DESCRIPTION

TITLE OF INVENTION: DESIGN METHOD AND SYSTEM FOR DOT-MATRIX VECTOR PATTERNS AND COLORED PHOTOVOLTAIC MODULES, AND COLORED PHOTOVOLTAIC MODULES

REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Chinese Invention Patent Application No. 2025103536061, filed on March 24, 2025, entitled "Colored Photovoltaic Module and Design Method Therefor, and Renewable Energy Generator", and Singapore Patent Application No. 10202500754Y, filed on March 24, 2025, entitled "Image-Based Photovoltaic Integrated Dot Pattern Enhancement", the contents of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

[0002] The present invention relates to the technical field of colored photovoltaic panels, and more particularly, to a method for designing a dot-vectorized pattern applied to a colored photovoltaic module, as well as a colored photovoltaic module and a design method therefor, and a system for designing a dot-vectorized pattern.

BACKGROUND

[0003] Colored photovoltaic panels have emerged as a promising avenue for integrating solar power generation into buildings and urban landscapes, offering both functional and aesthetic advantages. However, introducing color into photovoltaic panels presents challenges that need to be addressed. Traditional photovoltaic panels prioritize energy conversion efficiency, but when color is added, the absorption and utilization of light at different wavelengths become complex, resulting in colored photovoltaic panels typically exhibiting lower energy conversion efficiency compared to conventional panels. For example, due to its lower reflectivity, black often achieves an energy conversion efficiency 1-3% higher than blue panels. Nevertheless, through careful design, colored photovoltaic panels can present a variety of colors while maintaining a certain level of power generation efficiency.

[0004] The application of colored photovoltaic panels is mainly divided into two types: one is BAPV (Building-Applied Photovoltaics), where photovoltaic panels are added to the surface of existing buildings (e.g., roof-mounted brackets); the other is BIPV (Building-Integrated Photovoltaics), where photovoltaic components serve as the building's own structural or decorative materials (e.g., photovoltaic glass curtain walls, photovoltaic tiles), replacing traditional building materials (such as glass, exterior walls, roof tiles) to achieve the dual goals of power generation and building functionality, also known as building-integrated photovoltaic panels. However, whether it is BAPV, BIPV, or other photovoltaic panels, energy conversion efficiency must be considered. To ensure energy conversion efficiency, existing technologies have

proposed various colored photovoltaic panels. US Patent Application Publication No. US20180122973A1 discloses a layered structure for a solar cell panel, including a pattern layer used to integrate the solar cell into the remainder of the solar tile, thereby hiding it from view and achieving camouflage for the solar cell panel. US Patent Application Publication No. US20220336686A1 describes a solar module having arranged cell fingers and a front sheet with indentations, which provides a second textured pattern on the front sheet of the solar module to avoid eliminating visible interference fringes with the first textured layer, thereby integrating the solar module into a building. Patent Application Publication No. WO2019039942A1 creates a dot pattern on a foil using a rasterization algorithm and aligns it with parts of the photovoltaic module, thereby shielding specific components on the photovoltaic module, such as the conductive metallization pattern on the front surface of the photovoltaic module. That is, the role of its pattern layer is to shield specific components on the photovoltaic module, preventing these visible components from hindering the module's integration into a building and affecting the building's aesthetics. Patent Application Publication No. EP3537485A1 discloses a solar cell panel sealed by two cover parts, wherein the cover part comprises a glass base covering the light-incident surface of the photovoltaic cell panel, and a colored portion disposed on the glass base having a certain light transmittance. U.S. Patent No. US10256360B2 discloses a graphic layer having a visible image or pattern and a method for integrating same into a solar module, by providing a fully covered transparent layer on the photovoltaic module and forming discrete light-shielding areas with different transparencies in or on the transparent layer, to create an optical interaction between the discrete light-shielding areas and the continuous light-transmitting areas, generating a recognizable image identifier, thereby enhancing the visual expressiveness of the photovoltaic module. Furthermore, the transparency of the graphic layer can be adjusted by modifying the number, size, shape, and/or spacing of the discrete light-shielding areas. U.S. Patent No. US11018271B2 discloses a method for generating a graphic grid for a solar module, wherein a plurality of warp fibers and a plurality of weft fibers form a fiber grid on the photovoltaic cell, and the warp and weft fibers are colored to present a pattern. That is, it uses determined parameters to generate a graphic grid and meets energy efficiency and visual requirements by adjusting the grid opening size.

[0005] In the above-mentioned prior art, either a full coverage approach is adopted, where colored photovoltaic modules are achieved by setting different color regions with varying light transmittances, or patterns corresponding to the internal structure of the photovoltaic module are used, followed by color regions with different light transmittances to realize the colored photovoltaic module. Moreover, most of them primarily focus on the aesthetic effect of the pattern. However, the introduction of different colors with varying light transmittances may lead to localized heating imbalance during the energy conversion process, thus forming hot spots. Hot spots not only reduce the performance of the photovoltaic panel but may also impair its structural integrity over time. Additionally, due to considerations of energy conversion efficiency, the range of colors available in the actual design process is very limited. These issues hinder the

widespread application of colored photovoltaic panels as a viable energy generation solution, especially in applications where both performance and aesthetics are critical.

[0006] Patent Application Publication No. WO2023063893A2 discloses a photovoltaic device, wherein a cover member is formed on the light-incident surface of the photovoltaic panel by full-color printing. The cover member includes at least two colored and/or patterned regions, each region providing a uniform light transmittance and ensuring that each solar cell has the same shading (or electrical efficiency), thereby reducing current mismatch losses and hot spot effects, thus improving the overall efficiency, reliability, and safety of the photovoltaic device. Specifically, it selects several specified colors with acceptable transparency for full-color printing onto the photovoltaic panel, and then determines the transparency of each colored or patterned region by controlling factors such as ink density. However, the prior art mentioned above still adopts a full coverage approach and achieves colored photovoltaic modules through color regions with varying light transmittances. Additionally, although the prior art mentions providing patterns and/or colored regions on the photovoltaic panel, it does not disclose how to design a pattern that satisfies both the expected energy conversion efficiency requirements and the expected visual effect. If manual calculation is used, on one hand, it heavily relies on the professional experience of the personnel involved, and on the other hand, the workload is substantial. Moreover, most prior art only considers aesthetic effects while neglecting energy conversion efficiency, or conversely, only considers energy conversion efficiency while neglecting aesthetic effects.

[0007] Thus, it can be seen that the prior art lacks a solution specifically addressing how to balance energy efficiency and aesthetics while simultaneously considering the hot spot issue. In other words, a comprehensive solution that improves energy conversion efficiency, balances aesthetics, and reduces hot spot formation in colored photovoltaic panels has not yet been provided. Therefore, there is an urgent need for a novel design method to solve these problems, enabling colored photovoltaic panels to deliver higher energy output while maintaining long-term reliability. Such a design method would not only advance the field of photovoltaics but also significantly contribute to the integration of sustainable energy into diverse environments.

SUMMARY

[0008] The objective of the present invention is to provide a method and system for designing a dot vectorized pattern applied to a colored photovoltaic module, as well as a colored photovoltaic module and a design method therefor, to partially solve or alleviate the above-mentioned shortcomings in the prior art. This enables the colored photovoltaic module to achieve a perfect integration of aesthetics and energy efficiency, ensuring both efficient energy generation and aesthetic appeal of the photovoltaic module, while mitigating the hot spot issue, thereby effectively promoting the development of sustainable architecture.

[0009] To address the above-mentioned technical problems, the present invention specifically adopts the following technical solutions:

[0010] According to a first aspect of the present invention, there is provided a method for designing a dot-vectorized pattern applied to a colored photovoltaic module, wherein the method comprises the steps of: S101 obtaining an image to be converted and preset parameters; wherein the preset parameters comprise one or more of: a type of a reference dot vector unit, a reference pattern of the reference dot vector unit, a preset energy conversion efficiency Q_0 and/or a preset energy loss rate P_0 , and a preset dot density ρ_0; wherein the type of the reference dot vector unit comprises one or more of: an architectural style, an artistic style, and a natural style, and each style comprises at least one reference pattern formed by dots to produce different visual effects; S102 converting the image to be converted into a dot-vectorized pattern for application to the photovoltaic module based on the preset parameters, wherein the dot-vectorized pattern enables the colored photovoltaic module to have an energy conversion efficiency greater than or equal to the preset energy conversion efficiency, or enables the colored photovoltaic module to have an energy loss rate less than or equal to the preset energy loss rate, and enables each photovoltaic cell in the photovoltaic module to have an identical shaded area; wherein the dot-vectorized pattern comprises at least one of the reference patterns.

[0011] In some embodiments, wherein when preset parameters specified by a user comprise: the preset energy conversion efficiency Q_0 and/or the preset energy loss rate P_0, and the preset dot density ρ_0, step S102 specifically comprises the steps of: S1021 inputting the preset energy conversion efficiency Q_0 or the preset energy loss rate P_0 and the preset dot density ρ_0 into a pre-trained matching model to obtain a candidate dot-vectorized pattern set generated based on each reference dot vector unit, and pattern parameters corresponding to each candidate dot-vectorized pattern; wherein the pattern parameters comprise the dot density, the energy conversion efficiency and/or the energy loss rate, the number of the reference dot vector units on a single photovoltaic cell, and the size of each isolated dot in the reference dot vector unit; wherein each candidate dot-vectorized pattern set comprises candidate dot-vectorized patterns having the same style but generated based on different reference patterns; S1022 arranging all candidate dot-vectorized patterns in each candidate dot-vectorized pattern set in descending order according to a recommendation index, and respectively selecting, from each candidate dot-vectorized pattern set, the reference dot vector unit corresponding to at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index as a candidate object to be designated; wherein the recommendation index is: $T=Q_{i,j}^{a}*\rho_{i,j}^{b}*100\%$, or $T=P_{i,j}^{a}*\rho_{i,j}^{b}*100\%$; wherein a represents a weight of the energy conversion efficiency $Q_{i,j}$ or the energy loss rate $P_{i,j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, and b represents a weight of the dot density $\rho_{i,j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, and a + b = 1, and i = 1, 2, 3; S1023

when the candidate object is designated, converting the image to be converted into the corresponding dot-vectorized pattern based on the pattern parameters obtained in step S1021;

[0012] In some embodiments, when the preset parameters specified by the user comprise the type of the reference dot vector unit, the preset energy conversion efficiency Q_0 and/or the preset energy loss rate P_0, and the preset dot density ρ_0, the step S102 specifically comprises: S1021a inputting the type of the reference dot vector unit, the preset energy conversion efficiency Q_0 or the preset energy loss rate P_0, and the preset dot density ρ_0 into the pre-trained matching model to obtain a candidate dot-vectorized pattern set generated based on the reference dot vector unit of the specified type, and pattern parameters corresponding to each candidate dot-vectorized pattern, wherein the pattern parameters comprise the dot density, the number of the reference dot vector units on a single photovoltaic cell, and the size of each isolated dot in the reference dot vector unit, and the candidate dot-vectorized pattern set comprises candidate dot-vectorized patterns having the specified style but different reference patterns; S1022a arranging all candidate dot-vectorized patterns in the candidate dot-vectorized pattern set according to a recommendation index in descending order, and selecting, from the candidate dot-vectorized pattern set, the reference dot vector unit corresponding to at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index as the candidate object to be designated, wherein the recommendation index is: $T=Q_j^a*\rho_j^b*100\%$, or, $T=P_j^a*\rho_j^b*100\%$; wherein a represents a weight of the energy conversion efficiency Q_j or the energy loss rate P_j of the j-th candidate dot-vectorized pattern, and b represents a weight of the dot density ρ_j of the j-th candidate dot-vectorized pattern, and $a + b = 1$; S1023a when the candidate object is designated, converting the image to be converted into the corresponding dot-vectorized pattern based on the designated candidate object and the pattern parameters thereof.

[0013] In some embodiments, wherein the reference pattern of the architectural style comprises: a first dot array formed by a plurality of isolated dots arranged at equal intervals; and a plurality of second dot arrays formed by a plurality of isolated dots arranged at equal intervals and surrounding the first dot array; and/or, in some embodiments, the reference pattern of the artistic style comprises: a third dot array formed by a plurality of isolated dots arranged in a six-armed asterisk configuration; or comprises: two fourth dot arrays formed by a plurality of isolated dots arranged in a V-shaped configuration and symmetrically arranged, and a fifth dot array formed by a plurality of isolated dots and located on a symmetry axis of the two fourth dot arrays; and/or, in some embodiments, the reference pattern of the natural style comprises: a sixth dot array symmetrically arranged on left and right sides, and a seventh dot array symmetrically arranged on upper and lower sides; wherein the sixth dot array comprises: a first fan-shaped region formed by a plurality of isolated dots, and second fan-shaped regions symmetrically arranged on two sides of the first fan-shaped region, the first fan-shaped region comprises a plurality of first dot array curves arranged at intervals along a radial extension direction from a center point, wherein curvature of the first dot array curves gradually increases in a direction away from the center point; the second fan-shaped regions

comprise a plurality of second dot array curves arranged at intervals from a distal end toward a center point of the first fan-shaped region, wherein curvature of the second dot array curves gradually increases in a direction toward the center point of the first fan-shaped region; and/or wherein the seventh dot array comprises: a first fan-shaped region formed by a plurality of isolated dots, and second fan-shaped regions symmetrically arranged on two sides of the first fan-shaped region, the first fan-shaped region comprises a plurality of first dot array curves arranged at intervals along a radial extension direction from a center point, wherein curvature of the first dot array curves gradually increases in a direction away from the center point; the second fan-shaped regions comprise a plurality of second dot array curves arranged at intervals from a top end of the first fan-shaped region toward an arc endpoint of the first fan-shaped region, wherein curvature of the second dot array curves gradually increases from the top end of the first fan-shaped region toward the arc endpoint of the first fan-shaped region.

