Research on Application of 5G eMTC+HPLC in Intelligent Orderly Charging

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Abstract. In this paper, aiming at conventional charging of electric vehicles, it is impossible to form intelligent and efficient energy management, and it is impossible to participate in peak and valley regulation of power grid, so a new intelligent orderly charging network is studied and constructed. HPLC has been widely used as a mature technology for the collection of household electricity information. It has the characteristics of simple wiring and high communication reliability. 5G eMTC technology, with low power consumption, appropriate rate, deeper coverage, lower cost and high security slicing communication technology, that can provide services for ubiquitous electric Internet of things, such as orderly charging. According to the advantages of 5G eMTC and HPLC technology, this paper proposes the strategy of 5G eMTC + HPLC to build a new intelligent orderly communication network, and proposes a solution when the orderly charging network coexists with the existing HPLC information acquisition and communication system. Next, this paper studies the main functional modules of 5G eMTC + HPLC orderly charging system and the orderly charging business process.

1. Introduction
With the increasing number of electric vehicle users, the demand for electric vehicle charging is increasing day by day. It is estimated that by 2030, the number of electric vehicles in China will exceed 80 million, and the number of charging piles will reach 30 million. At the same time, the peak pressure of the whole network is constantly emerging, and flexible load regulation is imminent. However, the current charging process of electric vehicles is still in the conventional charging stage, and there is no intelligent and effective management of the charging process, so it cannot participate in the peak and valley regulation of the power grid. In view of this situation, it has become an important subject to study and build intelligent energy service system, implement orderly charging of electric vehicles, and improve the peak and trough elimination capacity of power grid [1-4].

The establishment of safe and reliable pile network communication is an essential link in the implementation of intelligent orderly charging. In this paper, the fifth Generation of Mobile Communications System Enhanced MTC (5G eMTC)+ high-speed Power Line Carrier Communication (HPLC) strategy is adopted to establish an intelligent orderly charging Communication network. An energy controller and an energy router are added in the design to connect to the master station. From the system level, the master station optimizes the allocation algorithm to obtain the guidance curve of electric vehicles charging load suitable for each station. The energy controller generates a reasonable and orderly charging plan and sends it to the energy router according to the charging load guidance curve issued by the master station. The energy router controls the charging pile to start the charging process. 5G eMTC can be used as the communication carrying channel between the energy controller and the master station as well as the energy controller. HPLC
technology can be used as a communication carrier channel between intelligent ordered charging energy controller and energy router. The advantages are as follows: HPLC can reduce the communication network wiring between charging piles, reduce the number of 5G terminals, and reduce operating costs; 5G eMTC network can provide high security network slicing communication with appropriate rate and low latency as well as better wireless communication coverage effect.

2. Introduction of Existing Charging Communication System

The following figure 1 is a schematic diagram of a system commonly used in existing charging piles for networking communication. Charging piles are wired to the routing gateway, which is connected to the master station through the Fourth Generation of Mobile Communications System (4G), and charging users' mobile apps are connected to the master station through 4G. This scheme has the following problems: 1. The total electricity consumption information of the power supply station area is not collected, and the load adjustment cannot be performed well according to the load status of the power supply station area, so as to carry out orderly charging of electric vehicles; 2. Communication cables need to be specially arranged between charging piles to increase wiring cost.

![Figure 1. Existing communication network of Charging piles.](image)

3. Introduction of HPLC Technology

HPLC communication technology uses the most popular power lines with the most extensive coverage for data transmission, and establishes communication network on the equipment of power supply system. It is simple to implement and easy to maintain, which can effectively reduce the operation cost and reduce the construction of new communication network [5-9]. The electricity information acquisition service based on HPLC technology has a working frequency of 0.7mhz ~12MHz, a maximum transmitting power ≤ -45dbm /Hz, a communication rate ≥1Mbps, an average network delay ≤30ms, data encryption, automatic and fast network networking of no more than 15 levels, and a maximum number of nodes up to 1016. The electricity information acquisition system using HPLC technology has realized such functions as high-frequency data acquisition, active power outage reporting, accurate clock management, phase topology identification, automatic platform identification, unified ID identification management, automatic file synchronization, communication performance monitoring and network optimization, with good application results. Orderly charge...
business of low-voltage distribution environment like electricity information acquisition system, are based on low voltage distribution area relationship as the foundation of the business management unit, charging pile of power supply station area electricity information collection, the user charge report to apply for master station and the host or the energy generated by the orderly charge configuration plan issued to charging pile.

