



## Planning and design method of garden type charging station in cold regions

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**Abstract:** With the continuous promotion of new energy vehicles in the world, various trends over the years show that cold regions are one of the most unfavorable regions for the use of electric vehicles. Compared with foreign countries, China's new energy vehicle industry started relatively late. At present, research and development and sales basically rely on strong support from the government and policy levels, especially in terms of charging technology and charging facility design and layout planning, which leads to poor charging experience of new energy owners. At the same time, there are many cities in cold regions in China, which are geographically vast, and often have extreme weather, so there is a large demand for vehicles with closed thermal insulation functions. Taking the main automobile charging stations in Harbin, China as an example, the paper investigates the ease of use and efficiency of users, analyzes the problems in the planning and design of the use path for vehicles to enter and exit the parking lot, and proposes a set of path planning and design strategies for garden interactive charging stations that are more comfortable to use and more efficient in combination with the cold landscape design methods. The conclusions are as follows: From the perspective of vehicle, the rear charging port can facilitate the vehicle to enter and exit the charging parking space; From the perspective of parking space planning, "vertical parking" and "inclined parking" can provide more parking spaces in the parking lot of the same area on the basis of meeting the Chinese Code for Parking Lot Planning and Design; From the point of view of charging station location, according to the charging characteristics of lithium-ion power battery, select a closed or semi closed place with thermostatic insulation effect, which can improve the charging efficiency of new energy vehicles. From the perspective of owner use and business model, the charging station and urban pocket park will be combined to establish a garden interactive new energy charging station with basic service supporting facilities, good compatibility with the surrounding environment, and can meet the basic leisure, catering and entertainment needs of drivers and passengers during the charging process. The steady flow of people in the urban charging station can keep the park with appropriate flow of people at all times. In addition, the urban park can improve the charging experience of the charging station users, thereby improving the reputation of the charging station, further attracting people, and improving the economic benefits of the charging station.

**keywords:**Garden type charging station; Interactive landscape; Cold landscape; Parking lot planning

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## I. Introduction

In the development plan of China's new energy vehicle industry from 2021 to 2035, it is proposed to accelerate the integrated development of new energy vehicles and energy, transportation, information, communication and other aspects, and strive to make pure electric vehicles become the mainstream of new vehicles after 15 years of continuous efforts. The charging service network is convenient and efficient, and the construction of hydrogen fuel supply system is steadily advancing. It can be seen that the policy of new energy vehicles in the future is very good, and the products are gradually upgraded. In this regard, new energy vehicles have incomparable advantages over traditional fuel vehicles, which is why many people choose electric vehicles. However, China's existing charging stations are insufficient in number, small in scale, backward in technology and imperfect, which cannot meet the energy supplement requirements of the growing new energy vehicles. However, most of the charging piles are located in urban areas or commercial areas, and the number of private charging piles is very small, which is difficult to meet the needs of people's daily life. Therefore, most citizens have no leisure and energy to install and maintain private charging piles and enjoy government subsidies. The existing charging stations can only realize the single function of charging, lacking other auxiliary functions, and can not meet other needs of users except for energy supplement.

## II. Analysis on the Use of Electric Vehicles in Cold Regions

### 2.1 Definition of cold cities and distribution of cold cities in China

"Cold city" refers to a city with an average temperature of 0°C (32°F) or lower in January and a latitude of 45° higher than the latitude, which is the basic consensus put forward in the Edmonton International Winter Cities Forum in 1986. Canadian scholar Norman Pressman believes that the climate characteristics of winter cities include five basic points: ①the temperature is generally lower than 0°C; ②Precipitation often occurs in the form of snow; ③The days and sunshine are short; ④The above three features last longer; ⑤The change of seasons is obvious. At present, the definition of cold region city is: a special urban group distributed in the Northern Hemisphere, which refers to a city that has a negative impact on urban life because of its long winter and harsh climate, and its average temperature in January is below -18°C. China has a vast territory under cold climate conditions. The average temperature in Heilongjiang, Jilin, Liaoning and the northeast of Inner Mongolia Autonomous Region in January is below -18°C. According to the standard that the average temperature of cold cities in January is below 0 °C developed by the above experts and scholars, there will be more cold cities nationwide, as shown in Figure 1.