[0014] In some embodiments, wherein the preset parameters further comprise a preset viewing distance, and step S102 further comprises the steps of: S1024 obtaining the preset viewing distance; when the preset viewing distance is less than or equal to a preset first distance threshold, performing step S1025; when the preset viewing distance is greater than the first distance threshold but less than or equal to a preset second distance threshold, performing step S1026; when the preset viewing distance is greater than the second distance threshold but less than or equal to a preset third distance threshold, performing step S1027; S1025 adjusting the size of the isolated dots based on a graphics-oriented rule; S1026 adjusting the size of the isolated dots based on a balance-oriented rule; S1027 adjusting the size of the isolated dots based on an energy-oriented rule.

[0015] In some embodiments, wherein step S102 further comprises the steps of: S1028 obtaining adjustment parameters, and performing randomization adjustment on a size and/or a number of isolated dots in a designated local region based on the adjustment parameters; wherein the adjustment parameters comprise a size of the designated local region; and/or, S1029 performing color adjustment on a designated region based on preset color adjustment parameters.

[0016] According to a second aspect of the present invention, there is provided a method for designing a colored photovoltaic module, wherein the method comprises: obtaining a dot-vectorized pattern applicable to the photovoltaic module according to the design method according to any one of the above embodiments; S103 forming, by using an opaque material, dots of the dot-vectorized pattern on a light incident surface of the photovoltaic module, and aligning the dot-vectorized pattern with the photovoltaic module, such that, for each photovoltaic cell in the photovoltaic module, a shielding area of the photovoltaic cell that is covered by isolated light-blocking regions in the dots is identical; wherein light-transmitting regions for light penetration are formed between the dots and between the isolated light-blocking regions.

[0017] According to a third aspect of the present invention, there is provided a colored photovoltaic module, wherein the colored photovoltaic module comprises a pattern layer disposed on a light incident

surface of a photovoltaic module, and the pattern layer comprises: at least one base dot-vectorized unit disposed on each photovoltaic cell, wherein the base dot-vectorized unit comprises a plurality of isolated light-blocking regions arranged according to a preset base pattern of a specified style; wherein part or all of the isolated light-blocking regions form a specified pattern on the photovoltaic module, such that an energy conversion efficiency of the photovoltaic module is greater than or equal to a preset energy conversion efficiency Q_0, or an energy loss rate of the photovoltaic module is less than or equal to a preset energy loss rate P_0; wherein the isolated light-blocking regions are formed by using an opaque material; wherein the specified style comprises an architectural style, an artistic style, or a natural style, and each style comprises at least one base pattern formed by a plurality of isolated light-blocking regions.

[0018] In some embodiments, wherein the base pattern of the architectural style comprises: a first dot array formed by a plurality of dots arranged at equal intervals, and a plurality of second dot arrays formed by a plurality of dots arranged at equal intervals and surrounding the first dot array, wherein gaps between the isolated light-blocking regions form light-transmitting regions of the photovoltaic module.

[0019] In some embodiments, the base pattern of the artistic style comprises:a third dot array formed by a plurality of dots arranged in a six-armed asterisk configuration, wherein gaps between the isolated light-blocking regions form light-transmitting regions of the photovoltaic module; or, the base pattern of the artistic style comprises: two fourth dot arrays formed by a plurality of dots arranged in a V-shape and symmetrically disposed, and a fifth dot array formed by a plurality of dots arranged along a symmetry axis of the two fourth dot arrays, wherein gaps between the isolated light-blocking regions form light-transmitting regions of the photovoltaic module.

[0020] In some embodiments, the base pattern of the natural style comprises: a sixth dot array symmetrically disposed on left and right sides and a seventh dot array symmetrically disposed on upper and lower sides; wherein, the sixth dot array comprises: a first fan-shaped region formed by a plurality of dots, and second fan-shaped regions symmetrically disposed on both sides of the first fan-shaped region, wherein the first fan-shaped region comprises a plurality of first dot-array curves arranged at intervals along a radial extension direction from a central point, and curvatures of the first dot-array curves gradually increase in a direction away from the central point; and the second fan-shaped regions comprise a plurality of second dot-array curves arranged at intervals from a distal end toward the central point of the first fan-shaped region, and curvatures of the plurality of second dot-array curves gradually increase in a direction toward the central point of the first fan-shaped region; and/or the seventh dot array comprises: a first fan-shaped region formed by a plurality of isolated dots, and second fan-shaped regions symmetrically disposed on both sides of the first fan-shaped region, wherein the first fan-shaped region comprises a plurality of first dot-array curves arranged at intervals along a radial extension direction from a central point, and curvatures of the first dot-array curves gradually increase in a direction away from the central point; and the second fan-shaped regions comprise a plurality of second dot-array curves arranged at intervals from a top end of

the first fan-shaped region toward arc endpoints of the first fan-shaped region, and curvatures of the plurality of second dot-array curves gradually increase in a direction from the top end of the first fan-shaped region toward the arc endpoints.

[0021] In some embodiments, wherein, when sizes of the isolated light-blocking regions are identical, a density $\rho 1$ of the isolated light-blocking regions in the base pattern of the architectural style is greater than a density $\rho 2$ of the isolated light-blocking regions in the base pattern of the artistic style, and the density $\rho 1$ of the isolated light-blocking regions in the base pattern of the architectural style is less than a density $\rho 3$ of the isolated light-blocking regions in the base pattern of the natural style; or, each photovoltaic cell is provided with one base pattern of the natural style.

[0022] According to a fourth aspect of the present invention, there is provided a system for designing a dot vectorized pattern, wherein the system comprises: a base pattern library configured to store different types of base dot vectorized units; wherein types of the base dot vectorized units comprise architectural style, artistic style, and natural style, and each style comprises at least one base pattern formed by dot arrays to produce different visual effects; a data acquisition module configured to acquire an image to be converted and preset parameters; wherein the preset parameters comprise one or more of: a type of the base dot vectorized unit, a base pattern of the base dot vectorized unit, a preset energy conversion efficiency Q_0 and/or a preset energy loss rate P_0, and a preset dot density ρ_0; a pattern conversion module connected to the data acquisition module and the base pattern library, and configured to convert the image to be converted into a corresponding dot vectorized pattern based on the preset parameters; wherein the dot vectorized pattern enables an energy conversion efficiency of a photovoltaic module to be greater than or equal to the preset energy conversion efficiency, or enables an energy loss rate of the photovoltaic module to be less than or equal to the preset energy loss rate, and ensures that a shading area of each photovoltaic cell in the photovoltaic module is identical.

[0023] **Beneficial Effects:** The present invention converts a specified image into a dot vectorized pattern composed of reference dot vector units. This dot vectorized pattern can not only present a variety of visual effects (for example, the visual effect of Marilyn Monroe and the cloud /leaf visual effects), thereby enhancing aesthetics, but also enable uniform light absorption across each photovoltaic panel. This ensures energy conversion efficiency while avoiding or mitigating the "hot spot" problem in colored photovoltaic panels. Furthermore, by providing reference patterns in multiple styles with different visual effects, the invention offers designers more creative space and grants greater flexibility in designing colored photovoltaic modules, thus facilitating broader application and promotion.

[0024] In the prior art, colored regions are typically applied onto a substrate (e.g., a transparent glass substrate, a transparent film, or a fiber grid), and then a specified pattern with a single visual effect (e.g., an image of Obama) is presented by repeatedly arranging these colored regions. While this method can convert any user-specified image into a dot vectorized pattern, it offers low flexibility for designers.

Regardless of the pattern, under the same color condition, the visual effect remains monotonous and lacks aesthetic variety. In contrast, the present application pre-arranges dots to form different styles and patterns, thereby creating reference patterns with distinct visual effects. This allows the use of reference patterns having different visual effects to present a user-specified pattern, resulting in a specified pattern with multiple visual effects (for example, any converted dot vectorized pattern in a row of FIG. 7 not only presents the secondary visual effect of Marilyn Monroe but also exhibits the primary visual effect of reference patterns in different styles). This not only provides designers with more creative material but also balances the energy efficiency and aesthetics of the colored photovoltaic cells. Additionally, it can present different visual effects to viewers at varying distances. For instance, viewers at a greater distance may only see Marilyn Monroe, while those at medium or close distances can see both Marilyn Monroe and the patterns formed by the preset patterns and their combinations. On the other hand, because the pattern on each photovoltaic cell is identical, and all isolated light-blocking regions are formed using an opaque material to create the dot vectorized pattern, the amount of light incident on each photovoltaic cell is nearly the same. This significantly reduces the probability of hot spot issues. Moreover, it eliminates the need to restrict color choices based on the light transmittance of colors, resulting in a richly colored final dot vectorized pattern that can closely approximate or restore the original color scheme of the specified pattern.

[0025] Furthermore, to ensure energy conversion efficiency while maintaining pattern resolution, when a reference dot vector unit is not specified, the system automatically matches a reference dot vector unit meeting expectations based on the user's preset parameters. This eliminates the need for manual calculations by the user, saving workload.

[0026] The present invention provides three styles, each containing reference dot vector units that present different visual effects. While this offers design flexibility, users cannot quickly determine, from the vast number of reference dot vector units, the specific pattern parameters required to generate a dot vectorized pattern that meets expectations based on each dot vector unit. Manually calculating each dot vector unit would significantly increase the designer's workload. To reduce this workload, based on the preset parameters input by the user, the system automatically identifies candidate dot-vectorized patterns and their pattern parameters that meet expectations, and recommends them to the user. This provides design freedom while reducing the designer's workload and dependence on the experience of specialized personnel. In summary, the advantages are: (1) Enhanced aesthetic appeal: Provides architects and designers with the flexibility to integrate any image into the photovoltaic module design. Furthermore, since all isolated dots are made of opaque material, the color of each isolated dot in the generated dot vectorized pattern is not restricted, allowing for diverse coloration, unlike methods using colored regions with different transparency or transmittance. (2) Increased energy harvesting: The design ensures maximum light penetration, thereby improving energy generation. (3) Uniform solar irradiance: Ensures that all photovoltaic cells receive nearly identical amounts of light, mitigating the hot spot effect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] To explain the technical solutions in the embodiments of the present invention or in the prior art more clearly, the following briefly introduces the accompanying drawings required for describing the embodiments or the prior art.

[0028] FIG. 1 is a flow chart of a method for designing a colored photovoltaic module according to the present invention; FIG. 2 is a flow chart of pattern design based on a design system of the present invention; FIG. 3 shows examples of three different dot vector units according to the present invention; FIG. 4a is a schematic diagram reflecting a photovoltaic panel with four cells each adopting a pattern; FIG. 4b is a schematic diagram reflecting hot spots on cells of a photovoltaic panel before and after adjusting pattern density; FIG. 5 shows a pattern selected by a user to be imported into design software; FIG. 6 is a schematic diagram illustrating colored photovoltaic panels obtained by the method of the present invention based on different pattern designs; FIG. 7 is a schematic diagram reflecting a user-selected pattern presented on cells using different dot patterns; FIG. 8a, FIG. 8b, and FIG. 8c are diagrams respectively reflecting fine-tuning methods adapted for patterns suitable for close, medium, and long viewing distances; FIG. 9 is a schematic diagram respectively reflecting manual adjustments of skin color, mouth color, and mouth color with partial face color; FIG. 10 shows a final output design pattern obtained using the method of the present invention; FIG. 11 shows various patterns after introducing randomness by adjusting dot sizes at different percentages; FIG. 12 is a comparison diagram before and after disabling randomization; FIG. 13 is a schematic diagram of different photovoltaic panels M1, M2, M3, M4, M6, M9 used during testing; FIG. 14 is a schematic diagram of different printed patterns used for photovoltaic panels M1, M2, M3, M4, M6, M9 in an experimental test; FIG. 15 is a schematic diagram of photovoltaic panels M7, M8, M9 using the same printed pattern but with different coverage rates in an experimental test; FIG. 16 is a schematic diagram of STC efficiency of solar panels with different color coverage rates; FIG. 17 is a schematic diagram of relative efficiency loss of solar panels with different color coverage rates compared to a reference solar panel M5; FIG. 18a-18f are voltage-current characteristic graphs for solar panels M1-M5, M5C; FIG. 19a-19d are voltage-current characteristic graphs for solar panels M6-M9; FIG. 20a is a summary graph of voltage-current characteristics for solar panels M1, M2, M3, M4, M6, M9; FIG. 20b is a summary graph of voltage-current characteristics for solar panels M1, M2, M3, M4, M5, M5C; FIG. 21 is a comparison graph of voltage-current characteristics and irradiance for solar panels M5 and M5C; FIG. 22 is a comparison graph of voltage-current characteristics and irradiance for solar panels M5, M7, M8, and M9; FIG. 23 is a box plot for different solar panels M1, M2, M3, M4, M6, M9; FIG. 24 is a schematic diagram reflecting different types of patterns optimized using different viewing distance pattern design methods; FIG. 25 is a schematic diagram reflecting converting a specified pattern of an artistic style into a dot vectorized pattern based on a third reference pattern; FIG. 26 is a schematic diagram reflecting converting a specified pattern of a natural style into a dot vectorized pattern based on a third reference pattern.

