>	12 h <sup>a</sup>	3 h <sup>a</sup>	20 min <sup>b</sup>
Connector	J1772	J1772	J1772 Combo, CHAdMO and Supercharger

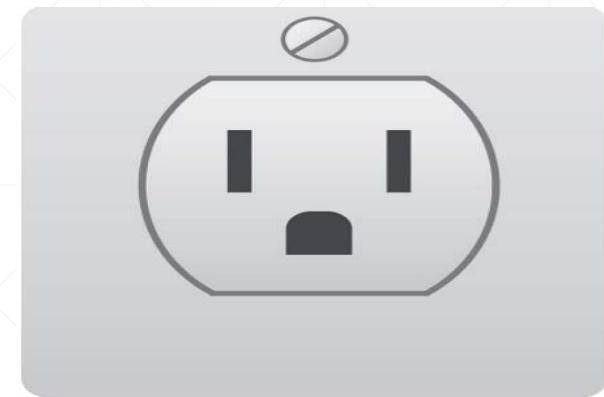
SAE: society of automotive engineering

<http://www.hydroquebec.com/data/electrification-transport/pdf/technical-guide.pdf>

## Level 1

- “Level 1” charging is just plugging in to a standard electrical outlet. Level 1 charging can be convenient for **home use**, but charges very slowly, offering about 5 miles of Range Per Hour (RPH). Level 1 is most useful when a vehicle will be parked for several hours.
- **Level 1** charging **does not require a special charging station**. It uses a Level 1 charging cable, which looks like a large laptop power pack cable and plugs into a standard 120-V outlet

Connector



Level 1



## Level 2

- Level 2 charging **requires a fixed charging station** supplied by a dedicated 208-V or 240-V branch circuit.
- Level 2 charging stations are ideal for times when you'll be parked for at least an hour, such as at work, restaurants, movie theaters, sporting events or longer shopping trips. Level 2 charging works up to **six times faster** than Level 1 charging.
- All electric vehicles sold in North America are equipped with a J 1772 charging socket, except Teslas, which require an adaptor.



# Level 3 (DC fast charging)

- Connector: J 1772 Combo (CCS), CHAdeMO and Supercharger



# EV charge basics and connectors

Type	When to Use	Connector
Level 1, Standard Wall Outlet (AC)	<ul style="list-style-type: none"> <li>+ Get some charge while you sleep</li> <li>Note: slower for cars with large batteries</li> </ul>	 <p>Note: you'll need your own cable to plug in to the wall for Level 1</p>
Level 2 Charging Station (AC)	<ul style="list-style-type: none"> <li>+ At work</li> <li>+ While you sleep</li> <li>+ Topping up around town</li> </ul>	 <p>J1772 connector</p>
DC Fast Charging	<ul style="list-style-type: none"> <li>+ Short stops</li> <li>+ Express Corridor locations</li> </ul>	   <p>SAE Combo (CCS)    CHAdeMO    Tesla</p>

- The most common connector is the **Level 2 J1772 EV plug**. **All vehicles** can use this connector standard in Canada and USA.
- Level 3:
  1. **Asian**: Nissan Leaf, Mitsubishi i-Miev, etc. These cars use the CHAdeMO connector standard.
  2. **American / European**: Chevrolet Volt, Chevrolet Spark, BMW i3, Mercedes, Volkswagen, etc. These cars use the SAE Combo CCS standard.
  3. **Tesla**: Model S and Model X. Tesla uses its own Tesla connector standard; CHAdeMO

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# EV charge basics and connectors

Examples of Charging Stations	Level 1	Level 2	DC Fast Charger	Tesla Supercharger
Electrical Current Type	AC	AC	DC	DC
Range per Charge Time	2-5 miles/ 60 minutes	10-20 miles/ 60 minutes	50-70 miles/ 20 minutes	170 miles/ 30 minutes
Vehicle Charge Ports	J1772 	J1772 	J1772 combo  CHAdeMo 	Tesla combo 
Vehicle Manufacturers that Use the Charge Ports	<ul style="list-style-type: none"> <li>• Audi</li> <li>• BMW</li> <li>• Cadillac</li> <li>• Chevrolet</li> <li>• Fiat</li> <li>• Ford</li> <li>• Hyundai</li> <li>• Kia</li> <li>• Mercedes</li> <li>• Mitsubishi</li> <li>• Nissan</li> <li>• Porsche</li> <li>• Smart</li> <li>• Tesla (w/adapter)</li> <li>• VW</li> <li>• Volvo</li> </ul>	<ul style="list-style-type: none"> <li>• Audi</li> <li>• BMW</li> <li>• Cadillac</li> <li>• Chevrolet</li> <li>• Fiat</li> <li>• Ford</li> <li>• Hyundai</li> <li>• Kia</li> <li>• Mercedes</li> <li>• Mitsubishi</li> <li>• Nissan</li> <li>• Porsche</li> <li>• Smart</li> <li>• Tesla (w/adapter)</li> <li>• VW</li> <li>• Volvo</li> </ul>	<p><b>J1772 combo –</b></p> <ul style="list-style-type: none"> <li>• BMW</li> <li>• Chevrolet</li> <li>• Tesla (w/adapter)</li> </ul> <p><b>CHAdeMo</b></p> <ul style="list-style-type: none"> <li>• Nissan</li> <li>• Mitsubishi</li> <li>• Tesla (w/adapter)</li> <li>• Toyota</li> <li>• Fuji</li> </ul>	<ul style="list-style-type: none"> <li>• Tesla</li> </ul>