Fig. 1 0 °C Isotherm of China in January

### 2.2 Low sales of new energy vehicles in Northeast China due to various unfavorable factors

According to the data of Shanghai Insurance Corporation of China, in October 2022, the sales volume of new energy vehicles nationwide will be 447300, with a monthly year-on-year growth of 52.79%. The sales volume of new energy vehicles in Heilongjiang Province was 1451, with a year-on-year growth of 121.9%, accounting for 0.32% of the total national sales volume. Although the sales volume of new energy vehicles in Heilongjiang Province accounted for a small proportion of the national sales volume, the growth rate was fast. From the sales volume of new energy vehicles in Heilongjiang Province, Northeast China seems to be the "forbidden area" and "vacuum zone" of new energy vehicles, as shown in Figure 2. Northeast China is in a low temperature environment for half a year, which has a great impact on battery performance. It is not optimistic that the severe cold weather in Northeast China will not only affect the electric vehicle's endurance mileage, but also affect the reliability of electronic equipment. The number and complexity of electronic equipment carried by electric vehicles are far greater than those of fuel vehicles, which also leads to an increase in the failure rate of electric vehicles in severe cold weather. However, from the perspective of the monthly year-on-year growth rate, consumers in Northeast China are increasingly

accepting new energy vehicles. This is because compared with traditional fuel vehicles, new energy vehicles have low use costs in the later period, high vehicle intelligence, simple vehicle maintenance, long maintenance cycle, and a light driving experience, such as Figure 3, low running noise.

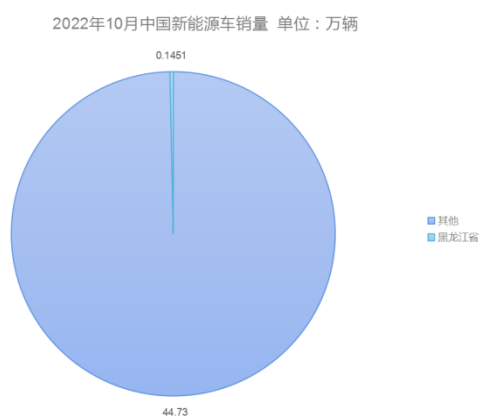


Fig.2 Sales volume of new energy vehicles in China in October 2022

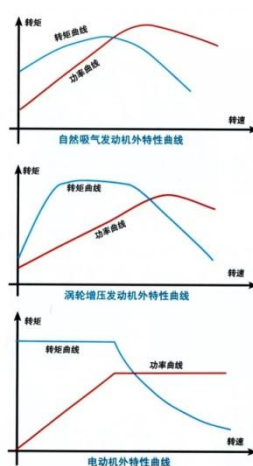


Fig. 3 External Characteristic Curve of Naturally Aspirated Engine, Turbocharged Engine and Motor

### 2.3 Charging and use status of electric vehicles in Harbin

As a necessary activity in the process of personal transportation, the charging of new energy vehicles is often mixed with users' positive or negative emotions. A longer charging time can affect the emotional level to some extent. At this stage, various kinds of planning are unreasonable. The design of the charging station is separated from humanism and isolated from the city. The single function and stiff landscape design are difficult to improve the negative mood of users during the charging time, which affects the physical and mental health of the public over time. According to the rough statistics of a charging APP, most of the fast charging piles in Harbin are distributed in densely populated areas, which makes the use of electric vehicles in Harbin more limited to areas within a radius of 100km. The existing concept of charging station planning and design mainly relies on experience to conduct extensive site selection and planning. The following phenomena, such as delayed construction of charging piles, unreasonable planning of charging stations, lack of supporting functions, and difficulty in integrating with the surrounding environment, have gradually emerged, which directly affects the normal use of charging piles and cannot meet user needs. Charging is one of the problems that local governments and major electric vehicle enterprises hope to solve, because the efficiency and convenience of electric vehicle charging is related to the development rhythm of China's new energy vehicle industry and the actual sales volume of pure electric vehicles. At the same time, it is also one of the most critical issues for consumers to decide whether to abandon fuel vehicles and choose electric vehicles.