DETAILED DESCRIPTION

[0029] To make the objectives, technical solutions, and advantages of the embodiments of the present invention clearer, the technical solutions in the embodiments of the present invention will be described clearly and completely below with reference to the accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are some, but not all, of the embodiments of the present invention. Based on the embodiments of the present invention, all other embodiments obtained by a person of ordinary skill in the art without making creative efforts shall fall within the protection scope of the present invention. As used herein, suffixes such as "module", "component" or "unit" used to indicate elements are merely used to facilitate the description of the present invention and do not have specific meanings by themselves. Therefore, "module", "component" or "unit" may be used interchangeably. As used herein, terms indicating orientation or positional relationships, such as "upper", "lower", "inner", "outer", "front", "rear", "one end", and "the other end", are based on the orientation or positional relationships shown in the drawings. They are only for the convenience of describing the present invention and simplifying the description, and do not indicate or imply that the referred device or element must have a specific orientation, be constructed and operated in a specific orientation. Therefore, they should not be construed as limiting the present invention. Furthermore, the terms "first" and "second" are used for descriptive purposes only and shall not be understood as indicating or implying relative importance. As used herein, unless explicitly specified and limited otherwise, terms such as "installed", "provided with", and "connected" should be interpreted broadly. For example, "connected" may refer to a fixed connection, a detachable connection, or an integral connection; it may refer to a mechanical connection, a direct physical connection, an indirect connection via an intermediate medium, or an internal communication between two elements. For a person of ordinary skill in the art, the specific meanings of the above terms in the present invention can be understood according to specific circumstances. As used herein, "and/or" includes any and all combinations of one or more of the associated listed items. As used herein, "a plurality of" means two or more, i.e., it includes two, three, four, five, etc. As used in this specification, the term "about" typically represents +/-5% of the stated value, more typically +/-4% of the stated value, more typically +/-3% of the stated value, more typically +/-2% of the stated value, even more typically +/-1% of the stated value, and even more typically +/-0.5% of the stated value. In this specification, certain embodiments may be disclosed in a range format. It should be understood that such description in a range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed range. Accordingly, the description of a range should be considered to have specifically disclosed all possible sub-ranges as well as individual numerical values within that range. For example, description of a range from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6, etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0030] As used herein, a "dot array" refers to a collection of isolated dots arranged according to a preset pattern, where the collection of isolated dots presents a specific pattern, i.e., forming a corresponding

primary visual effect, such as the cloud pattern effect shown in FIG. 3a to the leaf effect shown in FIG. 3c. When this dot array is applied to photovoltaic cells in a photovoltaic module using an opaque material, i.e., when the opaque material is used to directly form isolated dots on the photovoltaic panel, these isolated dots become isolated light-blocking regions on the photovoltaic cells, which are opaque (i.e., have 0% light transmittance). The gaps between the isolated light-blocking regions serve as light-transmitting regions (or light-transmitting channels) allowing light to pass through. The gaps between the isolated dots, i.e., the gaps between the isolated light-blocking regions, allow more sunlight to reach the photovoltaic cells. These gaps are crucial for enhancing the energy harvesting capability of the photovoltaic module. In some embodiments, the shape of the isolated dots may be regular geometric forms such as circles, rectangles, squares, or irregular shapes, as long as, when the dot array is applied to the colored photovoltaic module, it can satisfy the corresponding energy conversion efficiency, present the user-specified pattern, and meet the corresponding resolution requirements.

[0031] As used herein, an "architectural element" refers to various patterns or textures used by designers in traditional architectural design. An example is the cloud pattern from classic architectural design shown in FIG. 3a, which is formed by a plurality of isolated dots arranged according to a preset configuration. Of course, besides the cloud pattern, other patterns are possible, such as the "Eight Treasures" pattern, "Apsaras" pattern, etc. As used herein, if the pattern formed by the collection of isolated dots includes an architectural element (e.g., cloud pattern), this pattern is referred to as a reference pattern of an architectural style. Correspondingly, when dot arrays form different architectural elements, different reference patterns are obtained, i.e., reference patterns with different architectural styles are obtained. As used herein, a "geometric element" refers to various geometric patterns used by designers in modern architectural design, which possess a certain abstract or artistic quality. An example is the triangular pattern shown in FIG. 3b, where a plurality of isolated dots are arranged according to a preset configuration to form multiple triangular patterns. Of course, besides triangular patterns, other patterns are possible, such as the swastika pattern, the "Hui" pattern, etc. As used herein, if the pattern formed by the collection of isolated dots includes a geometric element, this pattern is referred to as a reference pattern of an artistic style. Correspondingly, when dot arrays form different geometric elements, different reference patterns are obtained, i.e., reference patterns with different artistic styles are obtained. As used herein, a "natural element" refers to patterns composed of green and/or curvilinear elements found in nature. An example is the leaf pattern shown in FIG. 3c, formed by isolated dots arranged following the curvilinear direction of leaves, where a plurality of isolated dots are arranged according to a preset configuration to form multiple leaves. Of course, besides leaf patterns, other patterns are possible, such as scrollwork, baoxiang flower pattern, etc. As used herein, if the pattern formed by the collection of isolated dots includes a natural element, it is referred to as a reference pattern of a natural style. Correspondingly, when dot arrays form different natural elements, different reference patterns are obtained, i.e., reference patterns with different natural styles are obtained. As used herein, "the dot vectorized pattern is aligned with the photovoltaic

module" means that the dimensions and shape of the dot vectorized pattern are identical to the total dimensions and shape of all photovoltaic cells in the photovoltaic module, and the area shaded by the isolated light-blocking regions on each photovoltaic cell is identical. As used herein, "coverage rate" refers to the percentage of the total area of the light incident surface of the photovoltaic cells in the photovoltaic module that is shaded by isolated regions or other elements (such as transparent glass used during experimentation, etc.).

[0032] In the prior art, colored photovoltaic modules achieve colored layers with different light transmittances by completely covering the light incident surface of photovoltaic cells with solid color ink or colored ink, and then adjusting the color or density of the ink, thereby ensuring the energy conversion efficiency of the photovoltaic cells. Compared to photovoltaic modules completely uncovered with ink, this approach significantly reduces the energy conversion efficiency of the photovoltaic module. In order to meet architectural aesthetic requirements while improving energy conversion efficiency and reducing/avoiding the hot spot effect on colored photovoltaic panels, the present invention provides a method for designing a colored photovoltaic module, comprising the steps of: obtaining an image to be converted, and a reference dot vector unit of a specified type; converting the image to be converted into a corresponding dot vectorized pattern based on the specified reference dot vector unit, forming the dot vectorized pattern on the photovoltaic module using an opaque material, and aligning the dot vectorized pattern with the photovoltaic module. Herein, the type of the reference dot vector unit may be selected by a user, or may be automatically matched by a system based on user-preset requirement parameters. For example, when a user sets parameters such as energy conversion efficiency Q_0, the system can automatically match an optimal reference dot vector unit meeting the requirements from among three types of reference dot vector units based on parameters such as energy conversion efficiency Q_0. Specifically, a matching model may be obtained through machine learning training for automatic matching. As another example, when the requirement parameters set by the user include: energy conversion efficiency Q_0, isolated dot size D, and the required number N of reference dot vector units on each photovoltaic cell, the system can automatically calculate the energy conversion efficiency for each reference dot vector unit based on these requirement parameters, and then select, from a candidate set where the energy conversion efficiency is greater than or equal to Q_0, the one with the maximum isolated dot density.

[0033] Based on the above design method, the present invention also provides a colored photovoltaic module, comprising a dot vectorized pattern aligned with the photovoltaic cells, wherein the dot vectorized pattern is obtained using the above-mentioned method for designing a colored photovoltaic module. Based on the above design method, the present invention also provides a method for designing a dot vectorized pattern applied to a colored photovoltaic module, comprising the steps of: providing a pattern import interface for a user; converting a specified pattern imported through the pattern import interface into a dot vectorized pattern.

Embodiment 1: A method for designing a colored photovoltaic module.

[0034] Referring to FIG. 1, a flowchart of a method for designing a colored photovoltaic module according to the present invention is shown. Specifically, the method comprises the steps of: S101 obtaining an image to be converted and preset parameters. S102 converting the image to be converted into a dot vectorized pattern for application on a photovoltaic module based on the preset parameters, wherein the dot vectorized pattern enables an energy loss rate of the photovoltaic module to be less than or equal to a preset energy loss rate (e.g., 20% or 30%), or the dot vectorized pattern enables an energy conversion efficiency of the photovoltaic module to be greater than or equal to a preset energy conversion efficiency, and a shaded area of each photovoltaic cell is identical. S103 forming, by using an opaque material, a dot vectorized pattern corresponding to the image to be converted on the photovoltaic module, and aligning the dot vectorized pattern with the photovoltaic module.

[0035] In step S101, referring to FIG. 2, an import interface may be provided in a user interface of a design system, allowing a user to import a specified image to be converted. Thus, when a user selects an image, the system can obtain the specified image and use it as the image to be converted. For example, referring to FIG. 5, when a user specifies an image of Marilyn Monroe in the user interface, the system uses this image as the image to be converted and converts it into a dot vectorized pattern for application on the photovoltaic module. Referring to FIG. 6, this dot vectorized pattern is generated based on the reference pattern shown in FIG. 3c.

[0036] Of course, in addition to importing an image to be converted, the user may also set some preset parameters in the user interface. Specifically, the preset parameters may include one or more of: a type of a reference dot vector unit, a reference pattern of the reference dot vector unit, a preset energy conversion efficiency Q_0 (and/or a preset energy loss rate P_0), a preset number N of reference dot vector units on each photovoltaic cell, a size D of isolated dots in each reference dot vector unit, and a preset dot density ρ_0.

[0037] In some embodiments, the types of the reference dot vector unit comprise: an architectural style, an artistic style, and a natural style. Each style comprises at least one reference pattern formed by dot arrays to form different specific patterns. Referring to FIG. 3a, taking a reference pattern of the architectural style including a cloud pattern as an example, it comprises: a first dot array 801 formed by a plurality of isolated dots arranged at equal intervals, and a plurality of second dot arrays 802 formed by a plurality of isolated dots arranged at equal intervals and surrounding the first dot array 801. That is, the first dot array 801 and the second dot arrays 802 form a preset cloud pattern, and the areas between them without isolated dots are uncolored regions 803. Of course, the gaps between the plurality of isolated dots are also uncolored regions 803. Correspondingly, when this first reference pattern is applied to a photovoltaic cell panel (e.g., forming the isolated dots in the dot array using an opaque material), each isolated dot forms an isolated light-blocking region. Correspondingly, the uncolored regions 803 between the isolated light-blocking regions

actually become light-transmitting regions (or light-transmitting channels) on the light incident surface of the photovoltaic cell panel, allowing light to pass through. That is to say, in this embodiment, apart from the isolated dot regions, there is no other structure on the light incident surface of the photovoltaic cell panel, which improves energy conversion efficiency or reduces the energy loss rate compared to a full coverage approach. Of course, in other embodiments, all isolated regions may be pre-arranged on a film with 100% or nearly 100% light transmittance and then covered onto the photovoltaic cell panel. Certainly, the dot array may also form other first reference patterns such as the "Eight Treasures" pattern or the "Apsaras" pattern. Referring to FIG. 3b, taking a reference pattern of the artistic style including a triangular element as an example, it comprises: a third dot array 804 formed by a plurality of isolated dots arranged in a six-armed asterisk configuration. Similarly, the gaps between the strokes of the six-armed asterisk are uncolored regions 803. When applied to a photovoltaic cell panel, the uncolored regions 803 between the isolated light-blocking regions become light-transmitting regions allowing light to pass through. Alternatively, described in another way, this reference pattern comprises: two fourth dot arrays 805 formed by a plurality of isolated dots arranged in a V-shaped configuration (including approximately V-shaped) and symmetrically arranged, and a fifth dot array 806 formed by a plurality of dots and located on a symmetry axis of the two fourth dot arrays 805. Referring to FIG. 3c and FIG. 3d, taking a reference pattern of the natural style including a leaf element as an example, it comprises: a sixth dot array 807 symmetrically arranged on left and right sides, and a seventh dot array 808 symmetrically arranged on upper and lower sides (i.e., formed by the sixth dot array 807 and the seventh dot array 808). Herein, referring to FIG. 3c, the sixth dot array 807 comprises: a first fan-shaped region 8071 formed by a plurality of isolated dots (similar to the shape of a ginkgo leaf), and second fan-shaped regions 8072 symmetrically arranged on two sides of the first fan-shaped region 8071 (also similar to the shape of a ginkgo leaf). The first fan-shaped region 8071 comprises a plurality of first dot array curves 8070 arranged at intervals along a radial extension direction from a center point, wherein curvature of the first dot array curves 8070 gradually increases in a direction away from the center point. The second fan-shaped regions 8072 comprise a plurality of second dot array curves 8070' arranged at intervals from a distal end toward a center point of the first fan-shaped region 8071, wherein curvature of the second dot array curves 8070' gradually increases in a direction toward the center point of the first fan-shaped region 8071. Referring to FIG. 3d, the seventh dot array 808 comprises: a first fan-shaped region 8071 formed by a plurality of isolated dots, and second fan-shaped regions 8072 symmetrically arranged on two sides of the first fan-shaped region 8071. The second fan-shaped regions 8072 comprise a plurality of second dot array curves 8070' arranged at intervals from a top end of the first fan-shaped region 8071 toward arc endpoints of the first fan-shaped region 8071, i.e., curvature of the second dot array curves 8070' gradually increases from the top end of the first fan-shaped region 8071 toward the arc endpoints of the first fan-shaped region 8071. As shown in FIGS. 3c and 3d, in the sixth dot array 807, the first fan-shaped regions 8071 on the left and right sides are tangent at a common vertex, and the center points of the first fan-shaped regions 8071 on the upper and lower sides are also located at this common vertex. Correspondingly, the arcs of the two second fan-shaped regions 8072