# Types of charging station



Type	Level 2	Level 3: CHAdeMo	Level 3: J1772 combo	Level 3: Supercharger
Voltage	220V	500V	500V	500V
Max Power	19.2kW	62.5kW	100kW	120kW
Compatible EVs	Nissan Leaf 2018 Chevy Bolt 2018 Tesla M3 (standard)	Nissan Leaf 2018 Tesla M3 (standard)	Chevy Bolt 2018	Tesla M3 (standard)

# Types of EV



Brand	Nissan Leaf 2018	Chevy Bolt 2018	Tesla M3 (standard)
Capacity	40kWh	60kWh	50kWh
Miles of range	150 miles	238 miles	220 miles
Connector	CHAdeMO; J1772	J1772 combo; J1772	Supercharger; CHAdeMO; J1772

## Problem Description

- There are a group of EV users asking for charging at **four type** charging stations. Each charging station has multiple **identical** charging points.
- Different type of charging stations are compatible with different type of Evans.
- Each charging point is able to charge one EV at one time.
- The charging request of EV user is characterized by **needed travelling distance** and feasible **charging time window**. EV user wants to charge their EVs in order to travel for that prederminted distance, thus, each charging station can estimate the needed charging duration for each EV user.
- An EV user can not accept a charging time which is not in the feasible charging time window.
- The charging station aims at maximizing the number of charging EVs such that all the charging constrains are satisfied.

2 points



1 point



1 point



2 points



Request:  
Needed Distance  
and Preferred  
time window



# Problem Formulation

$$\max \sum_i \sum_j Z_{ij}$$

▪ Subject to

$$\sum_{i \in M} Z_{ij} \leq 1 \quad j \in J$$

$$Z_{ij} \leq E_{ij} \quad j \in J \quad i \in M$$

$$H(2 + X_{kj} - Z_{ik} - Z_{ij}) + S_k \geq \frac{D_j}{v_{ij}} + S_j \quad j, k \in J \quad i \in M$$

$$S_j \geq r_j \quad i \in M \quad j \in J$$

$$(S_j + \frac{D_j}{v_{ij}}) Z_{ij} \leq d_j \quad i \in M \quad j \in J$$

$$S_j \geq 0$$

$$Z_{ij} \in \{0,1\}$$

$$X_{kj} \in \{0,1\}$$

Symbol	Meaning
M	The set of charging stations
i	charging point
J	The set of EV users
j	EV user
$r_j$	Earliest arriving time for user j
$d_j$	Latest departure time for user j
$S_j$	Charge starting time for user j
$D_j$	The travelling distance required by user j
$v_{ij}$	Miles obtained per time unit for user j on charging point i
$Z_{ij} = 1; Z_{ij} = 0$	EV j is assigned to point i ; otherwise
$X_{ki} = 1; X_{ki} = 0$	EV k is charged before EV i; otherwise
$E_{ij} = 1$	EV j can be charged at point i; otherwise

## Problem Description: input (Example)

- There are four types of EV charging station
- Each EV charging station has multiple charging points

No.	Charging Station Type	Charging Point	Charging Point
1	Level 2 ( $m^1$ )	$m_1^1$	
2	Level 3: CHAdeMo ( $m^2$ )	$m_1^2$	$m_2^2$
3	Level 3: J1772 combo ( $m^3$ )		
4	Level 3: Supercharger ( $m^4$ )	$m_1^4$	

## Problem Description: input (Example)

- There are a group of EV users. Each EV user has a EV for charging
- Each EV user has two requests: the needed driving distance and the preferred charging time window