### 2.4 Analysis of the use conditions of new energy vehicles in cold regions

In Northeast China, the vast majority of rational car buyers who purchase and use electric vehicles meet one or more of the following requirements: ① families or individuals own one or more fuel vehicles to meet the continuous and long commute needs; ② Fixed working and living places, no more than 100

kilometers per day; ③There are fixed and closed parking lots and private charging facilities; ④Full of passion for new technologies and new products, with a positive consumption concept.

Only when these conditions are met can electric vehicles be easily used in Northeast China. As mentioned above, electric vehicles are much cheaper than ordinary cars in terms of later maintenance and maintenance costs, and consumers who meet these conditions will not be so sensitive to the later use costs of cars. In Harbin, there is no policy constraint, and only the subjective will and needs of consumers can truly reflect the degree of recognition of consumers in a region for electric vehicles and their consumption capacity.

### 2.5 Potential users suitable for purchasing new energy vehicles

Regardless of the policy, traditional fuel vehicles can fully meet all the uses and conditions of new energy vehicles; However, electric vehicles cannot do that in many aspects, such as long commutes, commutes in remote areas, and severe cold weather. If all the following conditions are met, it is the most appropriate to purchase new energy vehicles: ①There is a conventional fuel vehicle; ②Private parking lot and charging facilities; ③The farthest traffic demand is within the urban area, with a travel radius of no more than 100km; ④The ambient temperature of the vehicle shall not be lower than - 10 °C. If any of these items do not meet the requirements, it means that it is not suitable to buy new energy vehicles at present. If they are purchased and used, there may be some problems.

## III. Charging station parking space planning and vehicle charging port layout method

### 3.1 Parking space planning of charging parking lot

There are three main parking modes: parallel, oblique and vertical. According to the design parameters of motor vehicle parking lot specified in the Code for Parking Lot Planning and Design of China, as shown in Figure 4, the width of small parking lot is 2.8m, the length of parking space is 7m, and the width of passage is 4m; Inclined (45 degree) parking lot, 4m wide, 5.2m long, 4m wide; The width of the small car parking space in the vertical parking lot is 2.8m, the length of the parking space is 6m, and the width of the passage is 6m. 50 meters from the parking lot × 50 meters as an example to draw a parking space. ①Vertical parking: 50 meters long and 50 meters wide, capable of parking 80 small cars, with an average floor area of 31.25 square meters, as shown in Figure 5. Among the three parking modes, the vertical parking cycle has the smallest floor area, but the turning radius is large and the passage is wide. ②Inclined parking: 50 meters long and 50 meters wide, it can park 62 small cars, with an average floor area of 40.32 square meters, as shown in Figure 5. Inclined parking has the advantages of convenient entry and exit, small turning radius, small channel width and area, but the entry and exit vehicles can only travel in a fixed direction, and there are triangle areas in front and behind, so each vehicle occupies a large area. ③Parallel parking: 50 meters long and 50 meters wide, capable of parking 60 small cars, with an average floor area of 41.67 square meters, as shown in Figure 5. To sum up, the parking space area occupied by vertical parking bicycles is the smallest. Vertical parking mode shall be adopted for underground garage of high-rise buildings. Parallel parking and oblique parking are suitable for parking on narrow roads. In order to improve the utilization rate of the charging pile, vertical parking and inclined parking shall be adopted as far as possible when more vehicles are charged at the same time within the unit area.