symmetric about the first fan-shaped region 8071 on the left and right sides are tangent at the center point of the first fan-shaped region 8071, while the center points of the two second fan-shaped regions 8072 symmetric about the first fan-shaped region 8071 on the upper and lower sides are located at the vertex of the first fan-shaped region 8071. As shown in FIGS. 3a to 3d, the number of isolated dots in each reference dot vector unit and the spacing between the isolated dots (i.e., the spacing between center points of the isolated dots) are pre-configured default values. Without changing the number of isolated dots or the spacing between them in each reference dot vector unit, and assuming the size of the isolated dots is identical, the dot density ρ_1 of the dot array in the reference pattern shown in FIG. 3a is greater than the dot density ρ_2 of the dot array in the reference pattern shown in FIG. 3b, and the dot density ρ_1 of the dot array in the reference pattern shown in FIG. 3a is less than the dot density ρ_3 of the dot array in the reference pattern shown in FIG. 3c or FIG. 3d. Herein, the dot density ρ is the ratio of the number n of isolated dots in the reference pattern to the area of the corresponding reference pattern. Of course, the boundary of each reference dot vector unit (i.e., the area of the reference dot vector unit) is the same, for example, the dot array is formed within a fixed-size rectangular region.

[0038] As mentioned earlier, the user can also set various parameters in the user interface, including desired energy conversion efficiency Q_0 (or STC efficiency) or preset energy loss rate P_0, the size D of isolated dots, and/or the type and/or number N of reference dot vector units on each photovoltaic cell, etc. For example, the user may set the desired energy conversion efficiency Q_0 (or STC efficiency) or preset energy loss rate P_0, as well as the type of reference dot vector unit in the user interface. As another example, the user may set the desired energy conversion efficiency Q_0 (or STC efficiency) or preset energy loss rate P_0, and the number N of reference dot vector units on each photovoltaic cell in the user interface, and then let the design system automatically match the optimal reference dot vector unit, isolated dot size D, and other parameters. As yet another example, the user may only set the desired energy conversion efficiency Q_0 (or STC efficiency) or preset energy loss rate P_0 and the preset dot density ρ_0 in the user interface, and then let the system automatically match the optimal reference dot vector unit, its number N, isolated dot size D, and other parameters. Refer to Embodiment 2 for details.

[0039] Typically, under each style, the number and spacing of isolated dots in each reference pattern adopt default values. However, by adjusting the size of the isolated dots, reference dot vector units with different shaded areas (i.e., different coverage rates) can be obtained. Therefore, it is also possible to find the corresponding optimal reference dot vector unit according to actual needs, i.e., to find the optimal reference pattern.

[0040] In step S102, the generated dot vectorized pattern comprises sub-patterns applied to each photovoltaic cell in the photovoltaic module, and the sub-pattern comprises at least one reference dot vector unit. For example, referring to FIG. 4a, each of the four photovoltaic cells of the colored photovoltaic

module corresponds to one reference dot vector unit. As another example, referring to FIG. 4b, each of the four photovoltaic cells of the colored photovoltaic module corresponds to four reference dot vector units spliced together. That is, identical sub-patterns are formed on each photovoltaic cell, and then the reference dot vector units on multiple photovoltaic cells are spliced to present a dot vectorized pattern that meets the expected resolution and corresponds to the specified image.

[0041] Since multiple photovoltaic cells in the colored photovoltaic module are connected in series or parallel, to avoid or mitigate the hot spot effect, the same number of reference dot vector units is generated on each photovoltaic cell, and the reference dot vector units on all photovoltaic cells adopt the same arrangement. That is, the dot vectorized pattern corresponding to the image to be converted is generated by using a specified type of reference dot vector unit, thereby ensuring that the shaded area on each photovoltaic cell is consistent, thus avoiding or mitigating the hot spot effect.

[0042] Additionally, dot density not only affects the shaded area on the photovoltaic cell, thereby influencing energy conversion efficiency, but also affects the resolution of the pattern presented by the dot vectorized pattern. Generally, assuming the size of the isolated dots is the same, the higher the dot density (i.e., the greater the number of isolated dots per unit area), the higher the resolution of the dot vectorized pattern, see FIG. 7. However, correspondingly, a higher dot density also means a larger shaded area, and thus lower energy conversion efficiency. Therefore, during specific implementation, the number of reference dot vector units on each photovoltaic cell and/or the size of the isolated dots can be set or adjusted according to actual requirements for energy conversion efficiency and the required resolution of the specified image, thereby setting or adjusting the dot density. For example, when the requirement for energy conversion efficiency is relatively high, but the resolution requirement for the specified image is relatively low (e.g., in applications like rooftops), one or a small number of reference dot vector units may be arranged on each photovoltaic cell. Conversely, when the requirement for energy conversion efficiency is relatively low, but the resolution requirement for the specified image is relatively high (e.g., in applications like billboards), multiple reference dot vector units may be arranged on each photovoltaic cell. Referring to FIG. 7, for each type of reference dot vector unit, corresponding dot vectorized patterns can be generated using, for example, 1 reference dot vector unit, 4 reference dot vector units, 9 reference dot vector units, or 16 reference dot vector units, thereby obtaining dot vectorized patterns with different energy conversion efficiencies and/or different resolutions. In the examples shown in FIG. 3a and FIG. 3d, since the dot density of the reference pattern of the natural style is the highest, the dot vectorized pattern generated based on the reference pattern of the natural style has the highest resolution; followed by the dot vectorized pattern generated based on the reference pattern of the architectural style.

[0043] In some embodiments, if the user has preset the energy conversion efficiency Q_0 (i.e., STC efficiency) or the energy loss rate P_0 (e.g., 20% or 30%), the preset dot density ρ_0, and the type of the reference dot vector unit. Correspondingly, this step S102 specifically comprises: S1021a inputting the

specified type of the reference dot vector unit, the preset energy conversion efficiency Q_0 or the preset energy loss rate P_0, and the preset dot density ρ_0 into a pre-trained matching model, to obtain a candidate dot-vectorized pattern set generated based on the reference dot vector unit of the specified type, and pattern parameters corresponding to each candidate dot-vectorized pattern in the set, wherein the pattern parameters comprise dot density, the number of the specified reference dot vector units on a single photovoltaic cell, and the size of each dot in the dot array of the reference dot vector unit; S1022a arranging all candidate dot-vectorized patterns in the candidate dot-vectorized pattern set in descending order according to a recommendation index T, and selecting from the candidate dot-vectorized pattern set at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index (e.g., the reference dot vector unit corresponding to the candidate dot-vectorized pattern with the highest index) as a candidate object to be designated; the recommendation index $T=Q_j^a*\rho_j^b*100\%$, or, $T=P_j^a*\rho_j^b*100\%$; wherein a represents a weight of the energy conversion efficiency Q_j or the energy loss rate P_j of the j-th candidate dot-vectorized pattern in the candidate dot-vectorized pattern set, and b represents a weight of the dot density ρ_j of the j-th candidate dot-vectorized pattern in the candidate dot-vectorized pattern set, and a + b = 1; S1023a when any candidate object to be designated is designated, converting the image to be converted into the corresponding dot vectorized pattern based on the designated candidate object and the pattern parameters thereof.

[0044] As mentioned earlier, each style includes different reference patterns. Therefore, the candidate dot-vectorized pattern set obtained in step S1021a includes candidate dot-vectorized patterns generated based on different reference patterns, for example, candidate dot-vectorized patterns generated based on a reference pattern having a cloud pattern, and candidate dot-vectorized patterns generated based on a reference pattern having an "Eight Treasures" pattern, etc.

[0045] Typically, when a user sets the energy conversion efficiency, they may also set, based on the current application scenario and experience, a desired dot density corresponding to a target resolution as a screening criterion. Therefore, when setting the energy conversion efficiency Q_0 (or/and the preset energy loss rate P_0), they will also set the preset dot density ρ_0. Consequently, each candidate dot-vectorized pattern in the candidate dot-vectorized pattern set from step S1021a conforms to the preset parameters, i.e., belongs to the same style, and its corresponding energy conversion efficiency is greater than or equal to the preset energy conversion efficiency Q_0 (or/and its energy loss rate is less than or equal to the preset energy loss rate P_0), and its dot density is greater than or equal to the preset dot density ρ_0.

[0046] Under the premise of meeting the preset energy conversion efficiency (i.e., greater than or equal to the preset energy conversion efficiency) or preset energy loss rate (i.e., less than or equal to the preset energy loss rate), different application scenarios have different requirements for energy conversion efficiency and pattern resolution. For example, for scenarios like rooftops, the requirement for energy

conversion efficiency is higher than that for pattern resolution (i.e., dot density). Therefore, the weight a is typically greater than the weight b. Conversely, for some building applications intended for advertising, the requirement for pattern resolution is higher than that for energy efficiency. Therefore, in the recommendation index of step S1022a, the weight b is greater than the weight a. The specific values of weights a and b are determined according to the actual application scenario and the experience of professional personnel.

[0047] Furthermore, even based on the same reference pattern of the same style, multiple candidate dot-vectorized patterns that meet the requirements (i.e., energy conversion efficiency greater than or equal to the preset energy conversion efficiency or energy loss rate less than or equal to the preset energy loss rate, and dot density greater than or equal to the preset dot density) but have different dot densities and different energy conversion efficiencies (or energy loss rates) can be generated. Correspondingly, during recommendation, for each reference pattern, one candidate dot-vectorized pattern with the maximum dot density may first be selected from among them (i.e., performing a primary screening). Then, the candidate dot-vectorized patterns from different reference patterns obtained through this screening are sorted, and at least one of the top-ranked patterns is recommended (i.e., performing a secondary screening). Since each reference pattern has initial pattern parameters: the number of isolated dots and the spacing between isolated dots (i.e., the distance between the centers of isolated dots), after the user designates an object, the number of isolated dots and the spacing between them for the designated object can also be adjusted. Of course, if the energy conversion efficiency and dot density of the adjusted designated object fall below the preset energy conversion efficiency and/or preset dot density, a prompt to readjust is issued.

[0048] Of course, after generating the dot vectorized pattern in step S102, i.e., after performing the image conversion, the color and size of the isolated dots in corresponding regions can be further adjusted according to actual requirements. For example, the dot size can be adjusted according to the required viewing distance. Specifically, this step S102 further comprises the steps of: S1024 obtaining a preset viewing distance; if the preset viewing distance is less than or equal to a preset first distance threshold, executing step S1025; if the preset viewing distance is greater than the first distance threshold but less than or equal to a preset second distance threshold, executing step S1026; if the preset viewing distance is greater than the second distance threshold but less than or equal to a preset third distance threshold, executing step S1027; S1025 adjusting the size of the isolated dots based on a graphics-oriented rule; S1026 adjusting the size of the isolated dots based on a balance-oriented rule; S1027 adjusting the size of the isolated dots based on an energy-oriented rule.

