Key Technology Research of Electric Cars Smart Dynamic Interactive Terminal Charging Path Planning

Li Suo*, Jian Sun*
State Grid Electric Vehicle Service Company, Beijing, China

*Corresponding author e-mail: suoli@evs.sgcc.com.cn, sunjian@evs.sgcc.com.cn

Abstract. In the future a large-scale of electric vehicles will have mutual interact and influence with cities’ intelligent transportation network and intelligent grid network. In recent years, with the popularity of the third-generation mobile communication technology, the use of the Internet for dynamic traffic information and navigation is competent for the traffic information transmission requirements, which can effectively reduce hardware requirements, expand the popularity of dynamic vehicle navigation technology. In this context, this paper proposes a "center" type of electric car charging dynamic route planning service system architecture, and the architecture of the server-side data management technology and services were studied, through GIS technology, the optimal allocation of each electric vehicle charging stations ultimately comes true, which ensures the coordination and harmonization of electric vehicles, charging stations and users, saves the time for travel and charging, and improves operating efficiency.

1. Introduction
The increasingly serious environmental pollution and the depletion of fossil energy have made the large-scale application of electric vehicles an inevitable trend [1]. Vigorously developing electric vehicles is a requirement of China's basic national policy of "energy saving and emission reduction" [2-3]. According to the national new energy automobile industry development plan, the scale of electric vehicles is expected to increase to 500,000 units in 2015[2, 4]. When electric vehicles become the main vehicle, users and power systems will face new problems. On the one hand, the owner needs to consider how to choose an optimal charging station and charging path, so that the total time for finding charging and charging is the shortest, and the charging power of the charging device is guaranteed to be the maximum power that the electric vehicle can accept, so as to complete the charging as soon as possible[5-7]; on the other hand, the power system needs to avoid the large concentration of electric vehicles concentrated in a charging station to cause overload and voltage levels are too low[3,8].

The research on charging path planning of electric vehicles has never been interrupted. The literature [6-7] uses V2G (Vehicle to Grid) to propose intelligent charging algorithms to minimize cost, minimize impact on system load and maximize profit. The literature [4-5,9] carried out research on the construction of urban road traffic evaluation system to realize the traffic evaluation when the vehicle is driving in the urban road network. Literature [8] explores a method for planning charging paths for electric vehicles based on geographic location and traffic conditions. Literature [10-11] explores the
optimization method of electric vehicle charging path with the lowest cost of use as the optimization goal. Reference [12] discusses the charging path charging strategy using the interaction information between the electric vehicle and the charging station with the minimum total charging time as the target.

In general, most of the existing researches are limited to the interaction between electric vehicles and transportation networks and the interaction between electric vehicles and distribution networks. There are not many studies on charging path planning for large-scale electric vehicles in combination with traffic conditions. This paper uses the Internet to publish and navigate dynamic traffic information. By researching the optimal path planning algorithm and combining GIS technology, it provides an optimal charging path to avoid charging resource imbalance, improve vehicle travel efficiency, and make electric The negative impact of the car's search for charging stations on the transportation system is minimized.

2. Dynamic charging path planning system and method

The new charging path planning technology can dynamically integrate the charging service network, distribution network, transportation network and other information through the wireless network to provide users with more accurate path planning solutions, and realize centralized processing and calculation on the server side, thus fundamentally solving the problem. The shortcomings in the navigation system provide users with more reliable and efficient services. The adoption of the dynamic charging path planning system architecture can not only reduce the hardware requirements of the intelligent interactive terminal, but also reduce the system's dependence on the terminal storage capacity. Users can get the latest map data in real time, and can integrate various auxiliary information to achieve a more accurate and efficient charging path.

The intelligent interactive terminal can automatically display the vehicle location, the traffic network map, the road condition and the charging facility distribution and working conditions, provide the driver with the best real-time driving route from the departure place to the charging station, and assist the driver to conveniently reach the destination; At the same time, the operation requirements of the power system are fully considered in the selection of the charging station, and the phenomenon of unbalanced charging resources is avoided to ensure the safe operation of the power system.

