Research on the Application and Development of Photovoltaic in the Road Domain Based on Patentometrics

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Abstract: This paper used patentometrics method to analyze the development of the application technology of photovoltaic in the road domain. Based on photovoltaic patent data in the road domain from PatSnap Global Patent Database from 2012 to 2021, the technical development trend, patent layout, technology hotspot and core patents first studied. Then, according to the distribution map of patent technology hotspots, the key technologies and application scenarios of photovoltaic application in the road domain, such as photovoltaic road slope, photovoltaic noise barrier, photovoltaic pavement, photovoltaic road canopy, photovoltaic parking canopy, PV powered charging station, were analyzed. Finally, combined with the application results of photovoltaic in the road domain in China, the main problems were analyzed, and the policy suggestions to promote the development of photovoltaic technology in the road domain in China were put forward from the aspects of improving top-level design, strengthening key technology research and patent layout, establishing and improving the standard specification system, demonstrating and promoting according to local conditions, and improving the market mechanism.

Keywords- photovoltaic; patentometrics; photovoltaic road slope; photovoltaic pavement; photovoltaic road canopy; PV powered charging station; photovoltaic parking canopy; Photovoltaic noise barrier

1. Introduction

Under the strategic background of "carbon peaking and carbon neutralization", it is of great significance to promote the integrated development of energy and transportation. As one of the important components of renewable energy, photovoltaic has the advantages of huge energy sources, green and environmental protection, pollution-free, safe and sustainable, flexible installation, short construction cycle, long service life, low operation and maintenance costs, diverse application forms, and wide application scope. In recent years, it has gradually become the mainstream direction of global energy transformation.

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Photovoltaic is an important strategic emerging industry in China. The industrialized mass production technology of key components such as photovoltaic cells and modules has reached the world's leading level, and the production equipment technology has basically achieved localization. China has mastered the core technologies of the whole industry chain from polysilicon purification technology, single crystal/polycrystalline growth technology to high-efficiency battery and module preparation technology, and photovoltaic products have cost and quality advantages. In 2021, the newly added PV grid connected installed capacity will be 54.88GW, and the cumulative PV grid connected installed capacity will reach 306GW, ranking first in the world. When the annual photovoltaic was 325.9 billion kW, the year-on-year growth was 25.1%[1]. China has developed into a photovoltaic producer with the most complete global industrial chain and the largest capacity and output.

Promoting the application of photovoltaic is of great strategic significance for optimizing the energy structure and improving the ecological environment. Since the 1980s, European and American have carried out the application exploration of photovoltaic in the road domain. Switzerland built the world's first photovoltaic noise barrier in 1989[2]. In 1996, the United States built a 2.1 kilowatt PV powered vehicle charging station in Santa Monica, California[3]. In 2006, the United States proposed the idea of photovoltaic pavement, and completed the first photovoltaic road slope demonstration project in 2008. France built the world's first solar road "Wattway" in 2016[4]. Germany and other European countries have taken the parking lot as an important infrastructure to support the installation of solar PV, and extended the incentive measures to promote its development since 2011[5].

By 2021, China's road mileage will reach 5.2807 million kilometers[6], occupying vast land resources, and providing a platform for the development and utilization of solar resources while undertaking transportation functions. In recent years, China has gradually carried out the research and practice of photovoltaic application technology to promote the transformation of road infrastructure from a simple energy consumption end to a coexistence mode of energy consumption end and energy supply end. Hu HW et al.[5] defined the concept of road energy collection technology based on photovoltaic, defined the scope and scenario of its application in roadside, pavement, space above the pavement, and summarized the latest research and application achievements in this domain. Jiang HF et al.[7] proposed an innovative application technology model for the integration of road infrastructure and solar clean energy. Yang PH et al.[8] discussed the development advantages of solar energy on highway slope and put forward development suggestions. Qiao F et al.[9] proposed to take improvement measures in sound absorption performance, power generation photovoltaic modules and other aspects for the application of photovoltaic noise barrier. Wei YL et al.[10] introduced the principle of PV powered charging station combined with expressway gas station and service area, and evaluated the economic benefits of PV powered charging station.