[0049] For example, referring to FIG. 8a and FIG. 24, when a pattern intended for close-range viewing (approximately 5 meters, i.e., the first distance threshold) is required, meaning it needs to be clearly visible at a close distance of about 5 meters, the system automatically adjusts the size of the isolated dots based on the graphics-oriented rule. This ensures that the energy harvesting efficiency of the photovoltaic module is

not affected by optimizing light penetration, thereby finding an optimal balance between close-range visibility and energy efficiency, ensuring the design is both aesthetically pleasing and efficient. The specific adjustment principles belong to the prior art and will not be repeated here. As another example, referring to FIG. 8b and FIG. 24, when a pattern intended for medium-range viewing (approximately 10 meters, i.e., the second distance threshold) is required, meaning it needs to be clearly identifiable at a medium distance of about 10 meters, the system automatically adjusts the size of the isolated dots based on the balance-oriented rule. While ensuring pattern visibility, it optimizes light penetration to ensure the energy harvesting efficiency of the photovoltaic module is not affected, thereby finding an optimal balance between medium-range visibility and energy efficiency, ensuring the design is both aesthetically pleasing and efficient. The specific adjustment principles belong to the prior art and will not be repeated here. As yet another example, referring to FIG. 8c and FIG. 24, when a pattern intended for long-range viewing (approximately 25 meters, i.e., the third distance threshold) is required, meaning it needs to be clearly identifiable at a distance of 25 meters or more, the system automatically adjusts the size of the isolated dots based on the energy-oriented rule, with the core objective of maximizing energy harvesting and efficiency. The specific adjustment principles belong to the prior art and will not be repeated here.

[0050] In step S103, an opaque material is used to form the dot array of the dot vectorized pattern, and the areas between the isolated dot arrays on the light incident surface of the photovoltaic panel form light-transmitting regions allowing light to penetrate.

[0051] In step S103, opaque coatings of different colors may be printed onto the photovoltaic cells. That is, the isolated light-blocking regions are arranged directly on the light incident surface of the photovoltaic cells, thus avoiding the impact of arranging other layers on light absorption.

[0052] In step S103, aligning the dot vectorized pattern with the photovoltaic module means that at least one reference dot vector unit on each photovoltaic cell is aligned with the photovoltaic cell. This ensures that each photovoltaic cell is shaded by similar regions of the pattern, and therefore, all photovoltaic cells receive nearly the same amount of solar irradiance, significantly reducing the probability of hot spot generation.

[0053] Since inks of different colors can affect the degree of light transmittance, potentially leading to the hot spot effect, in this embodiment, to avoid the hot spot issue, the coating material used for printing is opaque. Therefore, regardless of the color, as long as the type, number, and arrangement of the reference dot vector units on each photovoltaic cell are the same, they will produce the same shading effect on the photovoltaic cells, thus preventing hot spots.

[0054] In this embodiment, by providing three types of reference dot vector units with different styles (or containing different elements) for users to flexibly select, even the same specified image can present different visual effects, as shown in FIG. 7, thereby enabling users to design flexibly according to actual

needs. Compared to the prior art, which simply presents a specified image through densely arranged dot arrays, the visual effect here is richer. Moreover, the color of each isolated dot in each dot vector unit can correspond to the color of the corresponding area in the image to be converted, thereby converting the image to be converted into a dot vectorized pattern that meets energy conversion efficiency requirements. Since an opaque material will subsequently be used to realize the dot vectorized pattern, there are no longer color restrictions, allowing the design to adopt a color scheme nearly identical to the image to be converted, thereby maximizing the restoration of the image to be converted. Compared to the prior art, which uses colors with different light transmittances to form patterns on photovoltaic cells, significantly limiting color selection and failing to guarantee the fidelity of the image to be converted, this approach is advantageous.

[0055] In this embodiment, by specifying a reference dot vector unit, the user can convert any specified image into a dot vectorized pattern with multiple visual effects. For example, as shown in FIG. 25, based on a reference dot vector unit of the natural style, a blanket-style dot vectorized pattern (original image is a blanket pattern), a Mondrian-style dot vectorized pattern (original image is a pattern in Mondrian style), a Van Gogh-style dot vectorized pattern (original image is a pattern in Van Gogh style), a gradient color dot vectorized pattern, a mosaic tile dot vectorized pattern, and a silk-style dot vectorized pattern can be formed. Different patterns and material design types have their own characteristics and application scenarios in BIPV design. Patterns and materials such as blanket style, Mondrian style, Van Gogh style, gradient color, mosaic tiles, and silk style can not only provide unique aesthetic effects but also meet the functional requirements of buildings. By reasonably selecting and applying these patterns and materials, a perfect combination of architectural aesthetics and functionality can be achieved. As another example, shown in FIG. 26, based on a reference dot vector unit of the natural style, a leaf dot vectorized pattern (original image includes a leaf pattern), a flower dot vectorized pattern (original image includes a flower pattern), a water ripple dot vectorized pattern (original image includes a water ripple pattern), a rock stratum/stratum dot vectorized pattern (original image includes rock strata or strata), a fur dot vectorized pattern (original image includes fur), and a fruit dot vectorized pattern (original image includes fruit, such as a curved banana) can be formed. Different nature and texture pattern design types have their own characteristics and application scenarios in Building-Integrated Photovoltaic (BIPV) module design. Patterns such as leaves, flowers, water ripples, rock strata/strata, fur, and fruits can not only provide unique aesthetic effects but also endow buildings with natural vitality and energy. By reasonably selecting and applying these patterns, a perfect combination of architectural aesthetics and functionality can be achieved.

[0056] **Embodiment 2:** The present invention also provides another method for designing a colored photovoltaic module, which comprises the steps of the above-mentioned Embodiment 1. The difference is that, in this embodiment, the user only presets the energy conversion efficiency or the energy loss rate and the preset dot density ρ_0, without specifying any other parameters such as the type of the reference dot vector unit and the number N of reference dot vector units on each photovoltaic cell. Therefore, it is necessary to automatically specify or recommend at least one type of reference dot vector unit and its pattern

parameters, so that the finally obtained dot vectorized pattern meets expectations. Specifically, step S102 comprises the steps of: S1021 inputting the preset energy conversion efficiency Q_0 (or the preset energy loss rate P_0) and the preset dot density ρ_0 into a pre-trained matching model, to obtain three candidate dot-vectorized pattern sets generated based on the reference dot vector units of each style (i.e., a candidate dot-vectorized pattern set for the architectural style, a candidate dot-vectorized pattern set for the artistic style, and a candidate dot-vectorized pattern set for the natural style, wherein the candidate dot-vectorized pattern set for each style includes candidate dot-vectorized patterns generated based on different reference patterns of the corresponding style), and pattern parameters corresponding to each candidate dot-vectorized pattern; the pattern parameters comprise: dot density, the number of the reference dot vector units on a single photovoltaic cell, and the size of each dot in the dot array of the reference dot vector unit; S1022 arranging all candidate dot-vectorized patterns in each candidate dot-vectorized pattern set in descending order according to a recommendation index T, and respectively selecting from the three candidate dot-vectorized pattern sets at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index (for example, one candidate dot-vectorized pattern with the highest recommendation index from all candidate dot-vectorized patterns) corresponding to the reference dot vector unit as a candidate object to be designated; the recommendation index $T= Q_{i,j}^{a}*\rho_{i,j}^{b}*100\%$, or $T= P_{i,j}^{a}*\rho_{i,j}^{b}*100\%$; wherein a is a weight of the energy conversion efficiency $Q_{i,j}$ or the preset energy loss rate $P_{i,j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, b is a weight of the dot density $\rho_{i,j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, and $a + b = 1$, $i = 1, 2, 3$; S1023 when any candidate object to be designated is designated, converting the image to be converted into the corresponding dot vectorized pattern based on the number and the size of the isolated dots obtained in step S1021.

[0057] In some embodiments, the energy loss rate P and the energy conversion efficiency Q (i.e., STC efficiency) of the colored photovoltaic module are both related to the shaded area of each photovoltaic cell. The shaded area of each photovoltaic cell is related to the number of reference dot vector units arranged thereon (or dot density) and the size D of the isolated dots, i.e., $Q = f(N, D)$. Therefore, a training set can be pre-constructed to train a machine learning model, thereby obtaining the matching model. This model enables automatic conversion based on the input energy conversion efficiency or energy loss rate and dot density to obtain specific parameters such as the number of each reference dot vector unit in each style and the size of the isolated dots required to achieve the preset energy conversion efficiency (or preset energy loss rate) and preset dot density. The training set comprises: dot-vectorized pattern sets having different energy conversion efficiencies (or different energy loss rates, e.g., all greater than or equal to 20%-30%) and different dot densities, and each dot-vectorized pattern is pre-labeled with the type of the corresponding reference dot vector unit and its specific reference pattern (e.g., cloud pattern, or "Eight Treasures" pattern, etc.), and its pattern parameters, such as the number of reference dot vector units on each photovoltaic cell,

the size of isolated dots, and the spacing between isolated dots and the number of isolated dots in the reference dot vector unit. Of course, knowing the number of reference patterns on each photovoltaic cell (i.e., the number of reference dot vector units) and the corresponding size of isolated dots, the dot density ρ corresponding to the dot vectorized pattern can be calculated as $\rho = (N * n) / S$; wherein n is the number of isolated dots in the reference dot vector unit; S is the area of a single photovoltaic cell; N is the number of reference dot vector units on a single photovoltaic cell.

[0058] As mentioned earlier, even based on the same reference pattern of the same style, multiple candidate dot-vectorized patterns that meet the requirements (i.e., energy conversion efficiency greater than or equal to the preset energy conversion efficiency or energy loss rate less than or equal to the preset energy loss rate, and dot density greater than or equal to the preset dot density) but have different dot densities and different energy conversion efficiencies (or energy loss rates) can be generated. Therefore, the candidate dot-vectorized pattern set for each style includes not only candidate dot-vectorized patterns for each reference pattern within that style, but also multiple candidate dot-vectorized patterns corresponding to the same reference pattern within that style. Thus, during recommendation, for a candidate dot-vectorized pattern set of the same style, for each reference pattern, one candidate dot-vectorized pattern with the maximum dot density may first be selected from among them (i.e., performing a primary screening). Then, the candidate dot-vectorized patterns from different reference patterns obtained through this screening are sorted, and at least one of the top-ranked patterns is recommended (i.e., performing a secondary screening).

[0059] Correspondingly, when the user does not specify a reference pattern nor the type of the reference dot vector unit, but inputs the preset energy conversion efficiency or the preset energy loss rate and the preset dot density ρ_0 into the pre-trained matching model, three candidate dot-vectorized pattern sets corresponding to the three styles will be obtained, along with the pattern parameters for each candidate dot-vectorized pattern. For example, let $M_k=\{m_{k,1}, m_{k,2}\cdots m_{k,q}\}$ be the candidate dot-vectorized pattern set for the k-th style (k=1, 2, 3), where each candidate dot-vectorized pattern has an energy conversion efficiency greater than or equal to the preset energy conversion efficiency, or an energy loss rate less than the preset energy loss rate; wherein $m_{kj}(j=1,2\cdots p)$ is the j-th candidate dot-vectorized pattern in the k-th candidate dot-vectorized pattern set, and its corresponding pattern parameters obtained via the matching model include: dot density, the number N_k on a single photovoltaic cell, and the size of each isolated dot.

[0060] Furthermore, since the user does not specify the number of isolated dots and/or the spacing between isolated dots in each reference dot vector unit, the number of isolated dots and the spacing between them for each candidate dot-vectorized pattern are system default values, thereby reducing the system's computational load. Of course, if the user chooses to randomize the selection of the number of isolated dots and the spacing between them, then each candidate dot-vectorized pattern set generated by the matching model will include not only candidate dot-vectorized patterns corresponding to different reference patterns

of the same style, but also candidate dot-vectorized patterns of the same style and the same reference pattern but with different numbers of isolated dots and/or different spacings.

[0061] Since the user does not specify the type of the reference dot vector unit, multiple candidate dot-vectorized patterns of different styles that meet the requirements will be obtained. Therefore, to save the user's workload and quickly match the optimal pattern parameters under each type of reference dot vector unit, the recommendation index for each pattern in the candidate set corresponding to each reference dot vector unit can be calculated based on the weight a for energy conversion efficiency and the weight b for dot density (related to resolution) preset by the user according to actual needs. The pattern with the highest recommendation index is selected from each candidate set and recommended to the user. This allows the user to specify one according to their preference or actual needs and obtain the pattern parameters of the specified candidate dot-vectorized pattern for automatic image conversion. This not only provides users with a convenient and feasible design method but also greatly saves the user's workload.

[0062] In other embodiments, the user's propensity indices β_1, β_2, and β_3 for the three styles ($\beta_1+\beta_2+\beta_3=1$) can also be obtained in advance. Therefore, when the candidate dot-vectorized pattern with the maximum density recommended for each of the three styles is obtained, the recommendation indices of these three candidate dot-vectorized patterns can be optimized based on the propensity indices: $T=\beta_q*（Q_j^a*\rho^b*100\%）$, wherein β_q is the propensity index for the q-th candidate dot-vectorized pattern, q=1, 2, 3. Sorting is then performed based on the optimized recommendation indices, and the one with the highest recommendation index is recommended to the user.

[0063] Of course, further, if the reference dot vector unit in the candidate dot-vectorized pattern recommended to the user is not the reference dot vector unit with at least the highest propensity index, in addition to recommending the one with the highest recommendation index as mentioned above, the candidate dot-vectorized pattern corresponding to the reference dot vector unit with the highest propensity index may also be pushed as an alternative recommendation for the user's reference.