2.1. Dynamic Charging Path Planning System

2.1.1. System Architecture. The electric vehicle dynamic charging path planning service system architecture is a central service-based dynamic navigation technology. Different from the "autonomous" navigation technology, all data processing and path calculation are completed by the service center, and then the processed result is transmitted to the navigation terminal by wireless communication. The navigation terminal is only responsible for data display and human-computer interaction, interface. Thanks to the powerful processing and storage capabilities of the service center, it can comprehensively process various information in real time, such as the latest charging and changing facilities, grid information, real-time traffic information, etc., to provide real-time charging path for intelligent interactive terminals. Planning services.

The system is built on the popular Internet standard protocol, featuring distributed, interoperable and easy integration of existing GIS resources, and has good scalability. Combining XML and Web Service technologies with existing GIS application systems to implement GIS services can break the technical limitations of object systems, operating environments and development languages of various application systems, and break the limitations between services. Establish an open, collaborative network geographic information service platform. The whole service platform consists of three parts: data providing center, service center and intelligent interactive terminal:

1) The data providing center provides various data to the service center, including charging and replacing facility data, grid data, traffic information data, POI data and other commercial data;
2) The service center is the core of the whole system. It is responsible for processing the data provided by the data providing center and providing map incremental update service and path planning information service to the interactive terminal;

3) The intelligent interactive terminal utilizes the services provided by the service center to implement a dynamic planning path and update the navigation electronic map as needed.

Design a dynamic charging path planning system architecture, as shown in Figure 1.

2.1.2. Implementation Process. Generally, the operation of the dynamic path planning service is initiated by the interactive terminal, and after the service center calls the database data to complete the processing operation, the processing result is returned to the interactive terminal. Taking the common charging path planning as an example, the intelligent interactive terminal collects the real-time status of the electric vehicle and determines whether charging is required. If necessary, the user is prompted and searches for all charging stations within the maximum mileage range as candidate charging stations, and the charging probability of the vehicle at each charging station is calculated. The charging load is predicted based on the charging probability and sent to the power dispatching center.

The power dispatching center calculates the maximum allowable charging power of each charging station, and combines the real-time traffic data to obtain the travel and total charging time order, and sends it to the electric vehicle user. The electric vehicle charging path planning technology provides the best charging path for electric vehicle users, ensuring the safe operation of the power system. The path planning process is shown in Figure 2.

![Fig. 1 The system architecture of dynamic charging path planning](image-url)
2.2. Planning method

The intelligent interactive terminal of the electric vehicle acquires the user's charging demand through the interactive interface, and transmits the information to the operating system, and the information includes: the starting point A, the destination B, the initial state of charge $E_{soc0}$, the battery capacity $E_B$, the departure time $t_0$, and the maximum travel of the electric vehicle. The mileage $d_{max}$ and the $K_{PGeV}$ per unit of electric energy driving; the system selects the shortest distance $d_{ABmin}$ between the two points A and B according to the received information, selects the charging station T closest to the destination B, the destination B and the charging station T The distance between the shortest path is recorded as $d_{BTmin}$; the operation monitoring system judges the state of charge of the electric vehicle. If $d_{max} > d_{ABmin} + d_{BTmin}$, it is judged that the electric vehicle does not need to be charged, and if $d_{max} < d_{ABmin} + d_{BTmin}$, the user is prompted to charge the electric vehicle.

The operation monitoring system searches all the charging stations of the electric vehicle within the maximum mileage $d_{max}$ as the candidate charging stations (collection C) of the electric vehicle, and searches for each charging station $j$ from the point A to the candidate charging station set to the destination respectively. The total time of B is recorded as $t_j$, where $J \in C$, the probability of charging the electric vehicle at any one of the candidate charging stations $j$, where $s$ is the total number of charging stations; the system calculates the predicted charging power of the electric vehicle charging at the charging station $j$ to be $P_j = P_{jEV} P_{EV}$, where $P_{EV}$ is the maximum charging power expected by electric vehicle owners.