This paper adopts patentometrics method, based on the analysis of photovoltaic patent data in the road domain from 2012 to 2021, to reveal the technology layout, R&D subjects, R&D hotspots, and R&D trends in this domain. In combination with China's photovoltaic application results in this domain, it analyzes the current main problems and puts forward development suggestions.

2. Research Methods and Data Sources

This paper uses the PatSnap database, which integrates more than 170 million patent data from 126 countries/regions around the world since 1790. It not only provides patent information retrieval, but also supports patent reference retrieval and 3D patent map production. In this paper, IPC classification and keyword combination search are adopted. Based on the search and preliminary analysis of the photovoltaic patents in the road domain, the recent 10 years are determined to be the active period of technology research and development, and then a total of 2097 patent applications from 2012 to 2021 are extracted for the analysis. This research mainly adopts patentometrics methods such as technology development trend analysis, patent layout analysis, technology hotspot analysis, core patent identification, etc.

2.1 Analysis method of technology development trend

The statistics method is used to count the number of patent applications in each year, the number of patent applications for various technical topics or R&D directions in each year, and the number of patent applications in various countries/regions in the world in each year, so as to judge the overall development trend of technologies in this domain.

2.2 Patent layout analysis method

2.2.1 Distribution of patent types

Count the number and proportion of patents for invention, utility model, appearance design, etc., to provide reference for macro judgment of innovation capacity in this domain.

2.2.2 Geographical distribution

Count the number of patent applications and authorizations, the number of patentees and their proportion in the country (region) or provinces of China, to reveal the regional distribution of technology and patentees in this domain.

2.2.3 R&D direction distribution

According to the IPC classification, the number of patents in each R&D direction and the number of patents in each R&D direction in each year are counted to reveal the key technologies and their development trend in this domain.

2.3 Analysis method of technical hotspots

For each patent, feature words that can represent the core content of the patent are extracted. The feature words are obtained by analyzing the text content of the patent title and abstract. Use word segmentation technology to obtain the words with practical significance in the patent title and abstract, and use TF-IDF algorithm to weight each word. TF-IDF is the most classical weighting technology in the field of text information analysis and information retrieval[11], and its mathematical model is:

$$W = \mathrm{TF} \times \mathrm{IDF} = \frac{i}{m} \times \log \frac{N}{n}$$

In the above formula, W is the weight of vocabulary, TF(Term Frequency) is word frequency, IDF(Inverse Document Frequency) is the reverse file frequency, i is the number of occurrences of words in the patent, m is the total number of words in the patent, N is the total number of patents retrieved, n is the total number of patents containing the word.

Use patent map making tools, select words with high W value as feature words, and present them in the form of contour lines to form a distribution map of patent technology hotspots. The distance between patents with similar contents in the map is also similar, thus forming peaks. Different peaks represent patent clusters in a certain technical field. The patent technology hotspot distribution map uses different colours to represent the patent density.

2.4 Core patent identification method

The patent citation analysis method is used to count the number of patents cited. At the same time, count the number of patent documents with basically the same content that the patentee has applied for or approved in different patent organizations for many times, and the number of patent rights that request protection. The statistical analysis of the above three indicators provides a reference for identifying core patents in this domain.

3.Test Results and Discussions

3.1 Technical development trend of photovoltaic application in road field

3.1.1 Photovoltaic technology in the road domain has strong application and relatively weak innovation

Fig.1 shows the overall situation of photovoltaic patents from 2012 to 2021 in the road domain. The total number of patent applications is 2097, showing a declining trend after continuous growth. The number of patent applications reached a small peak in 2018. In recent 10 years, the average proportion of patent authorization in this domain is 62.57%. Among the above 2097 patents, the number of utility model patents was the largest, 1187, accounting for 63.27% of all patent applications. It can be seen that the current photovoltaic technology in this domain has strong applicability and relatively weak creativity, and the innovation in product shape, composition or combination is more than method invention or method improvement.