[0064] Furthermore, if the candidate dot-vectorized pattern ultimately selected by the user is not the candidate dot-vectorized pattern corresponding to the reference dot vector unit with the highest propensity index, the propensity indices of the three types of reference dot vector units are revised accordingly. For example, the propensity index of the originally highest one is decreased by a preset decrement, while the propensity index of the reference dot vector unit corresponding to the candidate dot-vectorized pattern ultimately selected by the user is increased by a preset increment. In this embodiment, using the propensity index to influence the recommendation, rather than directly converting the image based solely on the reference dot vector unit corresponding to the user's highest propensity index, is intended to provide users with different visualization effects. This grants users greater flexibility in selection and aesthetic possibilities, avoiding the limitations associated with relying on a single reference dot vector pattern.

[0065] Of course, in other embodiments, the user may not set the preset dot density but instead directly input an expected resolution. Correspondingly, the dot density can be automatically calculated based on the resolution set by the user, and then input into the matching model together with other preset parameters for matching. The specific calculation method belongs to the prior art and will not be described in detail here.

[0066] **Embodiment 3:** The present invention also provides another method for designing a colored photovoltaic module, which comprises the steps of the above-mentioned Embodiment 1. The difference is that, in this embodiment, not only the energy conversion efficiency Q_0 or the energy loss rate P_0 and the preset dot density ρ_0 are set, but also a specific reference dot vector unit (i.e., a reference pattern with a specific texture pattern under a corresponding style) is specified. Therefore, it is necessary to automatically recommend or specify one based on the parameters set by the user. Correspondingly, step S102 comprises the steps of: S1021b inputting the specified reference dot vector unit, the preset energy conversion efficiency Q_0 or the preset energy loss rate P_0, and the preset dot density ρ_0 into a pre-trained matching model, to obtain a candidate dot-vectorized pattern set generated based on the specified reference dot vector unit, and pattern parameters corresponding to each candidate dot-vectorized pattern in the set; the pattern parameters comprise dot density, the number of the reference dot vector units on a single photovoltaic cell, and the size of each isolated dot in the reference dot vector unit; S1022b arranging all candidate dot-vectorized patterns in the candidate dot-vectorized pattern set in descending order according to a recommendation index, and selecting from the candidate dot-vectorized pattern set at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index corresponding to the reference dot vector unit as a candidate object to be designated; the recommendation index $T=Q_j^a*\rho_j^b*100\%$, or, $T=P_j^a*\rho_j^b*100\%$; wherein a is a weight of the energy conversion efficiency Q_j or the energy loss rate P_j of the j-th candidate dot-vectorized pattern in the candidate dot-vectorized pattern set, b is a weight of the dot density ρ_j of the j-th candidate dot-vectorized pattern in the candidate dot-vectorized pattern set, and $a + b = 1$; S1023a when any candidate object to be designated is designated, converting the image to be converted into the corresponding dot vectorized pattern based on the designated object and its number on a single photovoltaic cell and the size of the isolated dots.

[0067] As mentioned earlier, even with the same style, different reference patterns will yield different dot vectorized patterns. Therefore, the candidate dot-vectorized pattern set in step S1021a includes multiple candidate dot-vectorized patterns generated based on the same reference pattern, and these candidate dot-vectorized patterns differ in at least one parameter among energy conversion efficiency (all greater than or equal to the preset energy conversion efficiency) or energy loss rate (all less than or equal to the preset energy loss rate), dot density (all greater than or equal to the preset dot density), isolated dot size, and the number on a single photovoltaic cell. Thus, to save the user's workload, during the recommendation in step S1022b, the recommendation is made based on the recommendation index.

[0068] **Embodiment 4:** The present invention also provides another method for designing a colored photovoltaic module, which comprises the steps of any one of the above-mentioned Embodiment 1, Embodiment 2, or Embodiment 3. The difference is that, in order to achieve greater visual diversity in the pattern to meet specific user preferences and design aesthetics, after adjusting the size of the isolated dots using the above adjustment rules, the size and/or number of isolated dots in local regions of the dot vectorized pattern can be further randomly adjusted. Correspondingly, this step S102 further comprises the step of: S1028 obtaining adjustment parameters, and performing a randomization adjustment on the size of the dots in a specified region based on the adjustment parameters. Herein, the above adjustment parameters include the size and position of a designated local region. The size of the local region refers to the percentage of the local region in the area of the dot vectorized pattern. Preferably, this percentage is from 10% to 90%. Although the pattern on multiple photovoltaic cells is repetitive, randomizing the size and/or number of isolated dots increases the aesthetic appeal of the pattern while ensuring effective light penetration.

[0069] Referring to FIG. 11, the visual effects after random adjustment of isolated dots within local regions of different percentages are respectively presented, including randomizing the size of isolated dots, and randomizing the number of isolated dots. Of course, if randomization is disabled, the size of isolated dots in the local region is determined by the grayscale value of the image, see FIG. 12.

[0070] Furthermore, the shaded area of the photovoltaic module can be estimated based on the area of each isolated dot after randomization, thereby estimating the energy conversion efficiency. If the estimated energy conversion efficiency is lower than a preset minimum energy conversion efficiency, a prompt is issued to adjust the size of the isolated dots until the estimated energy conversion efficiency is greater than or equal to the preset minimum energy conversion efficiency. For example, this can be based on the difference between the energy conversion efficiency estimated after randomization and the preset minimum energy conversion efficiency.

[0071] **Embodiment 5:** The present invention also provides another method for designing a colored photovoltaic module, which comprises the steps of any one of the above-mentioned Embodiment 1, Embodiment 2, Embodiment 3, or Embodiment 4. The difference is that, in this embodiment, the color of each isolated dot can also be adjusted to meet user requirements while significantly affecting the aesthetics and functionality of the solar cell design. Correspondingly, this step S102 further comprises the step of: S1029 performing color adjustment on a designated region based on preset color adjustment parameters. Herein, the preset color adjustment parameters are input by the user through a user interface. Specifically, the color adjustment parameters comprise: respective values of the G, B, and R color channels. For example, referring to FIG. 9, the skin color of a designated region is adjusted; or, the mouth color is adjusted; simultaneously, the mouth color and the face color of a designated region are adjusted. The final adjusted dot vectorized pattern is shown in FIG. 10.

[0072] **Embodiment 6:** A system for designing a colored pattern applied in a photovoltaic module.

[0073] Based on the design methods of the above embodiments, the present invention also provides a system for designing a colored pattern applied in a photovoltaic module, comprising: a base pattern library configured to store different types of reference dot vector units; the types of the reference dot vector units comprise: an architectural style, an artistic style, and a natural style, and each style comprises at least one reference pattern formed by dot arrays to have different visual effects or different specific patterns; for example, a reference pattern of a cloud pattern formed by a dot array constituting an architectural element; a reference pattern of a triangle formed by a dot array presenting a geometric element; and a reference pattern of a leaf formed by a dot array constituting a natural element; a data acquisition module configured to acquire an image to be converted and preset parameters; the preset parameters comprise one or more of: a type of a reference dot vector unit, a reference pattern of the reference dot vector unit, a preset energy conversion efficiency Q_0 (or a preset energy loss rate P_0), and a preset dot density ρ_0; a pattern conversion module, connected to the data acquisition module, configured to convert the image to be converted into a corresponding dot vectorized pattern based on the preset parameters; the dot vectorized pattern enables an energy loss rate of a colored photovoltaic module to be less than or equal to a preset energy loss rate (e.g., 20% or 30%).

[0074] In some embodiments, the dot vectorized pattern comprises at least one reference dot vector unit located on each photovoltaic cell, and the pattern formed by the at least one reference dot vector unit on each photovoltaic cell is identical.

[0075] In some embodiments, the design system further comprises a human-computer interaction module configured to interact with a user to obtain the image to be converted specified by the user, and send it to the data acquisition module.

[0076] In other embodiments, the user may not specify the type of the reference dot vector unit, but instead require the system to automatically recommend one based on parameters set by the user, such as the preset energy conversion efficiency Q_0 or the preset energy loss rate, and the preset dot density ρ_0. Correspondingly, the design system further comprises: a first matching module configured to input the preset energy conversion efficiency Q_0 and the preset dot density ρ_0 into a pre-trained matching model, to obtain a candidate dot-vectorized pattern set generated for each type of reference dot vector unit, and pattern parameters corresponding to each candidate dot-vectorized pattern, the pattern parameters comprising dot density, and/or the number of the corresponding reference dot vector units on a single photovoltaic cell, and the size of each isolated dot in each type of reference dot vector unit; a second matching module configured to calculate a recommendation index for each candidate dot-vectorized pattern, arrange all candidate dot-vectorized patterns in each candidate dot-vectorized pattern set in descending order according to the recommendation index, and respectively select from each candidate dot-vectorized pattern set at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index corresponding to the reference dot vector unit as a candidate object to be designated; the recommendation

index $T=Q_{i,j}^{a}*\rho_{i,j}^{b}*100\%$, or, $T=P_{i,j}^{a}*\rho_{i,j}^{b}*100\%$; wherein a is a weight of the energy conversion efficiency $Q_{i,j}$ or the energy loss rate $P_{i,j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, b is a weight of the dot density $\rho_{i,j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, and $a + b = 1$; a third matching module configured to, when any candidate object to be designated is designated, obtain the reference dot vector unit corresponding to the designated object, which serves as the reference dot vector unit specified by the user.

[0077] **Embodiment 7:** Colored Photovoltaic Module (BIPV/BAPV)

[0078] The present invention also provides a colored photovoltaic module obtained based on the above-mentioned method for designing a colored photovoltaic module, which will be described in detail below with reference to specific embodiments and accompanying drawings.

[0079] The colored photovoltaic module of the present invention comprises: at least one photovoltaic cell, on which a pattern layer is disposed. Specifically, the pattern layer comprises: at least one reference dot vector unit, each reference dot vector unit comprising: a plurality of isolated light-blocking regions arranged according to a preset reference pattern of a specified style, and part or all of the isolated light-blocking regions form a specified pattern, such that an energy conversion efficiency of the photovoltaic module is greater than or equal to a preset energy conversion efficiency Q_0 (or such that an energy loss rate of the photovoltaic module is less than or equal to a preset energy loss rate). Herein, the above-mentioned isolated light-blocking regions are formed using an opaque material.

[0080] In some embodiments, the styles of the reference dot vector unit comprise an architectural style, an artistic style, and a natural style, and each style includes different reference patterns formed by a plurality of isolated light-blocking regions. The above-mentioned preset reference patterns include: a reference pattern where a plurality of isolated light-blocking regions (or referred to as isolated dots) form architectural elements, such as the classic architectural element: cloud pattern shown in FIG. 3a; or a reference pattern where a plurality of isolated light-blocking regions (or referred to as isolated dots) form geometric elements, such as the geometric element: triangle shown in FIG. 3b; or a reference pattern where a plurality of isolated light-blocking regions (or referred to as isolated dots) form natural elements, such as the natural element: curves or leaves shown in FIG. 3c.

[0081] Specifically, referring to FIG. 3a, the reference pattern of the architectural style: cloud pattern comprises: a first dot array 801 formed by a plurality of isolated light-blocking regions arranged at equal intervals, and a plurality of second dot arrays 802 formed by a plurality of isolated light-blocking regions arranged at equal intervals and surrounding the first dot array 801, wherein the uncolored regions on the light incident surface of the photovoltaic module located between the first dot array 801 and the second dot arrays 802 are light-transmitting regions 803. Of course, the uncolored regions between the isolated light-

blocking regions within the dot arrays are also light-transmitting regions 803. Referring to FIG. 3b, the reference pattern of the artistic style: triangle comprises: a third dot array 804 formed by a plurality of isolated light-blocking regions arranged in a six-armed asterisk configuration. Alternatively, in other embodiments, the reference pattern of the artistic style: triangle comprises: two fourth dot arrays 805 formed by a plurality of isolated light-blocking regions arranged in a V-shaped configuration and symmetrically arranged, and a fifth dot array 806 formed by a plurality of isolated light-blocking regions located on a symmetry axis of the two fourth dot arrays 805. Similarly, the uncolored regions on the light incident surface of the photovoltaic module located between dot arrays and between isolated light-blocking regions are light-transmitting regions 803. Referring to FIG. 3c and FIG. 3d, the reference pattern of the natural style: leaf comprises: a sixth dot array 807 symmetrically arranged on left and right sides, and a seventh dot array 808 symmetrically arranged on upper and lower sides. Herein, referring to FIG. 3c, the sixth dot array 807 comprises: a first fan-shaped region 8071 formed by a plurality of isolated light-blocking regions, and second fan-shaped regions 8072 symmetrically arranged on two sides of the first fan-shaped region 8071. The first fan-shaped region 8071 comprises a plurality of first dot array curves 8070 arranged at intervals along a radial extension direction from a center point, and curvatures of the plurality of first dot array curves 8070 gradually increase in a direction away from the center point. The second fan-shaped regions 8072 comprise a plurality of second dot array curves 8070' arranged at intervals from a distal end toward a center point of the first fan-shaped region 8071, and curvatures of the plurality of second dot array curves 8070' gradually increase in a direction toward the center point of the first fan-shaped region 8071. Referring to FIG. 3d, the seventh dot array 808 comprises: a first fan-shaped region 8071 formed by a plurality of isolated light-blocking regions, and second fan-shaped regions 8072 symmetrically arranged on two sides of the first fan-shaped region 8071. The first fan-shaped region 8071 comprises a plurality of first dot array curves 8070 arranged at intervals along a radial extension direction from a center point, and curvatures of the plurality of first dot array curves 8070 gradually increase in a direction away from the center point. The second fan-shaped regions 8072 comprise a plurality of second dot array curves 8070' arranged at intervals from a top end of the first fan-shaped region 8071 toward arc endpoints of the first fan-shaped region 8071, and curvatures of the plurality of second dot array curves 8070' gradually increase from the top end of the first fan-shaped region 8071 toward the arc endpoints of the first fan-shaped region 8071.