The operation monitoring system calculates the time $t_j^{arr}$ required for the electric vehicle to reach the candidate charging station $j$, the required charging time $t_j^{dur}$, and the load forecast $L_j(t)$ of the electric vehicle charging at the candidate charging station $j$:

$$t_j^{arr} = t_0 + \frac{d_{jmin}}{v_j}$$  \hspace{1cm} (1)

$$t_j^{dur} = \frac{E_B - (E_{soc0} - d_{jmin} / K_{PGeV})}{P_{jEV}}$$  \hspace{1cm} (2)

At the time, $t < t_0$ or $t \geq t_j^{arr}$, $L_j(t) = 0$  \hspace{1cm} (3)
At the time, $t_0 \leq t \leq t_j^\text{arr} + t_j^\text{dur}$, $L_j(t) = P_j$  \hspace{1cm} (4)

Where $V_j$ is the speed of the vehicle from the starting point of the electric vehicle to the candidate charging on the path, and $d_j^\text{min}$ is the distance of the shortest path from the electric vehicle to the charging station $j$.

Repeating the above steps, the operation monitoring system superimposes the load predictions of all electric vehicles at the candidate charging station $j$, obtains the total charging load prediction of the charging station $j$, and transmits the total charging load prediction $L_j'(t)$ to the power dispatching center.

The power dispatching center calculates the maximum charging power of each charging station $j$ according to the received charging load prediction $L_j'(t)$ and the load forecast $L_j^0(t)$ of the grid load point to which the charging station belongs:

$$P_j^\text{max}(t) = \max \{ P_{EV}, L_j^\text{max}(t) - L_j^0(t) - L_j'(t) \}$$  \hspace{1cm} (5)

Wherein, the maximum allowable charging power of the grid load point to which the charging station $j$ is read from the power system database.

Repeating the above steps, the power system dispatching center calculates the allowable maximum charging power $L_j^\text{max}(t)$ of each charging station of each electric vehicle within the maximum mileage, and sends it to the operation monitoring system.

The operation monitoring system corrects the charging time of each electric vehicle according to the maximum charging power $P_j^\text{max}(t)$, obtains the corrected charging time $t_j^p$, and calculates the total time required for each electric vehicle from the departure point to the destination and the time required for charging. Time $t_j^p = \frac{E_a - (E_{soc} - d_j^\text{min})}{P_j^\text{max}(t) KPE}$ and sent to the power dispatch center.

The power dispatching center calculates the charging probability of each electric vehicle to the $j$th charging station as $t_j' = t_j + t_j^\text{dur}$ according to the total time $t_j'$, and calculates the charging power of each electric vehicle $P_j' = \frac{1}{t_j'} / (\frac{1}{t_1} + \frac{1}{t_2} + \cdots + \frac{1}{t_r})$ at the charging station $j= P_j' = P_j \times P_j^\text{max}(t_0)$, $j \in C$. And load forecasting:

At the time

$$t < t_0 \text{ or } t \geq t_j^\text{arr} + t_j^\text{dur}, \quad L_j'(t) = 0$$  \hspace{1cm} (6)

At the time

$$t_0 \leq t \leq t_j^\text{arr} + t_j^\text{dur}, \quad L_j'(t) = P_j'$$  \hspace{1cm} (7)

The power dispatching center superimposes the load forecast of all electric vehicles at the charging station $j$, obtains the total charging load prediction $L_j'(t)$, and superimposes it with the load forecast...
\( L_j^{O,old}(t) \) given by the power system, and calculates the load forecast of the grid load point to which the charging station \( j \) belongs:

\[
L_j^O(t) = L_j^{O,old}(t) + L_j^T(t)
\]

(8)

\( L_j^{O,old}(t) \) is the load forecast of the grid load point to which the charging station \( j \) belongs before the departure time \( t_0 \). The operation monitoring system sorts the total time \( t_j \) obtained in the above steps from small to large and displays it to the electric vehicle user through a graphical interface.