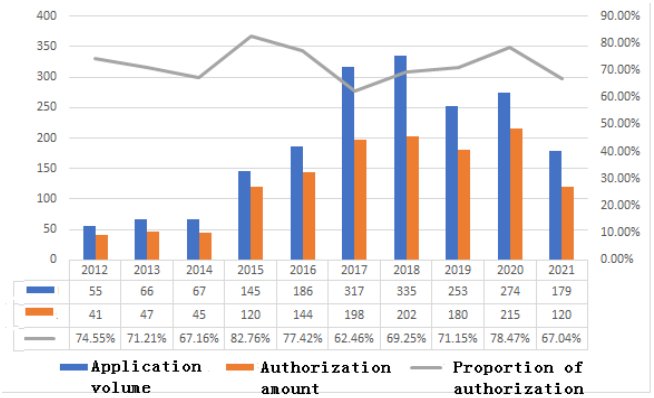

Fig. 1. Trends of photovoltaic patents in the road domain from 2012 to 2021

3.1.2 China is the largest source and application country of patent technology for photovoltaic in the road domain

Fig.2 shows the annual patent application trend of countries/regions in this domain. The earliest patent application appeared in 1986, and the recent 10 years were the active period of technology research and development, with the number of patent applications accounting for 98.3%. China's patent application in this domain began in 1998. Prior to this, the main patentees included Japan, France, Germany, etc. As mentioned in the introduction, these countries were the first countries to carry out research and practice on the application of solar photovoltaic in the road domain.

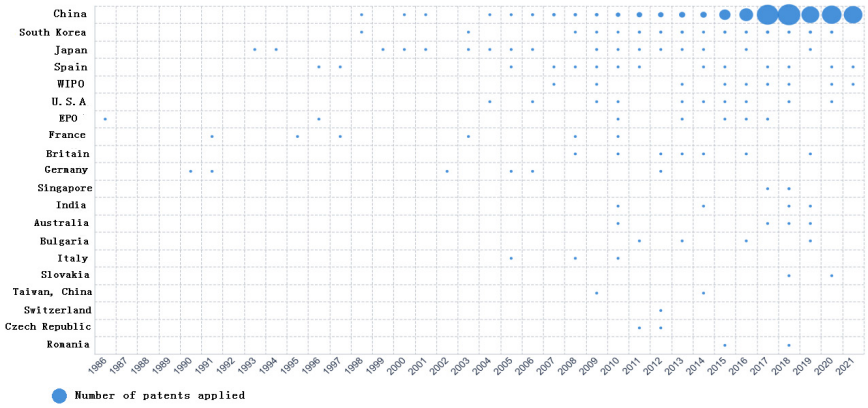

Fig. 2. Annual patent application trend in global countries/regions

In recent 10 years, the number of patent applications in China accounted for more than 88% of the total number of global patents, and the number of patents applied by Chinese inventors was basically the same as the number of patents accepted in China. In addition to China, the main technology source countries (regions) include South Korea, Spain, etc., and the

technology application countries (organizations) include South Korea, the World Intellectual Property Organization, etc.

In China, 25 provinces have carried out the layout of patents in this domain. Jiangsu, Guangdong, Zhejiang, Shandong, Anhui, Beijing, Henan, Sichuan, Shanghai and Hubei are provinces with more patents. Among them, Jiangsu applied for 264 patents. The number of patent applications in Jiangsu, Guangdong, Zhejiang and Shandong accounted for 1/3 of the total number of applications in China. The patentees are relatively dispersed, with a total of 1513 institutions and individuals active in research and development. State Grid Corporation of China, Hongyi Science and Technology Co., Ltd. and Chang'an University have the largest number of patent applications, but they do not have an absolute advantage.

3.1.3 The research and development of photovoltaic technology in the road domain mainly focuses on lighting equipment, battery devices, photovoltaic module structures, etc.