4. 5G eMTC Technical Introduction
The large-scale commercial application of 5G wireless communication provides support for the application of 5G in the power industry [10]. 5G eMTC technology is mainly aimed at internet of things services with low speed, low cost, low power consumption, wide and deep coverage, and large connection requirements. It reduces the cost and complexity of equipment, improves communication service coverage distance and signal penetration, and reduces the power consumption on the device side. 5G eMTC subcarrier bandwidth is 1.4mhz, the maximum transmitting power ≤23dBm, the maximum coverage loss 155.7dB, 1 receiving antenna, half duplex communication mode, and the maximum upstream and downstream rate of 1Mbps.

4.1. Appropriate Rate
Charge in the future application of communication between routers energy controller and energy rate are studied: ordered a packet that is commonly used in charging business about 200 bytes, a area according to the second 20 energy router concurrently at the same time, up to four times a business interaction, coupled with the loss of calibration such as bandwidth needed for the data communication, generally orderly charge about 300 kbit/s communication service demand bandwidth. In addition, electricity information acquisition service (including high-frequency acquisition service) requires hundreds of kbit/s in extreme cases. After the actual calculation and analysis of the stations where electricity information collection and orderly charging service are mixed, the data bandwidth required between the energy controller and the master station is no more than 1Mbps at most. On the basis of ensuring coverage and power consumption, 5G eMTC's communication rate can meet the data transmission requirements of energy controllers in orderly charging applications.

4.2. Deeper Coverage
For the orderly charging network, the power distribution room is often set in the basement with thick cement partition wall, and in the closed room with metal fire door, the wireless communication link attenuation is large. Hata model is commonly used to calculate the coverage in mobile communication. The calculation formula of Hata model is as follows:

\[ L(dB) = 69.55+26.16\log f -13.82\log Ht - a(Hr)+(44.9-6.55\log Ht)log d-K \]

where: \( L \): propagation loss (dB); \( f \): Operating frequency (MHz); \( Ht \): Transmitting antenna height (m); \( Hr \): Height of receiving antenna (m); \( a(Hr) \): Receiving antenna height correction factor; \( d \): Propagation distance (Km); \( K \): Correction factor for urban suburbs and open Spaces.

Hata model for dense urban areas is taken as an example to calculate the coverage distance of each channel, and a comparison with LTE is made to conclude that, in the same environment, LTE coverage radius is about 0.6-0.7km, and eMTC coverage distance is about 2Km. The specific parameters are shown in table 1. EMTC greatly increases the coverage distance and has good wall-penetrating capability, which can better guarantee good communication of 5G module in the energy controller installed in the distribution room.

4.3. Safer Data Communication
The existing electricity information acquisition system adopts the public 4G communication technology, which has security risks [11, 12]. 5G eMTC can realize end-to-end connection [13],
provide network isolation, meet the private network requirements of power grid communication, improve network privacy, and guarantee system security [14-16].

Table 1. Hata model references parameters.

|               | LTE   | eMTC  |
|---------------|-------|-------|
| (1) Data rate/ (kbit/s) | 20    | N/A   |
| (2) antenna number   | 1 t2r | 1 t2r |
| (3) Transmitting power /dBm | 23    | 23    |
| (4) Subcarrier bandwidth /kHz | 180   | 180   |
| (5) Number of subcarriers | 2     | 1     |
| (6) Bandwidth /kHz     | 360   | 180   |
| (7) Feeder loss /dB    | 0.5   | 0.5   |
| (8) Antenna gain /dBi  | 15    | 15    |
| (9) Noise power spectral density (Kt)/(dBm/Hz) | -174. | -174. |
| (10) Noise factor /dB  | 3     | 3     |
| (11) Noise power /dB   | 115.4 | 118.4 |
| (12) SNR or C/I/dB     | 4.3   | 16.3  |
| (13) Receiving sensitivity /dBm = (11) + (12) | 119.7 | 134.7 |
| Maximum coupling loss /dB = (3) - (13) | 142.7 | 157.7 |
| (15) Fast fading margin /dB | 0     | 0     |
| (16) Shadow fading margin /dB | 11.6  | 11.6  |
| (17) Interference margin /dB | 2     | 2     |
| (18) Penetration loss /dB | 11    | 11    |
| (19) OTA/dB            | 6     | 6     |
| (20) Total allowance /dB | 33.6  | 30.6  |
| Indoor maximum allowable road loss /dB = (3) - (7) + (8) - (20) | 123.6 | 141.6 |
| Indoor coverage radius /km | 0.68  | 2.22  |

Figure 2 is the schematic diagram of 5G bearing slice network:
1. 5G wireless module: 5G wireless terminal chip is built into the charging communication system and carries network chip identification;
2. 5G base station: Support 5G wireless terminal wireless access, complete slice resource allocation and isolation;
3. 5G core network: responsible for the access control and function selection of slices, and guide different terminal chips to access appropriate network slices.