3. GIS implementation

This article uses the ArcGIS platform, intelligent interactive terminal based on the secondary development of the ArcGIS Mobile module to achieve optimal path planning. The so-called integrated secondary development method refers to the use of professional geographic system tool software to realize the basic functions of the geographic information system, and the universal visualization software development tool as the development platform for secondary integration development. The integrated secondary development method can fully utilize the advantages of the geographic information system tool software for the management and analysis functions of the spatial database, and the efficiency and convenience of other visual development languages, and can greatly improve the development efficiency of the application system, and the application has Better appearance, more powerful database features, high reliability and easy maintenance.

Due to the limited memory of the mobile terminal platform and the relatively weak computing power, the intelligent interactive terminal has certain limitations in the ability to process massive spatial data. Therefore, this paper makes full use of the wireless network function of the intelligent interactive terminal, interacts with the high-performance server side in real time and utilizes its huge computing power, which can fully combine the advantages of the PC end and the mobile terminal, thereby realizing the function expansion of ArcGIS Mobile. By combining graphics and attribute data, practical problems such as information query, information management, and resource allocation related to spatial information are solved in a visual environment. The platform adopts B/S architecture, which consists of server and mobile client. The system architecture function is shown in Figure 3.

3.1. Server-side key technologies

The server system is a spatial database management module of the GIS system. It is mainly responsible for receiving requests from mobile clients and sending data to clients. The server can interact with the GIS database to manage space and attribute data, and use wireless APs and public network access points to pass WIFI wireless. Wireless networks such as networks or 3G and interactive interrupts perform data transmission interactions. The server system is built by the ArcGIS Web Application Developer Framework (ADF) in the Java Script environment and supports a large number of concurrent access and load balancing capabilities. Specific steps are as follows:

(1) Convert the required map data into the data in the geodatabase (such as shape) through ArcCatalog, and then save and render it into mxd file;

(2) Add the current user to the ArcGIS Server group;

(3) Use ArcCatalog or ArcGIS Manager to publish the MapService produced in the first step;

(4) Create a web application using ADF.

3.2. Mobile client key technology

Through the application of ArcGIS Mobile module to realize the functional requirements of mobile client LBS positioning, mobile navigation, path planning, on this basis, some advanced functions, such
as effect evaluation, spatial analysis, etc., will be expanded. These problems are also needed in subsequent research. The perfect part.

Fig. 3 GIS implementation architecture

3.2.1. Mobile database. Due to its own hardware limitations, mobile clients are not likely to have storage compared to desktop devices, but over-reliance on wireless networks limits the speed at which data is loaded. Therefore, it is possible to save some geometric map data and attribute data that are frequently accessed and have a small amount of data on the mobile terminal. The next time you need to access the data, you do not have to download it from the server side, but directly call the data in the cache, which can greatly speed up. The speed of data display and loading, and even interrupting the network connection will not affect the operation of the client.

MapCache is introduced in ArcGIS Mobile, and the data on the mobile side is the map cache file. Each layer is stored in a Bin file, including geometry data and attribute data. When we connect to the server, it will automatically download the cache file to the local. The changes made to the map are actually the local MapCache file.

3.2.2. Data loading and display technology. The intelligent interactive terminal provides two methods for loading data, one is that the client connection server downloads the map data from the server to the client to save the map cache and then displays it, and the other is that the map cache data can be pre-generated before the application is deployed. The app is released together.

3.2.3. Layer editing and management techniques. The layer is the basic unit of GIS data organization and management. Layering spatial data is an important part of GIS for data management. The layer editing function allows us to create a new layer for a thematic map or perform data maintenance on an existing layer, such as data collection, data update, adding annotations, adding text information around the features, vectorization, etc. The network is uploaded to the server.