Fig.3 shows the trend of patent in main R&D directions in this domain. The R&D mainly focuses on lighting equipment, battery devices, photovoltaic module structures, road signs/traffic signal devices, road vehicle traffic control systems, etc. Similar to the trend of patent application, the first small peak of each major R&D direction occurred in 2017-2018. Subsequently, the R&D layout of lighting equipment, battery devices, road vehicle traffic control systems and other technologies was gradually concentrated, and the number of patents reached a peak in 2020.

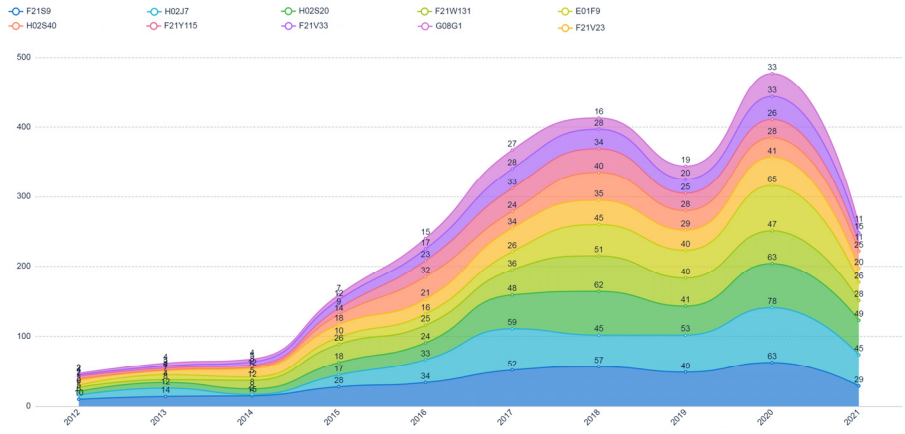

Fig. 3. Patent application trend of main R&D direction

3.1.4 The core patents of photovoltaic in the road domain are more abroad than at home, involving pavement, lighting devices, charging devices, monitoring devices and other fields.

Based on a comprehensive analysis of three indicators, including the number of patents cited, the number of patent documents with basically the same content that the patentee has applied for or approved many times in different patent organizations, and the number of patent rights requested for protection, we can identify core patents in this domain. It is found that important

patents have all appeared after 2015, and foreign patents are more than domestic patents. It can be seen that the patentee has preferred to layout abroad (especially in the United States). In terms of content, the core patents involve pavement, lighting devices, charging devices, monitoring devices, etc., among which there are relatively many patents for photovoltaic pavement and photovoltaic street lamps.

3.2 Application Scenarios and Key Technologies of Solar Photovoltaic in Road Field

Fig.4 shows the distribution map of patent technology hot spots drawn by using the analysis method of technical hotspots described in Section 2.3. The application of solar photovoltaic in the road domain mainly involves the photovoltaic road slope, photovoltaic noise barrier, photovoltaic pavement, photovoltaic road canopy, photovoltaic parking canopy, PV powered charging station, photovoltaic power grid, and photovoltaic road maintenance devices, photovoltaic road signs and markings, photovoltaic road municipal facilities, photovoltaic road monitoring devices, etc.