In addition, compared with traditional Long Term Evolution (LTE) terminals, eMTC terminals have a power consumption reduction of more than 35 times, and the supporting equipment can work for 10 years [17]. In terms of cost, eMTC terminal cost is reduced by 80% relative to LTE terminal equipment [18].

5. 5G eMTC+HPLC Orderly Charging Communication System
According to a study in the previous section, as well as to the existing residential electricity power supply network and orderly charging network fully research, this paper puts forward the HPLC + eMTC orderly charging of the communication network construction scheme, concrete implementation scheme as shown in figure 3.
(1) User APP interacts with the master station through 5G;
(2) User APP interacts with the energy router via Bluetooth;
(3) The energy controller interacts with the energy router through HPLC;
(4) The master station interacts with the energy controller through 5G;
(5) Energy router interacts with charging pile through CAN or RS485.

Due to the high real-time requirement of orderly charging network communication, if HPLC communication technology is also used in the electricity information acquisition system during the mixed construction with the electricity information acquisition network, the working frequency of HPLC should be selected according to the number of charging piles. For the power supply stations
with less than 300 households and less than 30 charging piles, the resident electricity information collection and orderly charging HPLC communication system can be shared. If there are more than 300 homes and charging power supply area, pile number greater than 30 energy need to use two controllers, one for residential electricity information acquisition, a manage charging pile, and points staggered two HPLC the work frequency of the communication system, such as electricity information acquisition HPLC communication network working band of frequencies 2-0. 7 MHz ~ 3 MHz, orderly charging HPLC operating frequency is recommended for frequencies nearer 4 MHz to 5.6 MHz.

5.1. Introduction of Functional Modules of Orderly Charging Station Area

(1) The Main Station
From the system level, the master station obtains the guidance curve of electric vehicles charging load suitable for each station area through the coordinated optimal energy allocation algorithm between the whole system or local stations. When orderly charging starts, the master station can independently generate specific charging plans corresponding to charging requirements. In the process of orderly charging, the master station can also directly send start-stop control commands.

The master station communicates with the energy controller or charging user via 5G network.

(2) Energy controller
Energy controller according to the main guidance issued by the electric vehicle charging load curve of input parameters, and all kinds of load forecasting based load forecasting curve calculation area, combining with the current power supply area of real-time load and the real-time charging, charging piles in the area through local control strategy algorithm, can charge the battery for new application to charge reasonable layout of the plan. Energy in the process of charging, the controller will give full play to its function of local autonomy, charging pile to Taiwan area for local real-time scheduling, on the premise of compliance with the requirement of safe operation with variable, according to the principle of optimum economy to properly adjust charging executing plan update, charging plan will give energy synchronous control system at the same time, the implementation of charging pile orderly charge local scheduling management of resource allocation.

The energy controller communicates with all charging piles via THE HPLC network.

The energy controller collects the electricity information of the three-phase master meter of the power supply station area through RS485 serial port.

(3) Charging pile
The charging pile can receive the charging plan issued by the master station or the energy controller through different information channels, and send control instructions such as starting charging, stopping charging or adjusting charging power to the charging pile at specified time points according to the charging plan. When the charging plan issued by the master station or the energy controller cannot be received, the built-in default charging plan can be implemented first, that is, the lowest power is maintained for continuous charging, with a lower priority, which will be replaced when the energy control system or the master station has a new charging plan input after communication is restored.

The charging pile communicates with the energy controller by HPLC. The charging pile communicates with the user’s mobile APP via Bluetooth.

5.2. Sequential Charging Business Process
The business process of orderly charging consists of four parts: Initiate charging application; Charging strategy calculation; Issue and implement charging plans; Report the charging completion.

Figure 4 is a business flow chart for generating a charging strategy for the energy controller.

(1) Initiate charging application
After the user's mobile APP scans the QR code and successfully establishes Bluetooth connection, the APP will issue an orderly charging application to the energy router, which will immediately
forward the charging application to the energy controller, and the energy controller will forward it to the master station.

(2) Charging strategy calculation
Local control of the energy controller generates the charging plan according to the local control strategy.

(3) Issue and implement charging plans
The energy controller sends the charging plan to the energy router, which executes the charging plan.

(4) Report the charging completion
After charging is completed, the energy router forwards the local charging metering information to the master station through the energy controller, and the master station settles accounts uniformly. Finally, the complete order information including charging time, charging amount, cost and other information is pushed to the user.

Figure 4. Business process for generating the charging strategy by energy controller.

6. Conclusion
This paper analyzes the defects of the existing charging network, studies the construction of a new intelligent ordered communication network using the strategy of 5G eMTC + HPLC, and proposes a solution when the ordered charging network coexists with the existing HPLC electricity information acquisition communication system.
Meanwhile, the main functional modules and business processes of orderly charging system of 5G eMTC + HPLC were further analyzed, providing a theoretical basis for subsequent implementation.

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