停车方式	垂直通道方向的停车带宽 (m)					平行通道方向的停车带长 (m)					通道宽 (m)					单位停车面积 (平方米)					
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	
平行式	前进停车	2.6	2.8	3.5	3.5	3.5	5.2	7.0	12.7	16.0	22.0	3.0	4.0	4.5	4.5	5.0	21.3	33.6	73.0	92.0	132.0
斜列式	30° 前进停车	3.2	4.2	6.4	8.0	11.0	5.2	5.6	7.0	7.0	7.0	3.0	4.0	5.0	5.8	6.0	24.4	34.7	62.3	76.1	78.0
	45° 前进停车	3.9	5.2	8.1	10.4	14.7	3.7	4.0	4.9	4.9	4.9	3.0	4.0	6.0	6.8	7.0	20.0	28.8	54.4	67.5	89.2
	60° 前进停车	4.3	5.9	9.3	12.1	17.3	3.0	3.2	4.0	4.0	4.0	4.0	5.0	8.0	9.5	10.0	18.9	26.9	53.2	67.4	89.2
	60° 后退停车	4.3	5.9	9.3	12.1	17.3	3.0	3.2	4.0	4.0	4.0	3.5	4.5	6.5	7.3	8.0	18.2	26.1	50.2	62.9	85.2
垂直式	前进停车	4.2	6.0	9.7	13.0	19.0	2.6	2.8	3.5	3.5	3.5	6.0	9.5	10.0	13.0	19.0	18.7	30.1	51.5	68.3	99.8
	后退停车	4.2	6.0	9.7	13.0	19.0	2.6	2.8	3.5	3.5	3.5	4.2	6.0	9.7	13.0	19.0	16.4	25.2	50.8	68.3	99.8

注：表中 I 类指微型汽车，II 类指小型汽车，III 类指中型汽车，IV 类指大型汽车，V 类指铰接车。

Fig.4 Design Parameters of Motor Vehicle Parking Lot in Code for Planning and Design of Parking Lot

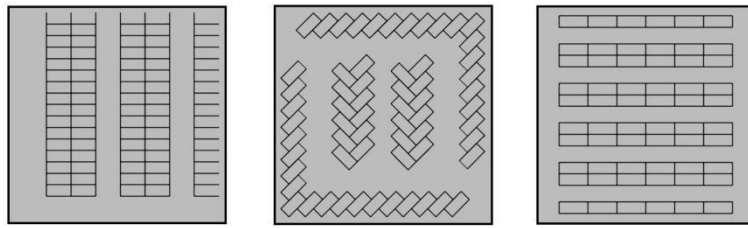


Fig.5 Schematic Diagram of Vertical Parking Lot, Inclined Parking Lot and Parallel Parking Lot

### 3.2 Layout analysis of electric vehicle charging ports

Charging is an important link in the use of electric vehicles, and the charging experience directly affects consumers' purchase decisions and use experience. As for the layout and location of electric vehicle charging ports, the host manufacturers have not reached an agreement, because each brand has its own unique considerations and practices, thus determining the location of its own product charging ports. At present, there are three types of electric vehicle charging ports: ①side rear, side front, as shown in Figure 6, front.



Fig. 6 Schematic Diagram of Side Rear Charging Port and Side Front Charging Port

The charging port is set at the rear side. When vertical parking is encountered, the vehicle will reverse and enter the warehouse. The front wheel swing range of the same model vehicle is narrow, and the space required for reversing is small, which means that the public roads in the parking lot can be designed narrower, and the public roads of the same width can also be easily parked and entered the warehouse. The charging port is set in the front of the side. When encountering a vertical parking space, in order to make the charging port closer to the charging pile, the charging port can only move forward and enter the warehouse. As the front wheel of the car is responsible for steering, "internal wheel difference" will occur when turning straight. The internal wheel difference is proportional to the vehicle wheelbase, increasing the space required for entering the warehouse. At the same time, when the charging port is set in front of the vehicle, it will form a blind area on the left and right sides when reversing out of the vehicle. It is difficult for the driver to detect the left and right sides of the rear, which is very easy to cause accidents.

The above two types of charging ports are arranged facing the parallel parking space on the side of the charging pile. The distance between the charging port on the side and the charging pile is relatively close, which is convenient for users to plug in and pull out the charging gun. Vehicles with the charging port set in the front not only have the same problems as those with the charging port set in the front of the side, but also face parallel parking spaces where the charging port is far away from the charging pile on the side, which makes it very difficult for users to operate, even when the charging line is not long enough to charge.