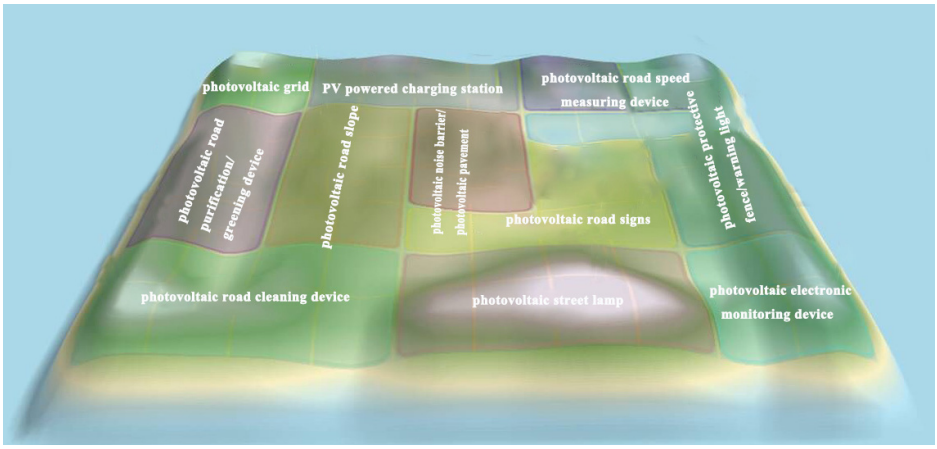

Fig. 4. Distribution map of patent technology hotspots

3.2.1 Photovoltaic road slope

Photovoltaic road slope uses supports to lay photovoltaic modules on the slope along the road, which has the function of slope protection while generating power. The layout of solar panels on the slope is not limited by the current material level, and the power generation efficiency is basically not affected by the traffic conditions. The key problem is to select the site and ensure the safe and stable operation of the system. The key technologies of photovoltaic road slope include: the evaluation method of the best potential installation site selection, the method of selecting the rack system and determining the erection position, the method of evaluating the stability impact of slope and support facilities, and the method of evaluating the traffic safety impact.

During the ten years from 2012 to 2021, the patent applications related to photovoltaic road slope mainly focus on the following three technical directions: Photovoltaic slope protection devices, that is, photovoltaic panels, inverters, batteries and other components are set up relying on slope landslide prevention devices; Photovoltaic slope stability monitoring device, that is, rely on the slope deformation monitor to install photovoltaic panels, storage boxes, etc;

Photovoltaic slope protection devices and methods under specific scenarios such as desert roads and expressway sections. From the perspective of patent layout, most of them are utility model patents that rely on slope protection, monitoring, sand control and other facilities to install photovoltaic modules, and almost no invention patents involving key technologies.

Following the practice of building photovoltaic plants on both sides of roads and railways in the United States, Japan, Germany and other countries, China issued "Guiding Opinions of the Ministry of Transport on Promoting the Construction of New Infrastructure in the Field of Transportation" in 2020, encouraging the rational layout of photovoltaic installations along roads such as service areas and slopes, and grid connected power supply with municipal electricity. However, at present, the development and utilization of solar resources on highway slopes are not much in China.

The layout of solar panels on the road slope will not lead to the change of land use. The technical requirements for installation are relatively low, the construction and maintenance are relatively simple, and the highway slope area in China is considerable. The development and utilization of solar resources based on the road slope contains huge potential. To strengthen the R&D and application of key technologies for photovoltaic road slope, the key is to form solutions or technical products in terms of improving power generation efficiency, ensuring the stability and safety of slopes after the installation of photovoltaic devices, and ensuring traffic safety.

3.2.2 Photovoltaic noise barrier

Photovoltaic noise barrier is a combination of noise barrier and photovoltaic system to reduce traffic noise and generate electric energy at the same time. The photovoltaic noise barrier is set in the road environment, and its performance in terms of actual noise reduction and power generation needs to be comprehensively considered. The key technologies include: the top and shape structure design, the noise absorption structure design, and the technology of double-sided power generation photovoltaic modules.

During the decade from 2012 to 2021, the patents related to photovoltaic noise barrier mainly focus on the technical direction of adding photovoltaic devices based on sound insulation screens, photovoltaic panel tilt angle adjustment and double-sided photovoltaic module device application, noise barrier structures that are conducive to heat dissipation, noise barrier structures that are easy to install and replace, damage proof noise barrier structures, sound feedback hysteresis suppression devices, and devices that prevent driver visual fatigue. From the perspective of patents, there is a patent layout in key technology fields, which has a certain technical foundation.

More than 10 countries, including Switzerland, Germany, France and the United Kingdom, have installed photovoltaic noise barriers[2]. Photovoltaic noise barriers have been installed in Suzhou and Shanghai[9] in China.

3.2.3 Photovoltaic pavement

Photovoltaic pavement is a new multi-functional pavement that applies photovoltaic layer to asphalt or cement concrete pavement surface, with dual functions of carrying traffic and clean power generation. Photovoltaic pavement structures mainly include solid plate structure and

hollow plate structure[12], and the key technologies involved include: photovoltaic pavement structure model design, pavement material design, connection circuit design, pavement performance test technology and standards, pavement heat collection technology, pavement maintenance and repair technology, etc.

