Research on Wireless Charging System of Electrical vehicles in Scenery Complementary Expressway

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Abstract. With the increasingly prominent global environmental and energy issues, the development of new energy electrical vehicles has become more and more important. In order to solve the problem of poor endurance of electrical vehicles, this paper studies the establishment of a wireless charging system for electrical vehicles based on the principle of wind-solar complementarity in the service area of long-distance driving of electrical vehicles, making full use of the environmental advantages of highway areas, and converting light energy and wind energy into electric energy for the use of electrical vehicles to achieve the purpose of electrical vehicles' endurance.

1. Preface

On September 8, 2017, Vice Minister of the Ministry of Industry and Information Technology Xin Guobin stated: "Many countries around the world have set a timetable for stopping the production and sale of traditional fuel vehicles. At present, the Ministry of Industry and Information Technology of China has also initiated relevant research and will work with relevant departments to formulate China's timetable." [1] Therefore, the transformation from traditional cars to new energy vehicles will become the key to China's breakthrough in the global automotive industry, where electrical vehicles account for a large proportion of new energy vehicles. On December 10, 2018, the National Development and Reform Commission, the National Energy Administration, the Ministry of Industry and Information Technology, and the Finance Department issued a document jointly: “Strive to improve the level of charging technology and the quality of charging facilities, accelerating the process of perfecting the standard charging system and fully optimize the arrangement of charging facilities, prominently enhancing the ability of interconnection and interoperability of the network of charging, upgrading the quality of charging operation services quickly and further optimize the environment of developing charging infrastructure and industrial structure in 3 years ”.[2]

The government’s policy guidance resulted in a rapid increase in the number of electrical vehicles, which will dramatically increase the pressure for the power supply grid [3]; meanwhile, the travel distance of electrical vehicles is limited due to the limited storage capacity of its accumulator, thus the charging system has to be set up within a certain range. The long distance of power supply requires larger investment and cause larger power loss when it is supplied by the municipal power grid when the highway is remote. This paper studies the wind-solar hybrid power generation systems established in
highway service areas to decrease the power loss as much as possible by charging the electrical vehicles wirelessly instead of using the municipal grid power supply.

2. Scenery complementary highway electric car wireless charging system

The wind-solar hybrid highway electrical vehicle wireless charging system is mainly composed of charging management system, power supply system, energy storage part and output circuit. The block diagram is shown in Figure 1. The power supply system is the key to the whole. The power supply system consists of three parts: the wind power generation module, the photovoltaic power generation module and the municipal power supply module. The car is charged by the accumulator. The charging system will collect information from the three modules of the power supply system and select one of the power supply modes to charge the accumulator based on the feedback when the accumulator is detected to be in deficient state by the charging management system. The wind power and photovoltaic module will be set as preferential power mode when the accumulator is in full power and wait to output.

![Block Diagram](image)

**Figure 1.** Scenery Complementary Expressway Eclectic Vehicle Wireless Charging System Diagram

3. Design of wireless charging system for electrical vehicles with wind and solar hybrid highway

3.1. Wind and solar hybrid power generation system.

At present, the wind-solar hybrid power generation technology has matured. Figure 2 is a schematic diagram of a typical wind-solar hybrid power generation system. The power generation system is mainly composed of wind turbines, solar photovoltaic cells, controllers, and batteries. The wind power generation system uses wind turbines to convert wind energy into mechanical energy, converting mechanical energy into electrical energy through a wind power generator, and then charges the accumulator through the controller; photovoltaic power uses the photovoltaic effect of solar panels to convert light energy into electrical energy and then charge the accumulator. Wind-solar hybrid power generation utilizes the complementarity of wind energy and solar energy to obtain a more stable output, and it can be reasonably designed and matched according to regional climate to ensure the availability of automobiles charging. The municipal power grid can be used as an emergency power supply mode under extreme weather conditions. The wind and solar hybrid power generation system is mainly used under normal conditions, which can be basically not powered by the municipal grid.
3.2. Energy storage system.