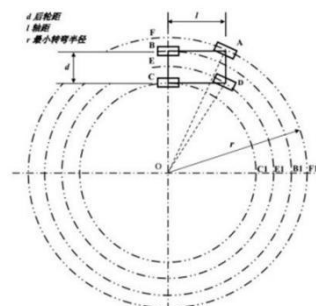


Fig.7 Schematic Diagram of Inner Wheel Difference

### **3.3 How to improve user charging experience**

The rapid development of China's automobile charging station, charging pile, power exchange station and other infrastructure has alleviated the "difficult charging" problem of new energy vehicles. However, at present, the utilization rate of urban public charging equipment in China is low, the proportion of "fault pile, slow pile, zombie pile" is high, and the installation proportion of private charging facilities is low. On the one hand, due to the increasing popularity of new energy vehicles, there are fewer public DC charging stations in some places, which will have a certain negative impact on the user experience of new energy vehicle charging; In addition, due to the unreasonable layout of the site, inadequate supervision and maintenance, in order to improve the city image, the charging station has been "built without management", and a large number of invalid piles and "zombie" piles exist in some areas, resulting in a large amount of waste and idle resources. With the increasing number of new energy vehicles and charging stations, the repair and maintenance department should follow up to ensure the normal operation of existing facilities. At the same time, relevant units should earnestly supervise the quality and use of charging equipment, take customers as the center, improve the service level, and resolutely prevent individual manufacturers from misappropriating new energy subsidies. Or adopt the power exchange mode of vehicle electricity separation, and take the manufacturer as the service provider to focus the efforts of all parties, so as to provide users with the fastest charging, reduce "mileage anxiety" and charging concerns, and improve the competitiveness of enterprises and user stickiness.

In addition, China is still faced with many imperfect electric vehicle manufacturers and imperfect industry norms, which causes that China cannot form a unified charging standard at present, and there is charging incompatibility. All new energy enterprises, charging pile manufacturers, charging platforms and relevant units need to pay attention to and improve.

To solve the core pain point of charging experience, it is necessary to improve the operation mechanism of charging infrastructure, while upstream and downstream manufacturers of the industrial chain need to cooperate to explore more innovative business models and operation models, and speed up the research and development of advanced technologies to effectively improve the charging service user experience. Provide public services for new energy vehicles, establish a differentiated management system, formulate parking management regulations for new energy vehicles, implement special parking spaces for new energy vehicles, preferential parking fees and other preferential measures, strengthen the supervision of charging places and equipment, support stations to set intelligent parking poles or locks to identify new energy vehicles, restrain fuel vehicles from occupying spaces and other violations, and ensure the charging convenience of new energy vehicles.

### **3.4 Fast charging time of lithium ion power battery at different temperatures**

Cai Guohui, Dong Tian, Li Yang, Li Xiang, Zheng Kun mentioned in the article "Fast Charging Characteristics of Lithium Ion Power Batteries at Different Temperatures" that the change trend of charging current at low temperatures (-20 °C, -5 °C) is small → large → small. In the initial stage of low temperature, the temperature inside the battery (the highest temperature of the cell) is low. As the charging continues, the internal temperature of the battery gradually increases, at about 20 °C at room temperature, The charging current reaches the maximum (100 A). When the internal temperature of the battery reaches about 30 °C, the charging current decreases again. At this time, the battery SOC has reached 90%, and then the charging current gradually decreases until it is fully charged. At normal temperature (25 °C) and high temperature (45 °C), the change trend of charging current is large → small. The current at the initial stage of normal temperature reaches (100 A). When the internal temperature of the battery reaches about 40 °C, the charging current decreases to 65 A, and when the SOC of the battery reaches 90%, the internal temperature of the battery is about 44 °C. The charging current gradually decreases to full charge, as shown in Figure 8. It can be seen that the charging of lithium ion battery in cold environment will experience a low current time when the battery heats up, and the charging speed is slow. Therefore, the charging time of electric vehicles in cold regions in China is longer than that in the south, and the waiting time of car owners for charging is also longer.