EV user	EV Type	Distance	Earliest arriving time	Latest departure time
#1	Nissan Leaf 2018 ( $j^1$ )	85 mile	9:00	13:00
#2	Tesla M3 ( $j^3$ )	75 mile	9:00	11:00
#3	Chevy Bolt 2018 ( $j^2$ )	60 mile	12:00	15:00
#4	Chevy Bolt 2018 ( $j^2$ )	45 mile	9:00	11:00
#5	Nissan Leaf 2018 ( $j^1$ )	100 mile	9:00	13:00
#6	Nissan Leaf 2018 ( $j^1$ )	80 mile	10:00	17:00
#7	Chevy Bolt 2018 ( $j^2$ )	80 mile	9:30	10:30

partially overlap

# Electric Vehicle Compatibility

	<b>Level 2 (<math>m^1</math>)</b>	<b>Level 3: CHAdMo (<math>m^2</math>)</b>	<b>Level 3: J1772 combo (<math>m^3</math>)</b>	<b>Level 3: Supercharger (<math>m^4</math>)</b>
Nissan Leaf 2018 ( $j^1$ )	Compatible	Compatible	-	-
Chevy Bolt 2018 ( $j^2$ )	Compatible	-	Compatible	-
Tesla M3 (standard) ( $j^3$ )	Compatible	Compatible	-	Compatible

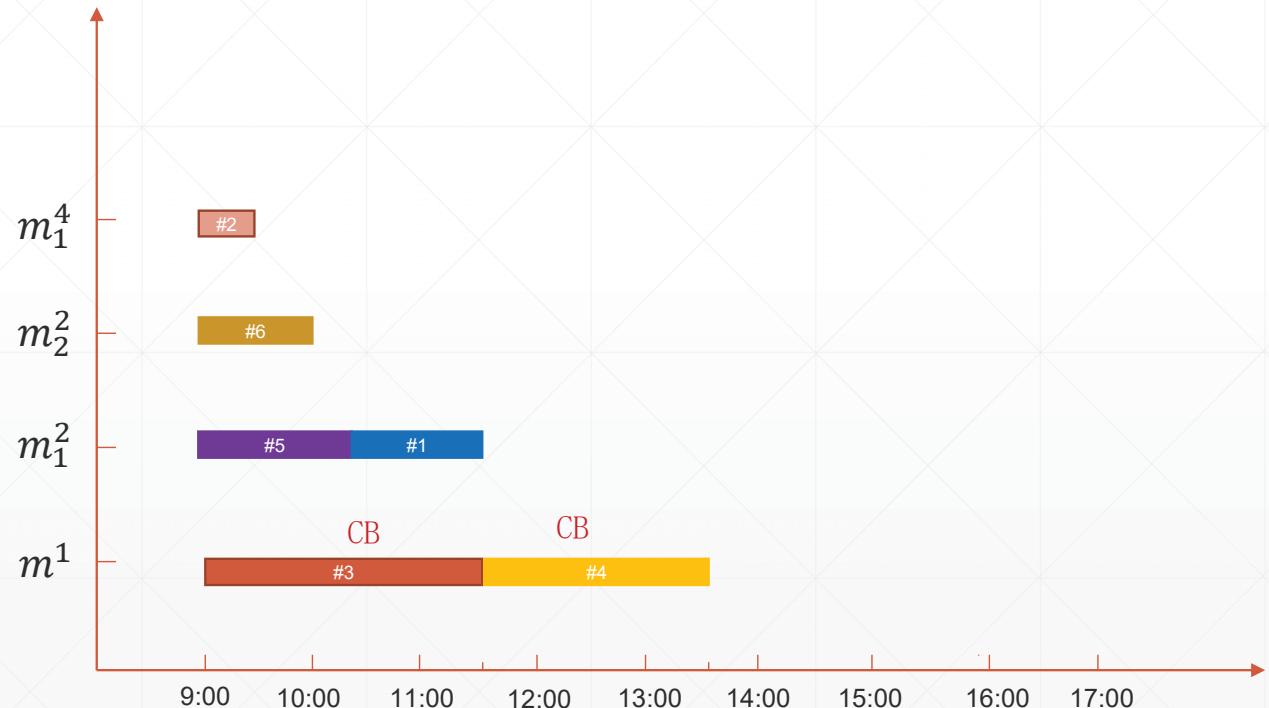
# Electric Vehicle miles range per hour

	Level 2 ( $m^1$ )	Level 3: CHAdeMo ( $m^2$ )	Level 3: J1772 combo ( $m^3$ )	Level 3: Supercharger ( $m^4$ )
Nissan Leaf 2018 ( $j^1$ )	22 mile/hour	73 mile/hour	-	-
Chevy Bolt 2018 ( $j^2$ )	24 mile/hour	-	130 mile/hour	-
Tesla M3 (standard) ( $j^3$ )	25 mile/hour	85 mile/hour	-	160 mile/hour

[https://www.clippercreek.com/wp-content/uploads/2018/01/SMUD\\_Charge-Times-Chart-20180108\\_Final\\_Low-Res.pdf](https://www.clippercreek.com/wp-content/uploads/2018/01/SMUD_Charge-Times-Chart-20180108_Final_Low-Res.pdf)

## Problem Description: output (Example)

- $m^1$  (#3, #4)
- $m_1^2$  (#5, #1)
- $m_2^2$  (#6)
- $m^4$  (#2)
- The total number is: 6



# Reference

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**Thank you !**

