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Distributed Photovoltaic and Electric Vehicles Charge in Highway Environment

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Abstract. Under the general trend of global carbon neutrality, the new energy industry will be pushed to a peak. Among many new energy sources (solar energy, wind energy, water energy, biomass energy, etc.), solar energy has the advantages of wide distribution, small regional restrictions, high conversion efficiency and complete industrial chain. At present, the main carrier of China's new energy industry application is electric vehicles, how to use solar energy to provide energy for electric vehicles, especially to achieve long-distance energy supply is an important problem to be solved. For the highway environment, this paper proposes a power station design that independent of the power grid system and integrates photovoltaic power generation, storage and charging. Distributed photovoltaic panels are deployed in the expressway network to realize solar power supply and meet the charging demand of electric vehicles for long-distance driving. It will help to solve the "anxiety" problem of long-distance driving of electric vehicles, and support the implementation of China's "carbon neutral" strategy.

Keywords: integration of photovoltaic power generation, storage and charging; electric vehicle; expressway; carbon neutrality

1. Introduction

The world's energy structure is undergoing a change from fossil energy to renewable new energy, energy crisis and environmental pollution are pushing the new energy industry to a peak, but also put forward new challenges to the whole new energy industry. In 2020, the world's major countries have announced carbon neutrality goals, the International Energy Agency has formulated a zero carbon implementation path milestone [1], China clearly put forward the goal of "2030 carbon peak,2060 carbon neutrality". The medium - and long-term carbon neutrality goal will have an important and far-reaching impact on the energy and environmental policies of countries around the world.

Under the combined action of multiple factors such as policy, capital and market, a new energy industry pattern consisting of three plates on the supply side, storage side and application side has basically taken shape. Among many new energy sources (solar energy, wind energy, hydro energy, biomass energy, etc.), solar energy has the advantages of wide distribution, small geographical restrictions, high conversion efficiency, and complete industrial chain. At present, the mainstream application trend of China's new energy is electric vehicles, but due to the high cost of photovoltaic power supply into the grid, the additional impact on the grid, the location of large photovoltaic base stations and other factors, the problem of collaborative development between plates has become increasingly prominent, resulting in the current electric vehicle power source is still heavily dependent on traditional power plants, "new" energy in name only, The implementation of China's "carbon neutral" strategy has a long way. At the same time, due to the limited battery capacity, electric vehicles need to be charged several times during long-distance travel. At present, the construction of charging stations in the service areas of expressways is slow, and the number of charging piles is limited, resulting in the phenomenon that vehicles often queue for charging for a long time when they arrive at the service areas. Therefore, how to efficiently use solar energy to

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provide energy for electric vehicles while solving the "anxiety" problem of long-distance travel is an important direction of current research.

2. Advantages of Photovoltaic Power Generation

In terms of new energy supply, in the context of global carbon neutrality, electricity will become the most important form of terminal energy consumption by 2050, accounting for 51%[2]. In addition to the most traditional hydropower, the most rapid development is photovoltaic and wind power, photovoltaic and wind power will contribute to more than 63% of renewable energy generation. Among them, with the continuous technological progress and scale expansion of China's polysilicon industry, since 2004, the cost of photovoltaic power generation system has fallen off the cliff (module and system prices and photovoltaic electricity prices have fallen by 92%, 87.5% and more than 82%, respectively), and the carbon emissions of the whole industry chain are extremely low (carbon dioxide generated per KWH of electricity is only about 43g, far lower than thermal power 1000g), the cost and environmental advantages make photovoltaic power generation is expected to become the largest source of electricity in the future. And due to the continuous progress of technology, PV bid price continues to decline, investment costs and power generation costs decline year by year. On November 18,2023, the General Office of the Tibet Autonomous Region People's Government issued the "On further optimization and adjustment of the region's on-grid electricity price and sales electricity price Guide to reduce social electricity costs", the centralized photovoltaic power station on-grid electricity price reduced to 0.1 yuan per degree [3]

Another very important advantage is that photovoltaic power generation is obtained by direct current, which can be directly supplied to electric vehicles, thus greatly reducing the cost of electric vehicles. However, currently limited by the geographical location of photovoltaic power generation, the need for inverter AC boost into the grid, can be transmitted to the user end, to the user end and then buck rectifier for direct current, after two transformations, not only serious energy loss, but also greatly increased the investment, the cost of electricity increase up to 55%, the application of new energy is very unfavorable.