[0082] Preferably, since the number of isolated light-blocking regions in each type of reference dot vector unit adopts a default value, when the sizes of the isolated light-blocking regions are identical, the density ρ_1 of the isolated light-blocking regions in the reference pattern having the cloud pattern is greater than the density ρ_2 of the isolated light-blocking regions in the reference pattern having the triangle, and the density ρ_1 of the isolated light-blocking regions in the reference pattern having the cloud pattern is less than the density ρ_3 of the isolated light-blocking regions in the reference pattern having the leaf. The above-

mentioned specified pattern is specified by the user. Specifically, it can be downloaded via the internet, or specified in a library of the design system.

[0083] In this embodiment, the colored photovoltaic module used for building facades offsets building energy consumption through high design flexibility in color and pattern, and has the following advantages: (1) Customizable aesthetics in architecture. It can be customized to suit the unique visual requirements of any facade or architectural design by selecting from a variety of colors and patterns according to actual design needs. (2) Mitigation of hot spot risk. The dot vectorized pattern of the colored photovoltaic panel generated by the design methods of the above embodiments can minimize the impact of hot spots and ensure uniform energy distribution on the surface. (3) Advanced energy production. Compared to non-colored high-efficiency solar photovoltaic panels, most efficiency losses are kept within 20%.

[0084] Referring to FIG. 14 and FIGS. 15-16, based on the design methods of the above embodiments, colored photovoltaic modules M1, M2, M3, M5, M6, M9 having different dot vectorized patterns are respectively obtained. Each colored photovoltaic module comprises four photovoltaic cells, and the specified patterns formed by all isolated light-blocking regions on the four photovoltaic cells are different. (1) M1 to M4, M6 to M9: various printed patterns (color coverage rate from 18.66% to 61.51%); (2) M7, M8, M9: the same original printed pattern, but with different coverage rates: M-7 adopts full printing, with a color coverage rate of 100%; M-8 has a color coverage rate of 61.58%; M-9 has a color coverage rate of 26.48%.

[0085] Based on the colored photovoltaic module, the present invention also provides a renewable energy generator, comprising the above-mentioned colored photovoltaic module.

[0086] **Embodiment 8:** Characteristics and Reliability Testing of the Colored Photovoltaic Module

[0087] The characteristics and reliability of the colored photovoltaic module obtained by the design method according to any one of the above Embodiments 1-5 will be described below in conjunction with laboratory-scale test results. This test aims to evaluate the energy conversion efficiency of photovoltaic panels with various printed patterns and compare them with a reference benchmark photovoltaic panel M5 without a printed pattern. Furthermore, these evaluations were performed under Standard Test Conditions (STC: 1000 W/m², 25°C, AM 1.5G) using a high-precision solar simulator, ensuring the reliability of the study results.

[0088] According to the test results, the energy conversion efficiency improvement of the colored photovoltaic module (PV) obtained by the design method according to any one of Embodiments 1, 2, 3, 4, or 5 above is significantly better than that of full-color printed photovoltaic modules (e.g., M7) currently available on the market. Although the energy conversion efficiency of each colored photovoltaic module with a pattern is lower than that of the reference benchmark module M5, the application of the pattern

obtained by the design method of the present invention can effectively mitigate the efficiency loss. Moreover, colored photovoltaic modules with different pattern coverage rates (i.e., different blocking areas) all exhibit an acceptable reduction in energy conversion efficiency.

[0089] Laboratory-scale tests were conducted on colored photovoltaic modules obtained by the design method of the present invention to evaluate the performance of various photovoltaic panels with different printed patterns (including dot-vectorized patterns obtained by the design method of the present invention) and to compare their efficiency with the reference benchmark module M5 and a full-color printed photovoltaic panel M7 currently available on the market. The tests were performed using state-of-the-art solar simulators to ensure accuracy and reliability.

[0090] Equipment and Methods Used for the Testing:

[0091] 1. Solar Simulators: The electrical characteristics of the photovoltaic modules were tested using two state-of-the-art solar simulators with the following performance parameters: Pasan SunSim 3B by Meyer Burger (10 ms pulse); ModuleTest 3 by h.a.l.m. (100 ms pulse).

[0092] 2. Test Procedure: The test procedure was carried out under Standard Test Conditions (STC): 1000 W/m² irradiance, 25°C temperature, AM 1.5g spectrum.

[0093] The following colored photovoltaic modules, featuring various different printed patterns, were evaluated: (1) Referring to FIG. 13 and FIG. 14, M1 to M4, M6 to M9: Various printed patterns obtained by the design methods of the above embodiments, with color coverage rates ranging from 18.66% to 61.51%, see Table 1; (2) Referring to FIG. 15, M7, M8, M9: The same printed pattern (all obtained by the design methods of the above embodiments), but with different coverage rates (e.g., achieving different coverage rates by changing the size of the isolated regions): M7 is fully printed, with a color coverage rate of 100% (i.e., there are no transparent areas between the isolated dots); M8 uses a high coverage rate pattern, with a color coverage rate of 61.58%; M9 uses a low coverage rate pattern, with a color coverage rate of 26.48%; (3) Reference benchmark photovoltaic panel M5: A standard photovoltaic cell without any printed pattern; (4) M5C: Based on M5, covered with colored glass, with a color coverage rate of 26.48%.

[0094] 3. Results and Analysis.

[0095] 3.1 Performance Indicators: Table 1 below summarizes the key performance indicators for each photovoltaic module, including maximum power (Pmax), voltage at maximum power (Vmp), current at maximum power (Imp), open-circuit voltage (Voc), short-circuit current (Isc),and module energy conversion efficiency under standard test conditions (STC efficiency). Also listed is the efficiency loss compared to the reference baseline photovoltaic panel M5.

[0096] Table 1 Key performance indicators for each photovoltaic module

photovoltaic module	Pmax（W）	Vmp（V）	Imp（A）	Voc（V）	Isc（A）	STC efficiency（%）	coverage	Energy loss rate compared to M5 (%)
M1	200.95	32.22	93.56	39.35	6.61	13.64	26.48%	18.00
M2	187.52	32.27	87.16	39.18	6.14	12.73	26.48%	23.47
M3	213.67	32.27	99.32	39.41	6.96	14.50	18.66%	12.64
M4	193.83	32.28	90.06	39.24	6.30	13.15	26.48%	20.93
M5	176.62	32.30	82.02	39.18	5.73	11.98	0%	0.00
M5C	176.62	32.30	82.02	39.18	5.73	11.98	26.48%	27.99
M6	193.47	32.76	88.58	39.64	6.12	13.13	26.48%	21.09
M7	28.80	32.34	13.36	36.72	0.92	1.95	100.00%	88.27
M8	107.34	32.83	49.05	38.66	3.37	7.29	61.51%	56.15
M9	198.80	32.52	91.69	39.49	6.44	13.50	26.48%	18.86

[0097] All table data are based on a standard 60-cell photovoltaic panel (1.6 m × 1 m).

[0098] Referring to FIG. 16 and Table 1, the STC efficiencies of solar panels with different color coverage rates are compared: the M7 panel (full color) has a color coverage rate of 100%, but its STC efficiency is the lowest, at only 1.95%. This indicates that the traditional full-color printing method significantly reduces the STC efficiency of the solar panel. The M5 panel (a standard photovoltaic cell without any printed color) serves as the reference benchmark module, with a color coverage rate of 0% and the highest STC efficiency of 16.63%. Compared to M5, the STC efficiencies of the M1, M2, M3, M4, M5C (covered with colored glass), and M6 panels range from 12.73% to 14.5%, while the benchmark STC efficiency of M5 is 16.63%. A comparison of the M7, M8, and M9 panels shows that, under the premise of having the same number of reference dot vector units, controlling the size of the isolated dots can significantly affect both the STC efficiency and the aesthetics of the solar panel. The dot vectorized patterns generated by the design methods of the above embodiments effectively balance aesthetics and the STC efficiency of the solar panel. Referring to FIG. 17 and Table 1, the relative efficiency losses of panels with different color coverage rates are compared against the reference benchmark panel M5. Since the M5 panel consists of standard photovoltaic cells without any printed pattern and serves as the benchmark for comparison, its color coverage rate and relative efficiency loss are both 0%. Among these, the relative efficiency losses of the M1, M2, M3, M4, and M6 panels compared to the M5 panel range from 12.64% to 21.09%. In contrast, the full-color M7 panel exhibits a significant relative efficiency loss compared to the M5 panel, reaching as high as 88.27%. However, by using the design methods of the above embodiments,

the efficiency of the M8 and M9 panels has been improved, with relative efficiency losses of 56.15% and 18.86%, respectively.

[0099] In summary, the design method of the present invention effectively balances aesthetics and solar panel efficiency. The design method allows for the creation of visually appealing solar panels while minimizing the relative efficiency loss compared to conventional unprinted photovoltaic cells, whereas the energy conversion efficiency is improved compared to photovoltaic cells with full-color coverage.

[0100] 3.2 Analysis Summary: Referring to FIG. 18a to 18f, these are detailed voltage-current versus irradiance diagrams for each of modules M1 to M5 and M5C (each photovoltaic module comprises 60 photovoltaic cells). Referring to FIG. 19a to 19d, these are detailed voltage-current versus irradiance diagrams for M6 to M9 (each module comprises 60 photovoltaic cells). FIG. 20a is a detailed voltage-current versus irradiance diagram for M1, M2, M3, M4, M6, and M9 (each module comprises 60 photovoltaic cells). It presents a comparative analysis of the voltage-current characteristics versus irradiance levels for solar photovoltaic panels M1, M2, M3, M4, M6, and M9. The relationship between voltage (V) and current (A) for each solar photovoltaic panel is shown, with voltage on the x-axis and current on the y-axis, and irradiance (W/m^2) is represented by the area under the curves. FIG. 20b is a detailed voltage-current versus irradiance diagram for M1, M2, M3, M4, M5, and M5C (each module comprises 60 photovoltaic cells).From FIG. 20a and 20b, the impact of different patterns and colored glass covers on the STC efficiency of photovoltaic panels can be seen: Impact of the pattern: Panels with printed patterns (M1 to M9) generally exhibit lower STC efficiency compared to the reference benchmark panel M5, with efficiency losses ranging from 12.64% (M3) to 88.27% (M7). Benchmark performance (M5): The original cell without any printed pattern serves as the benchmark, having the highest maximum power (Pmax) and STC efficiency under Standard Test Conditions (STC). Impact of colored glass cover (M5 covered with colored glass): Covering the original cell with glass significantly reduces the STC efficiency, highlighting the impact of additional layers on photovoltaic performance. From FIG. 20a, it can be seen that M1 exhibits the highest current output across the entire voltage range, closely followed by M2. The current outputs of M3, M4, and M6 are slightly lower, with their curves clustering together, indicating similar and stable performance of the products obtained based on the design schemes of the above embodiments.

[0101] 3.3 Detailed Comparison.

[0102] 3.3.1 Comparison between M5 and M5C: M5: The original cell without any printed pattern serves as the benchmark, with a maximum power (Pmax) of 245.000 W and an STC efficiency of 16.63% under Standard Test Conditions (STC). M5C (covered with colored glass): The standard cell covered with colored glass shows a reduced maximum power (Pmax) of 176.616 W and an STC efficiency of 11.98%, indicating the impact of the glass cover. The efficiency loss compared to M5 is 27.99%. Referring to FIG. 21, the voltage-current characteristics and irradiance levels of two solar panels are compared: M5 (original

cell without printed pattern) and M5C (standard cell covered with colored glass). M5 serves as the benchmark, with a maximum power output of 245.000 W and an efficiency of 16.63% under Standard Test Conditions (STC). In contrast, the M5C model, which has a colored glass cover, shows a reduced maximum power output of 176.616 W and an STC efficiency of 11.98%. FIG. 21 clearly demonstrates the impact of the colored glass cover on the electrical performance of the panel. The current output of M5C is consistently lower than that of M5 across the entire voltage range. This reduction in current output is directly attributed to the optical losses introduced by the colored glass cover, affecting light transmission and energy conversion efficiency. The irradiance area under each curve provides a visual representation of the difference in power generation potential between the two. The irradiance area of M5 is significantly larger than that of M5C, indicating its superior power output capability. The smaller irradiance area of M5C is a direct result of the negative impact of the colored glass cover on the panel's performance.