3.2.4. GPS positioning technology. The intelligent interactive terminal provides three GPS-related controls, GPS Serial Port Connection, GPs File Connection and GPS Display based on the ArcGIS Mobile platform. GPS Serial Port Connection is a class for reading GPS information. When the system is connected to the GPS through the COM port, using the open method of the GPS Serial Port Connection, you can start receiving GPS information and parsing the NMEA GPS statement to obtain the current time and coordinate information. Use the Close method to stop receiving data. GPS File
Connection is a class that simulates GPS format data. It can read pre-stored binary files in NMEA format to simulate GPS location information. The GPS Display class method can display the NMEA data obtained through parsing on the Map control.

4. Conclusion
With its good environmental protection effect and flexible and diverse energy utilization, electric vehicles have become one of the most important development directions of the automotive industry. The dynamic charging path planning method proposed in this paper can effectively reduce the adverse effects of large-scale intelligent electric vehicle rapid charging on road traffic network and medium voltage distribution network compared with the most recent charging path planning strategy; it can be more rationally distributed. The number of smart electric vehicles that go to the charging station to charge at different time points, reduce the road congestion rate and road saturation near the individual charging stations, improve local traffic congestion; effectively control the charging load of each charging station in each time period, optimize the load of each charging station Time and space distribution.

References
[1] Chu W, Li S, Jiang Q, et al. Speed Estimation for All-Wheel Drive Vehicles Based on Multi-information Fusion. Automotive Engineering, Vol. 11 (2011) No. 33, p.962-966.
[2] ZHANG Wen-liang, WU Bin,LI Wu-feng, LAI Xiao-kang. Discussion on Development Trend of Battery Electric Vehicles in China and Its Energy Supply Mode. Power System Technology, Vol. 3 (2009) No. 33, p.1-5.
[3] Chu W, Luo Y, Han Y, et al. Rule-Based Traction System Failure Control of Distributed Electric Drive Vehicle. Journal of Mechanical Engineering, Vol. 10 (2012) No. 48, p.90-95.
[4] Zhu Fuling. Research on Urban Road Traffic Congestion Evaluation Index System. Southeast University, 2006, p.6.
[5] Shen Yannan. Urban road traffic evaluation method and evaluation system development. Beijing Jiaotong University, 2008, p.5.
[6] CHEN Lei, HUANG Qi, ZHANG Chang-hua, TIAN Jia-shen. Study on control strategy of EV charging system considering fault influence. Power System Protection and Control, Vol. 7 (2012) No. 40, p.117-122.
[7] Sortomme E., EI-Sharkawi M. A., Optimal Charging Strategies for Unidirectional Vehicle-to-Grid. Smart Grid, IEEE Transactions on, Vol. 1 (2011) No. 2, p.131-138.
[8] Yuichi Kobayashi, Noboru Kiyama, Hirokazu Aoshima, et al. A Route Search Method for Electric Vehicles in Consideration of Range and Locations of Charging Stations. Baden-Baden: 2011 IEEE Intelligent Vehicles Symposium: IV, 2011, p.6.
[9] XIE Tianhui, LI Wufeng, BAI Desheng, CUI Yu, LUO Xiaoying. China Academic Journal Electronic Publishing House. The Application of GIS in Electric Vehicle Charging/Battery Swap Infrastructure and Operation, 2012.
[10] Sweda T M, Klabjan D. Finding Minimum-cost Paths for Electric Vehicles. IEEE. 2012 IEEE International Electric Vehicle Conference, 2012, p.1-4.
[11] Gao Haili, Jia Kebin, He Wei. Research and application of algorithm for path matching and track playback. Computer Applications and Software, Vol. 4 (2010) No. 27, p.26-28.
[12] Yang S.N., Cheng W.S., Hsu Y.C., et al. Charge Scheduling of Electric Vehicles in Highways. Mathematical and Computer Modelling, 2011. doi: 10.1016/j.mcm.2011.11.054.