3. Distributed Photovoltaic Laying Scheme

The silicon-based cells commonly used in photovoltaic power generation have a maximum actual conversion efficiency of about 24% [4], and require a large enough installation area to ensure a sufficient amount of electricity supply, so photovoltaic land becomes a tricky problem. In order to avoid high inverter loss and transmission costs, it is ideal for photovoltaic power stations to be built near the power terminal to supply power directly, and the dense area of power terminals is often the area of land shortage. In response to this dilemma, different distributed photovoltaic power station program is proposed, the overall idea is to jump out of the traditional photovoltaic power station layout thinking, in the existing facilities to increase photovoltaic modules, in order to make full use of three-dimensional space, such as fish pond photovoltaic, vegetable greenhouse photovoltaic, farmland photovoltaic, building photovoltaic, etc..However, the limitations are also very obvious, distributed program provides a very limited amount of installation Considering the dependence on the facility itself needs a certain degree of lighting, photovoltaic modules can not be installed in accordance with the maximum density, so it can not ensure that a large number of electric vehicles to achieve effective power supply centralized. This scheme intends to use the highway non-functional area distributed photovoltaic laying scheme. The guardrail and green belt along the highway are mainly used to install the distributed photovoltaic modules.The advantage of the scheme is that it can effectively use the highway long distance and non-functional area space advantages and laying enough photovoltaic panels on the existing space. At the same time, a certain distance of the highway emergency lane is designated as a temporary charging area for vehicles, which can greatly improve the utilization of the emergency lane while reducing investment.

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According to the provisions of Technical Standard of Highway Engineering (JTG B01-2014) and General Code for Design of Highway Traffic Engineering and Facilities Along the Highway in China , the average interval of service area is recommended to be 50km. The suitable position can be found in the middle section of the two service areas, and the fixed installation method with the best Angle is adopted. Laying 5km of photovoltaic panels, the width of green belt on both sides is about 3 meters, and the total installation area can reach 30,000 square meters.

4. Power Generation Calculation

Photovoltaic power generation calculation using the national standard formula calculation method, this calculation method is the national standard algorithm, is the most comprehensive and accurate algorithm for power generation calculation. According to the "photovoltaic power station design code" GB50797-2012 article 6.6.2 formula for calculation.

$$Ep=H_A \times P_{AZ}/Es \times K \tag{1}$$

In Formula (1):

Ep -- Power generation (kWh)

H_A - Total solar irradiation (kWh/m²)

Es - Irradiance (constant) under standard conditions, with a value of 1kW/ m²

P_{AZ} - Installed capacity (kWp)

K -- Comprehensive efficiency coefficient, affected by the photovoltaic array inclination, power generation system availability, light utilization, collector line loss coefficient, photovoltaic module surface contamination coefficient, correction coefficient and other parameters.

HA: According to the distribution of total irradiation on the optimal tilt plane of fixed power generation in all provinces (autonomous regions and municipalities) in China in 2021 released by the Wind Energy and Solar Energy Center of China Meteorological Administration, the average value of total annual irradiation of Beijing, Hebei, Tianjin and Shanxi in North China is about 1664.73 kWh/m² , and the optimal installation inclination is about 33° ;

PAZ： 5762.5kWp (PV module: 1676mm × 994mm, peak power 320Wp, number of modules 18000, installed capacity 5762.5kWp, component area 30000 ㎡);

K: For the grasp of the comprehensive efficiency factor, it is necessary to calculate the cable line loss, inverter loss, transformer loss, component loss (temperature, occlusion, MPPT tracking loss rate, etc.), etc. For non-senior photovoltaic practitioners, it is difficult to calculate accurately. Usually, the value of K is between 75%-85%, for general projects, in the preliminary design stage, it can be taken as 80%;

Calculate the result according to the above formula (1):

$$Ep=H_A \times P_{AZ}/Es \times K=1664.73 \times 5762.5/1 \times 80\%=7674.4 \text{ MWh}$$

The annual power generation is about 7,674.4MWh, which can reduce CO2 emissions by about 76,000 tons.

5. Power Supply Calculation

In terms of energy storage, power batteries can be used in echelons. Decommissioned power batteries recycled and modified are used as energy storage batteries. Since power batteries are designed to provide high power density to support vehicle acceleration and long driving time. This type of battery needs to be charged and discharged quickly, while at the same time having a long service life. A battery with a health value of less than 80% is no longer suitable for continued use in electric vehicles. The design of energy storage batteries is more focused on energy density, cycle life and cost effectiveness, and does not require rapid charge and discharge functions. Moreover, the basic structure of the two batteries is relatively consistent, and only need to reconfigure the battery management system. Energy storage systems require more sophisticated battery monitoring and management to ensure safe and efficient operation. This includes monitoring the battery's voltage,

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current, temperature and other parameters, and managing the battery's charging and discharging process. Therefore, the recycling of power batteries can effectively reduce the construction cost and play a certain role in environmental protection. In this scheme, the energy storage capacity of not less than 5 daily average power generation can be considered, and the construction scale of about 50MW/100MWh energy storage power station can be built. Power supply capacity calculation: the endurance capacity of electric vehicles on the market is usually about 400 km [5], and the capacity of its battery battery is generally 50kWh. Considering the secondary loss of 10% in the charge and discharge process, the daily power generation of a single station in this design scheme can provide the charging demand for 370 electric vehicles.

6. Summary

At present, new energy vehicles have become a strategic industry and new economic growth point in China, and the sound of new energy vehicle charging facilities will rapidly promote the further development of new energy vehicles. This paper studies and designs the use of distributed photovoltaic charging mode for electric vehicles in the highway environment, which can realize the efficient use of solar energy on the premise of no power expansion and transformation in the service area of the highway, solve the problem of large-scale electric vehicles driving long way charging difficult, and help China to achieve "carbon neutrality".

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