The patents related to photovoltaic pavement in the ten years from 2012 to 2021 mainly focus on the following five technical directions: Photovoltaic pavement structure and construction methods and devices, including solid plate structure, hollow plate structure, pavement structure conducive to heat exchange and ventilation, pavement structure with special functions such as drainage, light transmission, anti-skid, snow melting, pavement structure with good buffer effect, photovoltaic pavement method, pavement detection, reinforcement, alignment installation support and other accessories; Materials, prefabricated components and construction process, including high light transmittance and high strength pavement materials, piezoelectric, thermoelectric, drainage, improving illumination, reducing internal stress, bonding with pavement materials and other components, and construction process of photovoltaic modules; Photovoltaic pavement maintenance device, including cleaning/sweeping tools, deicing and snow melting system, etc; Charging methods and equipment based on photovoltaic pavement, including wireless charging methods, charging booth/parking spaces, zero pressure tires, etc; Photovoltaic pavement information management system. There are many photovoltaic pavement patents, and the layout involves key technical fields such as photovoltaic pavement structure and pavement materials.

Photovoltaic pavement was first proposed by the United States. France, Germany, the Netherlands, Japan, Spain, Hungary and other countries have built solar pavement test roads[5]. China has carried out photovoltaic highway test exploration in Shandong and Zhejiang.

There are relatively many researches on photovoltaic pavement, but the application is still in the exploration stage due to the influence of cost, service life, safety and other factors. It is necessary to accelerate the research and practice of structural design, construction technology, maintenance technology, heat collection technology and other aspects.

3.2.4 Photovoltaic road canopy

Photovoltaic road canopy is to set up a photovoltaic system above the road carriageway, which can simultaneously realize multiple functions such as power generation, sunshade, rain and snow protection, highway alignment guidance, auxiliary lighting, intelligent monitoring, etc. Key technologies involved include: structure, orientation and inclination design methods considering the effects of environmental shadow shielding, wind load, etc.

During the decade from 2012 to 2021, the patents related to photovoltaic road canopy are mainly concentrated in two technical directions, namely, photovoltaic canopies and their structures, and photovoltaic canopy snow removal devices. From the perspective of patent layout, it mainly solves the key problem of canopy structure design.

The United States, Belgium, Germany, Austria and other countries have built photovoltaic canopies relying on highways and railway tunnels, which can effectively extend the life of roads and reduce noise pollution while providing power[13-15].Relying on Mengtuan Toll Station of Shandong Qinglan Expressway, Northwest Hubei Expressway, Xinling Tunnel of Hangzhou Jinzhou Quzhou Expressway, Nanhu Service Area of Jiaxing, Zhejiang Province,

China has tested and built photovoltaic systems.

The initial construction cost of photovoltaic road canopy is high, and the operation and maintenance are difficult. Since it was proposed, the development has been slow. Research and development are mainly focused on the canopy structure design. It is necessary to further evaluate its power generation efficiency, and demonstrate its safety, stability, cost performance, etc.

3.2.5 Photovoltaic parking canopy

Photovoltaic parking canopy refers to the photovoltaic system installed on the parking shed, which can realize all functions of the traditional parking shed and simultaneously produce renewable energy. The key technology is the design method of parking shed structure, orientation and inclination considering the effects of environmental shadow and wind load.

The photovoltaic parking canopy is built based on the traditional parking lot. The construction method is relatively simple, and the research on its structure and performance is less. At present, there is no patent layout in this domain. The photovoltaic parking canopy mainly serves electric vehicles, and energy management, electric vehicle charging strategy, and impact on the power grid are the focus of attention.