The accumulator energy storage system mainly uses the redox reaction between the electrodes to realize the conversion and storage of electric energy [7]. Presently, the main types of energy storage batteries that have been widely used in the market are: lead-acid batteries, nickel-cadmium batteries, sodium-sulfur batteries, and lithium-ion batteries [8]. The main parameters are shown in Table 1.

Table 1. Main types and parameters of power batteries

| type of battery            | Specific energy [Wh/kg] | Specific power density [Wh/l] | Specific power [W/kg] | Cycle life [times] | cost  |
|---------------------------|-------------------------|------------------------------|-----------------------|--------------------|-------|
| Lead-acid batteries       | 30-45                   | 30-90                        | 200-300               | 400-600            | 150   |
| Nickel-cadmium batteries  | 40-60                   | 80-110                       | 150-350               | 600-1200           | 300   |
| Sodium-sulfur battery     | 100                     | 150                          | 200                   | 800                | 250-450|
| Lithium Ion Battery       | 90-130                  | 140-200                      | 250-450               | 800-1200           | 200   |

Since the energy storage system is adoptable for a wide range and the operating environment is unstable, it is preferred to consider the type of accumulator that is low in cost and stable in working process, not tending to occur safety accidents. The materials and work requirements of lead-acid batteries are much lower than those of other types of batteries, and relatively highly sealed. Besides, accidents are less likely to happen during the high-current discharge process and its positive and negative electrodes and the electrolyte will not cause a big problem even if there is a leak. Thus the lead-acid accumulator is selected as the energy storage element in the system.

3.3. Charging management system.

According to Max's charging law [9], if the charging current is greater than the acceptable curve during charging, the charging time of the accumulator will not be shortened, but the gassing reaction will be caused by the polarization phenomenon. The energy input will decrease and the charging duration will be overtime. While when the charging current is less than the acceptable curve, it will undoubtedly prolong the charging duration and reduce the charging efficiency as well.

The accumulator accepts a charging current curve expression:

\[
I = I_0 e^{-\alpha t}
\]  

(1)

In the formula,
- \(t\)——Charging time
- \(I\)——The maximum charging current acceptable to the accumulator at time \(t\) during charging;
- \(I_0\)——The maximum charge current that is acceptable when the accumulator begins to charge;
- \(\alpha\)——Attenuation rate
According to the analysis above, it should be ensured that the voltage and current during the charging process are maintained within the acceptable curve range to make the charging process more efficient.

Moreover, since the wind-solar charging system uses accumulator as an energy storage component and the accumulator capacity is limited, it is impossible to reserve electric energy indefinitely. In summary, the accumulator charging process needs to be managed, dividing the charging management system into two parts: charging monitoring and charging control.

3.3.1. Charging monitoring. The system monitors three aspects of the charging process: the residual energy in the accumulator, the three-way charging mode power quality, and the charging current and voltage.

Through monitoring the stored energy of the accumulator during the charging process by chip CN3768, the accumulator is assured to maintain enough electric energy all the time. The PCF8591 chip is used to collect the voltage information of the three-way power supply, and the charging quality is monitored to ensure that the system can select a more reasonable charging mode.

By monitoring the voltage and current during charging, a more efficient charging process is ensured.

3.3.2. Charging Control. The system adopts a single-chip microcomputer to control the charging circuit of the three-way charging source.

The accumulator voltage is first collected by chip CN3768 to determine whether the accumulator needs to be charged while working. If not, the process is looped until the accumulator is detected insufficient while if so, the chip PCF8591 will collect the voltage information of the fan charging and the solar panel charging module and send it back to the single-chip microcomputer, turning on the relay of the charging module terminal with higher voltage, thereby completing the charging operation. If it came across rare harsh environmental situations, neither the fan charging module nor the solar panel charging module is able to work. Hence, the relay of the municipal power grid will be connected in order to ensure the reliability of the power supply, charging the accumulator through the grid and last till the accumulator is fully charged.