样品编号	SOC	充电时间 (min)			
		-20 °C	-5 °C	25 °C	45 °C
1#	0~10 %	43.83	24.13	4.48	8.9
	10~90 %	66.87	54.15	52.04	120.58
	90 %~ 满电	48.87	44.58	31.30	63.63
	0~ 满电	159.57	122.86	87.82	193.11
2#	0~10 %	41.82	24.35	4.72	10.15
	10~90 %	66.97	53.85	48.45	118.23
	90 %~ 满电	48.32	45.23	36.51	62.57
	0~ 满电	157.11	123.43	89.68	190.95

Fig. 8 Fast charging time of lithium ion power battery at different temperatures

### 3.5 Reduce the idle of private charging piles

The peak charging speed of electric vehicles represents the technical strength of a new energy vehicle manufacturer. At present, it only takes about one hour for mainstream electric vehicles to charge from 0% SOC to 80% SOC with DC fast charging. In order to improve the utilization rate of charging piles, reduce the occupation of vehicles with full or no charge, and increase the turnover, many DC fast charging stations will charge a certain parking fee or management fee in addition to the electricity fee, And with the increase of parking time, the ladder price will rise. This means that when the vehicle owner uses the fast charging pile to charge, he or she will not leave the vehicle, wait with the vehicle, or leave the vehicle, and return to the charging station to remove the vehicle after the vehicle is fully charged (about 1 hour). The former causes a waste of the owner's time, while the latter is difficult to complete other work that is difficult to determine the completion time within the hour of leaving the charging station. At the same time, the price of public fast charging piles is much higher than that of private slow charging piles when charging the same amount of electricity. Therefore, you can rent your own parking space and private charging pile to new energy owners whose destination is near your own parking space through legal platforms or channels during the idle period; On the contrary, you can also rent private parking spaces and charging posts around your travel destination in the same way to supplement your vehicle's energy. This not only makes full use of cheap energy, avoids the idleness of private parking spaces and charging piles, but also facilitates the majority of new energy owners and further reduces the cost of vehicle use.

## IV. Design Idea of Charging Station in Cold Regions

### 4.1 Functional design of garden style interactive charging station in cold regions

It can be seen from the above that the indoor or underground garage with thermal insulation function can be selected for the site selection of the charging station, which can reduce the heating time (20~25 °C) of the power battery and thus shorten the charging time. Traditional urban charging stations often have single function and small area. If users do not leave the charging station within 20 to 60 minutes of charging, they need to wait until the vehicle is charged to the planned capacity. If you leave the charging station, it is difficult to complete other work or things within 20 to 60 minutes. This paper envisages the combination of charging stations and urban pocket parks. The steady flow of people in urban charging stations can keep the park at all times suitable for the flow of people, and urban parks can improve the charging experience of charging station users, thereby improving the reputation of charging stations, further attracting people, and improving the economic benefits of charging stations.

### 4.2. Appearance design of charging station

As a public service place for charging new energy electric vehicles, the car charging station needs to realize the service functions of fast, simple, safe and comfortable car charging. The design of the electric vehicle charging station should start from the perspective of people and fully consider the modeling style, spatial layout, surrounding environment and other factors, so as to achieve a harmonious, beautiful and modern look. The rational planning and design of garden interactive charging stations and their supporting facilities are of great significance for the efficient and rational popularization and application of new energy vehicles and the integration of new energy charging stations into the urban environment. Its advantage is that it can fully understand the psychological and physiological needs of new energy vehicle owners when they supplement energy for vehicles, and can also provide a good supporting service system for new energy vehicles and improve user satisfaction.