3.2.6 PV powered charging station/ charging pile/charging system

The PV powered charging station/charging pile/charging system is used to install the photovoltaic system in the expressway service area or power supply station to provide charging services for electric vehicles, new energy vehicles, etc. The charging station generally adopts the battery replacement mode of photovoltaic and battery charging, which is composed of solar photovoltaic cell module array, DC combiner box, photovoltaic inverter, photovoltaic charging controller and battery[10]. At present, the main technical problems are the instability of photovoltaic, the cost of batteries, and the derailment from the domestic and foreign electric vehicle charging pile standards.

During the ten years from 2012 to 2021, the patents related to PV powered charging stations/charging piles/charging systems are mainly concentrated in the following three technical directions: Charging devices, including distributed charging stations, charging piles or charging systems set on one or both sides of the road, charging piles installed in the expressway service area, movable charging piles on the road, instant systems that can realize charging while driving on the road, and wind solar complementary power generation devices, the charging station, charging pile or charging system set up relying on the underground space, street lamps and guardrails of the road; Charging station location and capacity determination methods, including methods applicable to urban roads and highways; Shape design of electric vehicle intelligent parking charging station.

Under the background that the government encourages the promotion of new energy vehicles and all regions actively promote the construction of charging facilities, PV powered charging station using in the road domain has a broad application prospect.

3.2.7 Other applications

The application of photovoltaic technology in the road domain also includes the photovoltaic

power grid, photovoltaic/wind power station, photovoltaic system set on both sides of the road or the bridge, on the street lamps, above the overpass, isolation belt and other spaces above the road surface, as well as the photovoltaic micro grid system and photovoltaic plant management monitoring system set in the expressway service area. Photovoltaic power grid, photovoltaic road purification/greening device, photovoltaic road cleaning device, photovoltaic street lamp, photovoltaic electronic monitoring device, photovoltaic protective fence/warning light, and photovoltaic road speed measuring device are highly patent intensive and mature in layout.

4. Conclusion

4.1 Main problems

4.1.1 The application of photovoltaic technology in the road domain is far from the national requirements of China.

Many policies at the national level in China encourage the rational layout of photovoltaic and energy storage facilities at transport hub stations, along highways, railways and other routes, the establishment of a self consistent energy system for transport, and the integration of transport infrastructure networks, information networks and new energy networks. From the current situation, there are many patents that simply combine photovoltaic with transportation facilities and are relatively less innovative. In terms of the layout of photovoltaic facilities based on highway infrastructure and service facilities such as highway slopes, service areas and hub stations advocated by the state, the number of patents for photovoltaic road slope, photovoltaic road canopy and photovoltaic parking canopy is small, and there are fewer patents for inventions involving key technologies, and the technology application and development are slow. The key technologies of photovoltaic noise barrier have a certain foundation, but are rarely used. Road PV powered charging station is not effectively promoted due to the influence of power generation stability, battery cost, standards, etc. The application of photovoltaic in the road domain is still in its infancy. Most of the completed projects are experimental projects. Many problems such as structural design, safety impact, management and maintenance, and power consumption need to be studied and solved.

4.1.2 The application of photovoltaic in the road domain lacks standard specifications.

At present, the application scale of photovoltaic in the road domain is small, and few standards and specifications have been formed. The current national, industrial and local standards have clear requirements for the design and construction of highway slopes, service areas, facilities along the line, transportation hubs, etc. The layout of photovoltaic facilities in transport hub stations and along the highway should, on the one hand, comply with the current technical specifications for highway engineering design and construction, and on the other hand, comprehensively consider the site selection, structural design, circuit design, management and maintenance, cost-effectiveness and other issues. It is necessary to consider the technical specifications for photovoltaic applications in the series of standards for green road construction.

4.1.3 The combination of production, education and research is not close, the application of research results is slow, and the degree of industrialization is low.

