IMMC 2018 Greater China Winter Problem A （简体 繁體 English）

Resources Allocation for Electric Vehicle Charging Stations

Background and Description

China's *Guidelines for the Development of Charging Infrastructure for Electric Vehicles* suggests that the number of electric vehicles (EV) nationwide will be beyond 5,000,000 by 2020, of which electric buses, over 200,000; electric taxis, more than 300,000; logistics, environment, and public sanitation electric vehicles, more than 200,000; governmental, public, and private electric vehicles, over 4,300,000. It is estimated that by 2020, if electricity fee is at RMB ¥1.6 per Kilowatt-hour (kWh) (RMB ¥ 0.8 for electricity fee plus ¥ 0.8 for service fee), the market size for electric vehicle charging may reach RMB ¥ 53-132.5 billion.

1) The Levels of EV Charging Station

According to the standards document by a city- *Technical Specifications for Electric Vehicle Electricity Supply and Security*: *Charging Station*, the construction levels for EV charging station is categorized as follows.

- Level I Charging Station The charging capacity of Level-I charging station is 6800 kWh or higher. The number of handling EVs per day for charging or battery swapping is over 200 large or medium-sized commercial vehicles, or more than 500 passenger cars.
- Level II Charging Station The charging capacity of Level-II charging station is between 3400 and 6800 kWh. The number of handling EVs per day for charging or battery swapping is 100- 200 large or medium-sized commercial vehicles, or 200-500 passenger cars.
- Level III Charging Station The charging capacity of Level-III charging station is between 1700 and 3400 kWh. The number of handling EVs per day for charging or battery swapping is 40- 100 large or medium-sized commercial vehicles, or 100-200 passenger cars.
- Level IV Charging Station The charging capacity of Level-IV charging station is less than 1700 kWh. The number of handling EVs per day for charging or battery swapping is 40 or less large or medium-sized commercial vehicles, or less than 100 passenger cars.

The above Level I - IV charging stations can all be installed with rechargeable power batteries of a certain capacity so as for the optimization of electricity usage between peak-hours and valley-hours.

2) The Recharging Modes of EV Charing Station (Three Types of Charging Mode)

- Slow-charging Mode EVs are designed to maximize the mileage on one charge fulfilling almost a whole day's power consumption. Recharging could be conducted only at night.

Because the value of electric current in slow charging is not very high, such mode provides an option to charge EV in slow way at home parking lot.

- Fast-charging Mode EVs have moderate mileage on one charge. Recharging could be conducted during spare time in fast mode. However, the high-value electric current in fast charging will be harmful to the public power grid although fast-charging may greatly save the charging time. Therefore, fast charging is suitable for standardized charging stations only.
- Battery Swapping Mode Rechargeable vehicle battery packs are designed in standardized way so as to facilitate replacement. Charging stations can swap a discharged battery or battery pack for a fully charged one immediately and professionally in order to ensure the normal driving of EVs. Because of the requirement for high level of professionalization, the battery/pack swapping mode is only suitable for standardized charging stations.

3) Time-of-Use Pricing for General Industrial Usage

Period Property	Time Period	Electricity Price (RMB ¥/kWh)
Peak Hours	10：00-15：00，18：00-21：00	1.322
Flat Hours	7：00-10：00，15：00-18：00，21：00-23：00	0.832
Valley Hours	23：00-7：00	0.369

Questions

1) Location Selection for Charging Stations

For a region in the city mentioned above, there are 10 candidate locations for charging stations and 30 locations that users demand for EV charging. The Appendix provides a map to show the demand and candidate locations as in the attached graphic file, and the demand quantity and coordinates of candidate and demand positions are shown in Table 1 and 2, and the charging station level and the construction cost are as shown in Table 3. Assuming that the unit mileage cost for charging an EV is RMB ¥ 1/ km, and considering the distribution characteristics of EV users, your team is requested to construct a model to select locations for different levels of charging stations, taking into account both the initial construction cost of charging station and the aim to minimize the charging cost for EV users. With your model, please determine the location and level, for each charging station, and the distribution characteristics of EV users on choosing charging station at each demand location.

2) Time-of-Use Pricing

For stations of fast-charging mode and with rechargeable power batteries, please create a model to plan and adjust the charging price on the basis of periods of time-of-use in order to minimize the cost for charging stations to purchase general industrial electricity. You may need to consider the industrial time-of-use pricing, the main factors that may influence EV users' charging behavior such as charging price, distribution of EVs charging during a whole day, etc.

3) Implications Beyond

The underdevelopment in construction of charging piles/stations has become the primary factor restricting the new energy vehicles. According to your understanding of the situation, please analyze the problems impeding the broad application of charging piles/stations and give your solution proposal (which could be from technological, commercial, or public policy perspectives).

Your submission should include a 1-page Summary Sheet and your solution cannot exceed 20 pages for a maximum of 21 pages. The appendices and references should appear at the end of the paper and do not count towards the 20 pages limit.

Appendix

The coordinates of the locations of candidate charging stations and user demand positions in a certain region of the city are shown in the attached graphic file (file name: coordinates of charging stations and demand positions.png), the relevant demand quantity and coordinate values are shown in Table 1 and Table 2. The construction costs corresponding to charging station levels are shown in Table 3.

Table 1 Coordinates of User Demand Positions and Demand Amount

Demand Location	X	Y	Demand (Number of EVs)
1	1268.491263	453.572581	33
2	1222.619624	427.360215	35
3	1345.256048	492.891129	22
4	1151.471774	429.232527	29
5	1265.682796	527.528898	28
6	1207.641129	589.315188	34
7	1167.386425	630.506048	37
8	1166.450269	582.762097	45
9	1142.110215	528.465054	37

10	1045.686156	503.188844	45
11	1087.813172	597.740591	50
12	948.325941	605.229839	33
13	831.306452	426.424059	29
14	816.327957	350.59543	35
15	927.730511	382.424731	43
16	823.817204	493.827285	42
17	816.327957	584.634409	23
18	689.946909	444.211022	34
19	760.158602	241.065188	31
20	678.713038	271.958333	37
21	567.310484	409.573253	41
22	568.24664	333.744624	24
23	529.864247	461.997984	29
24	420.334005	459.189516	32
25	191.911962	335.616935	32
26	240.59207	211.108199	22
27	400.674731	204.555108	24
28	541.098118	235.448253	26
29	596.331317	482.593414	33
30	695.563844	501.316532	31

Table 2 Coordinates of Candidate Charging Station Positions

Candidate Position	Coordinate X	Coordinate Y
A	1284.405914	463.870296
B	1162.705645	593.059812
C	1158.024866	418.934812
D	857.518817	562.166667
E	772.328629	343.106183
F	725.520833	302.851478
G	574.799731	448.891801
H	464.333333	377.743952
I	205.954301	315.021505
J	920.241263	427.360215

Table 3 Charging Station Levels and Construction Costs

Charging Station Level	**Service Capacity** **（Number of EVs/Day）**	**Construction Cost** **（RMB ￥ 10 Thousand）**
1	350	650
2	250	530
3	110	400
4	70	350