### 4.3 Charging pile design case

The charging pile in this case, combined with the street lamp lighting system, can realize multiple functions. Indicator lights of various colors are installed on the lighting position to display the status of the charging pile. The outlet of the charging cable is set at a higher position to prevent the cable from colliding with the vehicle body and causing damage to the vehicle surface when the user is using it. The side plug-in charging gun and display screen are adopted, so that users can stand at one side of the charging pile to operate, and can keep a certain distance from the parking space to avoid collision with users who are operating the charging pile when other vehicles are backing up, thus causing safety problems. The operator standing next to the charging pile can also see the condition of the parking lot with the corner light of his eyes, so as to better ensure the safety of use. From the appearance, the charging pile has the characteristics of small size, simple use and convenient use, which has no impact on the planning of the entire charging station. From the functional point of view, the number of basic facilities of the charging station can be reduced in combination with the lighting function of the street lamp; The size and shape shall conform to ergonomics and user's usage habits; The design of status indicator light, upper outlet cable, side charging gun and operation screen fully reflects the humanized design idea, as shown in Figure 9.

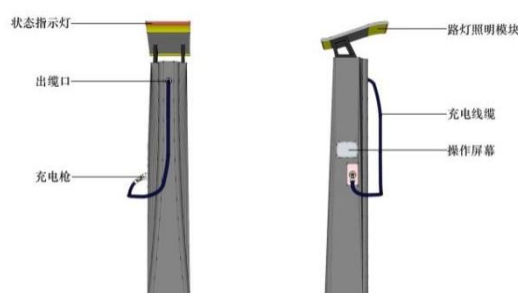


Fig. 9 Front view and side view of charging pile

## V. Summary

### 5.1 Parking lot design and charging port location layout of new energy vehicle charging station

After the above research and analysis, it can be basically determined that for the layout planning of the parking lot of the electric vehicle charging station, the two parking lot planning modes of "vertical parking" and "inclined parking" can accommodate more vehicles to charge at the same time within the unit area. For the location of the electric vehicle charging port, the charging port arranged behind the side can meet the requirements of convenience, safety Space saving is the three key points that can effectively improve the experience of electric vehicles in cold regions.

### 5.2 Design method of garden interactive charging station and charging pile

The garden interactive charging station can achieve the organic integration of urban functional infrastructure, decorative infrastructure and ecological infrastructure. First of all, the garden interactive charging station can achieve high efficiency and green environmental protection. Second, the garden interactive charging station planning and design has other advantages while meeting the charging demand: 1. The garden type charging station can seamlessly connect with photovoltaic parks, parks or wetland parks in other cities, saving land area; 2. The innovation of the garden type charging station in the architectural layout makes the charging station small in building scale and floor area; 3. The functions of the charging station can be adjusted according to the needs of consumers (such as air conditioning, lighting, entertainment systems and other power projects); 4. Improve the utilization efficiency of urban space resources and improve the utilization efficiency of resources.

The appearance design of the charging pile is more scientific, futuristic and friendly. On the basis of realizing the basic functions, its shape design minimizes the space occupied, looks smaller, more flexible and more three-dimensional, making it more suitable for practical use. More use of smooth curves provides a sense of fashion for the design language and color of the charging pile, and integrates human emotions into the design. The shape of the charging pile has both a sense of technology and affinity, making it more in line with the needs of users. In terms of functions, the design of the charging station is more compatible, more efficient, more stable and more durable. After the charging pile is put into use, there are still many problems, such as: poor functional compatibility, slow charging speed, long service life, poor stability, difficult maintenance, etc. These problems will not only have a great impact on the user's experience, but also lead to a decline in the utilization rate of the charging pile, resulting in a waste of social resources. In



the design practice of the charging pile, the designer should follow the concept of technological innovation, constantly explore various problems, and propose corresponding solutions to minimize the problems that may occur in use. In terms of human-computer interaction, the design of charging pile is more concise and humanized. The operation interface is the only way to connect people and products, which directly affects the user's experience. In the process of use, the user interface should be simplified as much as possible to reduce the difficulty of user operation and increase the adaptability of users. In addition, its ergonomic design should also meet the needs of users, so that users can feel simple and comfortable when using, fully reflecting the humanization of the design.

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