Since the 13th Five Year Plan, China's photovoltaic technology has developed rapidly, and the technology in photovoltaic cells, modules and other fields has reached the world's leading level. In terms of the integrated development of transportation and energy, a series of research work has been carried out around the self consistent supply of green energy for highways, smart solar highways, etc[16], and several technical schemes have been proposed, including photovoltaic road slope, photovoltaic road canopy, integrated parking space for optical storage and charging, highway solar toll gate frame, photovoltaic glare proof panel, and smart photovoltaic pavement[7]. However, from the perspective of the layout of patents and the construction of related projects, the layout of photovoltaic road slope, photovoltaic road canopy, photovoltaic parking canopy and other patent technologies relying on road infrastructure for photovoltaic is sparse, lacking patents to solve key technical problems, and lacking innovation. There are relatively many researches on photovoltaic pavement, but the technical problems in terms of cost, service life, safety, etc. have not been solved, and the application prospect is unclear. In addition, the analysis of applicability, feasibility, safety and cost-effectiveness of various application scenarios for the combination of photovoltaic and road is insufficient, and the technical schemes of various application scenarios have not been tested and explored. The application and transformation of research achievements are not enough. Most of the projects implemented are mainly aimed at scientific research and test. The application of photovoltaic in the road domain is still in the early stage of development, with a low degree of industrialization.

4.2 Development suggestions

4.2.1 Overall planning and improvement of top-level design

In conjunction with the National Development and Reform Commission, the National Energy Administration, the Ministry of Industry and Information Technology and other administrative department in charge, as well as the State Grid Corporation of China and other enterprises, under the guidance of the integrated development policy of transportation and energy, we should fully analyze various scenarios for the application of photovoltaic in the road domain, determine the goal of photovoltaic, propose top-level design and technical route, make a good industrial development plan, and support photovoltaic projects in transportation fixed assets investment.

4.2.2 Strengthen key technology R&D and patent layout.

Relying on various science and technology planning projects, carry out key technology breakthroughs in the application of photovoltaic in the road domain, mainly including: the best potential installation site selection evaluation method, the method of rack system selection and location determination, the method of slope and support facility stability impact assessment, the method of traffic safety impact assessment and other photovoltaic road slope design and construction technologies; The structure optimization design technology of photovoltaic noise barrier shall be considered to improve power generation, reduce noise, prevent glare, prevent collision, etc; Evaluation technology for structural performance and power generation efficiency of photovoltaic road canopy; Pavement structure model design, new pavement

materials, pavement maintenance, pavement heat collection and other photovoltaic pavement technologies; Structural design method, integration of power generation, energy storage and charging and other key technologies of photovoltaic parking canopy. Strengthen the transformation of research achievements, and strengthen the patent layout of photovoltaic in the application fields of highway infrastructure and service facilities, such as photovoltaic road slope, photovoltaic road canopy, PV powered charging stations, photovoltaic parking road canopy, and photovoltaic noise barrier.

4.2.3 Establish and improve the standard and specification system.

Summarize the achievements of photovoltaic construction projects that have been completed and put into operation in the road domain, combine the research results of transportation and energy integration, refine and form the technical requirements for the application of photovoltaic technology to highway infrastructure and service facilities, and supplement them to the series of standards for green road construction, so as to guide the design, construction, management and maintenance of photovoltaic projects in the road domain.

4.2.4 Promote photovoltaic technology in accordance with local conditions in green road demonstration projects.

We should guide and encourage the promotion and application of clean solar resources in accordance with local conditions in the construction of green road demonstration projects in Class I and II areas rich in solar resources. According to the geographical environment, traffic flow characteristics, road power supply demand, etc., the photovoltaic facilities are deployed based on the road slope, service area, tunnel, etc., tracking the research and application benefits of photovoltaic technology, and accumulating industrial experience.

4.2.5 Improve the market mechanism and guide the sound development of enterprises.

The foregoing analysis of the patent holders of photovoltaic in the road domain shows that the research and development subjects are scattered, and most of them are small and medium-sized enterprises. No research and development subjects with absolute advantages and monopoly status have been formed. It is necessary to work with the Ministry of Industry and Information Technology and other administrative department in charge to strengthen the product identification and quality supervision, establish and improve the market access mechanism, promote the incorporation of photovoltaic into the national carbon emission trading and other market construction, ensure the application effect of photovoltaic technology, guide the sound development of enterprises, and promote the innovation and industrialization of photovoltaic technology in the road domain.

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