3.4. Output circuit.

Currently, there are two main types of charging methods for electrical vehicles: wired charging and wireless charging. For wired charging, frequent plugging and unplugging will cause the socket to wear, to age and generate electric sparks; Damage to the line will bring safety hazards like electric leakage and the adaptability to storm frost weather is also poor. The wireless charging method embeds the transmitting coil into the ground, not occupying the ground space and has no external leakage interface. The advantages of it is safer, convenient and flexible operation, lower cost and excellent user experience [10]. Considering the using environment of the system, the wireless charging mode should be chose. The system selects the magnetic coupling resonant wireless transmission as the charging method, which is widely used in the field of wireless charging of electrical vehicles. Besides, the transmission distance is further improved by adding a tuning network at the transmitting end and the receiving end [11]. As shown in picture 2, the magnetically coupled resonant wireless power transmission technology enables the system to maintain higher efficiency and greater power even when transmitting at a medium distance (the transmission distance is several times larger than the diameter of the transmission coil), and the power transmission is not subject to spatial non-magnetic obstacles. The impact is more applicable to the technical requirements of electric vehicle air gap (15 ~ 45cm), high efficiency (> 85%) and high power (kW level) [12].
4. Advantages, Disadvantages and Application Prospects of Wireless Charging System for Electrical vehicles in Scenery Complementary Expressway

4.1. Advantages
The wind-solar hybrid power generation system can save most of the electric energy, and also avoid the large loss caused by the long-distance transmission line when it is powered by the municipal power grid, reducing the power supply pressure of the municipal power grid. The three-way power supply mode ensures the reliability of the power supply of the system.

The charging management system can manage the charging switch and charging mode by monitoring the residual energy in the accumulator, the three-way power quality, the charging current and voltage, so that the energy storage efficiency of the system is maximized and the system can always be able to output.

The lead-acid accumulator is selected as the energy storage device. It is the safest and most stable one among the many accumulator types used in the market today. Plus, its economic cost is relatively low and working life is longer.

The power output mode selects the magnetic coupling resonant wireless transmission mode. Compared with the traditional wired charging, the wireless charging mode can adapt to the working environment with relatively uncertain weather. Because it is laid underground, not occupying the ground position, the space utilization of the charging area is improved. Now the technology is relatively mature and no security risks since it has not many lines.

4.2. Disadvantages
In terms of the power generation system, due to different climatic conditions in different regions, its efficiency will be different. Meanwhile, the unpredictable traffic flow will cause the charging load to be unevenly distributed in time and space. Therefore, the scale of the power generation system and the geographical distribution of the system should be carried out from simulation calculation according to the climate environment of different regions, and it is not suitable to set up the system in specific regional environments;

In terms of power output, since the system adopts wireless output mode, its anti-offset capability, material and shape of the output coil, and reasonable assembly of the on-board coil have a huge impact on the charging efficiency. Thus the efficiency of the wireless charging part and the convenience of improvement has yet to be studied.

4.3. Application prospects
With the continuous popularization of electrical vehicles, the power supply pressure to the municipal power grid will continue to increase, with huge energy loss, and the main energy sources of the system are wind energy and solar energy. It is estimated that the total annual solar radiation to the country can reach 335kJ–837kJ/ (cm2-year). The areas having above 2200 hours of annual sunshine duration accounts for at least two-thirds of the national territory. The wind energy 10 meters above land is estimated to be around 35.26kW, and it is more abundant above the sea, which is around 750 million kW [13]. Therefore, the popularity of the system will greatly reduce the power supply pressure of the municipal grid, also reducing the loss of electrical energy.

5. Conclusion
With the gradual shortage of fossil energy, traditional cars are gradually being replaced by new energy vehicles, and the use of electrical vehicles is increasing. The wind-light complementary highway wireless charging system can make up for the disadvantage of short operating range of electrical vehicles and response to the government call for energy saving and emission reduction actively, improving the charging system and fasten the application and popularization of high-quality convenient charging facilities. The research results of this paper can provide powerful technical guidance for wireless charging devices for electrical vehicles.
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