[0103] 3.3.2 Comparison between M5 and M7, M8, and M9: M7: The panel with another specific pattern exhibits a significant performance drop, with a maximum power (Pmax) of 28.801 W and an STC efficiency of 1.95% under Standard Test Conditions (STC), see Table 1. The efficiency loss compared to M5 is 88.27%, see Table 1 and FIG. 17. M8: This panel has a maximum power (Pmax) of 107.345 W and an STC efficiency of 7.29%, see Table 1 and FIG. 16. The efficiency loss compared to M5 is 56.15%, see Table 1 and FIG. 17. M9: The printed panel with yet another specific pattern shows a maximum power (Pmax) of 198.803 W and an STC efficiency of 13.50%, see Table 1 and FIG. 16. The efficiency loss compared to M5 is 18.86%, see Table 1 and FIG. 17. It is evident from the comparison that M7 has the lowest performance, followed by M8, and then M9. This trend highlights the impact of pattern coverage rate on STC efficiency.

[0104] Referring to FIG. 22, a comparative analysis of the voltage-current characteristics versus irradiance levels for solar panels M5, M7, M8, and M9 is presented. In the figure, voltage is on the x-axis, current is on the y-axis, and irradiance (W/m^2) is represented by the area under the curves. M5, serving as the reference panel without any printed pattern, exhibits the highest current output across the entire voltage range. In contrast, M7, which has a full-color printed pattern, shows the lowest current output among the compared models. This significant reduction in current output can be attributed to the optical losses introduced by the continuous colored layer on the surface of the M7 panel. Interestingly, the M8 and M9 models, which employ dot-vectorized patterns designed according to the design methods of the above embodiments, demonstrate better performance compared to the M7 model. The current output of M8 is higher than that of M7, indicating that the optimized dot-vectorized pattern enhances light transmission and minimizes optical losses compared to a full-color printed pattern. M9 further improves upon the performance of M8, suggesting that a refined dot-vectorized pattern (due to its coverage rate, i.e., smaller blocking area) can effectively balance aesthetic appeal and solar cell efficiency. Furthermore, M5 has the largest irradiance area, indicating its superior power output capability. M9 closely follows M5, demonstrating the effectiveness of the optimized dot-vectorized pattern in maintaining high power output

while incorporating aesthetic design elements. The irradiance areas for M8 and M7 progressively decrease, reflecting their lower power generation capacity.

[0105] In summary, FIG. 22 provides a comprehensive comparison of the voltage-current characteristics and irradiance levels of solar panel modules with varying degrees of colored printed patterns. It presents the trade-off between aesthetic design and solar cell performance, indicating the potential of optimized dot-vectorized patterns to achieve a balance between visual appeal and energy generation efficiency.

[0106] 4. Efficiency Loss Comparison: Referring to FIG. 23, a box plot illustrates the efficiency loss of different solar panels compared to the benchmark panel M5. The box plot includes the M1, M2, M3, M4, M6, and M9 panels.

[0107] 4.1 Components of the Box Plot: Boxes: Represent the interquartile range (IQR), containing the middle 50% of the data. Whiskers: Extend from the box to the minimum and maximum values within 1.5 times the IQR. Outliers: Data points located outside the whiskers, indicating variability or unique characteristics.

[0108] 4.2 Interpretation of the Efficiency Loss Box Plot: Referring to FIG. 23: M1: The efficiency loss values are tightly clustered around the median, indicating consistent performance. There are no significant outliers, suggesting stable efficiency loss relative to M5. M2: Similar to M1, the efficiency loss is consistent, with a slightly wider interquartile range. No outliers are present, indicating stable efficiency loss performance. M3: The median efficiency loss is higher compared to M1 and M2, indicating a more significant performance drop relative to M5. The interquartile range is wider, suggesting greater variability in efficiency loss values. No significant outliers are present, indicating the variability is within expected ranges. M4: Shows a similar distribution of efficiency loss to M3, but with a slightly lower median efficiency loss. Variability is similar to M3, with no significant outliers. M6: The median efficiency loss is lower than that of M3 and M4 but higher than that of M1 and M2. The interquartile range is similar to M4, indicating moderate variability. No significant outliers are present. M9: The median efficiency loss is similar to M6 but slightly higher. The interquartile range is slightly wider, indicating greater variability. No significant outliers are present.

[0109] 4.3 Summary of Efficiency Loss Comparison: The box plot provides a visual summary of the distribution of efficiency losses for different solar panels relative to the unprinted panel M5. The M3 panel exhibits the highest efficiency loss and the greatest variability, while the M1 and M2 panels demonstrate the most stable performance with the smallest efficiency losses. The M4 and M6 panels show moderate efficiency loss and variability, with the M9 panel having slightly higher variability than M6. The analysis indicates that M5 (the benchmark) performs best, with the highest Pmax and STC efficiency, whereas the panel with a specific printed pattern (M7) shows a significant performance drop. The sparsely printed

pattern (M3, which has the smallest coverage rate) shows improved performance compared to other printed patterns (M2, M4, M6, M9 with the same coverage rate). Furthermore, covering the original cell with plain glass (M5 covered with glass) also significantly reduces efficiency.

[0110] 5. Characteristics of the Colored Photovoltaic Module. The colored photovoltaic panel obtained by the design method of the above embodiments has the following several notable characteristics: (1) Customizable aesthetics in architecture: Select from a variety of colors and patterns to meet the unique visual requirements of any facade or architectural design. (2) Mitigation of hot spot risk: Capable of automatically generating colored photovoltaic panel graphics and minimizing the hot spot effect while ensuring uniform energy distribution across the surface. (3) Applicability to different buildings: Suitable for commercial, residential, and public buildings, with sufficient versatility to be integrated into various projects. (4) Advanced energy production: Compared with non-colored high-efficiency solar photovoltaic panels, most efficiency losses are kept within 20%.

[0111] 6. Conclusion: By evaluating the performance of various photovoltaic panels with different printed patterns and comparing their efficiency with a benchmark module under Standard Test Conditions (STC): The original cell without any printed pattern (M5), serving as the benchmark, achieves the highest maximum power (Pmax) of 245.000 W and an STC efficiency of 16.63%. The cell covered with colored glass (M5C) shows significantly reduced performance, with a Pmax of 176.616 W and an STC efficiency of 11.98%, representing an efficiency loss of 27.99% compared to the benchmark. Panels with various printed patterns (M1 to M9) generally exhibit lower efficiency than the benchmark, with efficiency losses ranging from 12.64% (M3) to 88.27% (M7). The panel with a fully printed pattern (M7) demonstrates the most significant performance drop, with a Pmax of 28.801 W and an STC efficiency of 1.95%. Panels with a high coverage rate pattern (M8) and a low coverage rate pattern (M9) perform better than the fully printed panel but still show notable efficiency losses compared to the benchmark. The study indicates that while the benchmark panel without any printed pattern (M5) offers the highest efficiency, adding printed patterns generally reduces performance. However, the extent of this reduction varies depending on the type and coverage rate of the pattern. The fully printed panel (M7) shows the greatest performance decrease, whereas panels with a sparse pattern (M3) and low coverage rate (M9) maintain better efficiency. The efficiency improvement using the colored photovoltaic graphic generation algorithm is significantly better than that of the full-color printed panel (M7).

[0112] All Pmax values in this test are calculated based on a standard 60-cell photovoltaic panel (1.6 m × 1 m) (i.e., a photovoltaic panel or photovoltaic module having 60 photovoltaic cells).

[0113] It should be noted that, herein, the terms "comprises," "comprising," or any other variation thereof are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that includes a list of elements includes not only those elements but also other elements not expressly listed, or elements inherent to such process, method, article, or apparatus. Without further limitation, an element

defined by the phrase "comprising a ..." does not preclude the presence of additional identical elements in the process, method, article, or apparatus that includes the element.

[0114] Through the description of the above implementations, those skilled in the art can clearly understand that the methods of the above embodiments can be implemented by means of software plus a necessary general hardware platform, and of course also by hardware, but in many cases the former is a better implementation. Based on such understanding, the technical solution of the present invention essentially, or the part that contributes to the prior art, may be embodied in the form of a software product stored in a storage medium (such as ROM/RAM, a magnetic disk, an optical disc), comprising several instructions for causing a computer terminal (which may be a mobile phone, a computer, a server, or a network device, etc.) to perform the methods described in various embodiments of the present invention.

[0115] The embodiments of the present invention have been described above with reference to the accompanying drawings, but the present invention is not limited to the above specific implementations, which are merely illustrative and not restrictive. Under the teaching of the present invention, those of ordinary skill in the art can make many forms without departing from the spirit of the present invention and the scope protected by the claims, all of which fall within the protection of the present invention.

CLAIMS

1. A method for designing a dot-vectorized pattern applied to a colored photovoltaic module, wherein the method comprises the steps of:

S101 obtaining an image to be converted and preset parameters; wherein the preset parameters comprise one or more of: a type of a reference dot vector unit, a reference pattern of the reference dot vector unit, a preset energy conversion efficiency Q_0 and/or a preset energy loss rate P_0, and a preset dot density ρ_0; wherein the type of the reference dot vector unit comprises one or more of: an architectural style, an artistic style, and a natural style, and each style comprises at least one reference pattern formed by dots to produce different visual effects;

S102 converting the image to be converted into a dot-vectorized pattern for application to the photovoltaic module based on the preset parameters,wherein the dot-vectorized pattern enables the colored photovoltaic module to have an energy conversion efficiency greater than or equal to the preset energy conversion efficiency, or enables the colored photovoltaic module to have an energy loss rate less than or equal to the preset energy loss rate, and enables each photovoltaic cell in the photovoltaic module to have an identical shaded area;

wherein the dot-vectorized pattern comprises at least one of the reference patterns.

2. The method according to claim 1, wherein when preset parameters specified by a user comprise: the preset energy conversion efficiency Q_0 and/or the preset energy loss rate P_0, and the preset dot density ρ_0, step S102 specifically comprises the steps of:

S1021 inputting the preset energy conversion efficiency Q_0 or the preset energy loss rate P_0 and the preset dot density ρ_0 into a pre-trained matching model to obtain a candidate dot-vectorized pattern set generated based on each reference dot vector unit, and pattern parameters corresponding to each candidate dot-vectorized pattern; wherein the pattern parameters comprise the dot density, the energy conversion efficiency and/or the energy loss rate, the number of the reference dot vector units on a single photovoltaic cell, and the size of each isolated dot in the reference dot vector unit; wherein each candidate dot-vectorized pattern set comprises candidate dot-vectorized patterns having the same style but generated based on different reference patterns;

S1022 arranging all candidate dot-vectorized patterns in each candidate dot-vectorized pattern set in descending order according to a recommendation index, and respectively selecting, from each candidate dot-vectorized pattern set, the reference dot vector unit corresponding to at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index as a candidate object to be designated;

wherein the recommendation index is:

$T=Q_{i,j}^{a}*\rho_{i,j}^{b}*100\%$, or

$T=P_{i,j}^{a}*\rho_{i,j}^{b}*100\%$

wherein a represents a weight of the energy conversion efficiency $Q_{i,\ j}$ or the energy loss rate $P_{i,\ j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, and b represents a weight of the dot density $\rho_{i,\ j}$ of the j-th candidate dot-vectorized pattern in the i-th candidate dot-vectorized pattern set, and a + b = 1, and i = 1, 2, 3;

S1023 when the candidate object is designated, converting the image to be converted into the corresponding dot-vectorized pattern based on the pattern parameters obtained in step S1021;

or,

when the preset parameters specified by the user comprise the type of the reference dot vector unit, the preset energy conversion efficiency Q_0 and/or the preset energy loss rate P_0, and the preset dot density ρ_0, the step S102 specifically comprises:

S1021a inputting the type of the reference dot vector unit, the preset energy conversion efficiency Q_0 or the preset energy loss rate P_0, and the preset dot density ρ_0 into the pre-trained matching model to obtain a candidate dot-vectorized pattern set generated based on the reference dot vector unit of the specified type, and pattern parameters corresponding to each candidate dot-vectorized pattern,

wherein the pattern parameters comprise the dot density, the number of the reference dot vector units on a single photovoltaic cell, and the size of each isolated dot in the reference dot vector unit, and the candidate dot-vectorized pattern set comprises candidate dot-vectorized patterns having the specified style but different reference patterns;

S1022a arranging all candidate dot-vectorized patterns in the candidate dot-vectorized pattern set according to a recommendation index in descending order, and selecting, from the candidate dot-vectorized pattern set, the reference dot vector unit corresponding to at least one candidate dot-vectorized pattern ranked at the front according to the recommendation index as the candidate object to be designated,

wherein the recommendation index is:

$T=Q_j^{a}*\rho_j^{b}*100\%$, or

$T=P_j^{a}*\rho_j^{b}*100\%$;

wherein a represents a weight of the energy conversion efficiency Q_j or the energy loss rate P_j of the j-th candidate dot-vectorized pattern, and b represents a weight of the dot density $\rho(j)$ of the j-th candidate dot-vectorized pattern, and a + b = 1;

S1023a when the candidate object is designated, converting the image to be converted into the corresponding dot-vectorized pattern based on the designated candidate object and the pattern parameters thereof.

3. The method according to Claim 1, wherein the reference pattern of the architectural style comprises:

a first dot array formed by a plurality of isolated dots arranged at equal intervals; and a plurality of second dot arrays formed by a plurality of isolated dots arranged at equal intervals and surrounding the first dot array; and/or,

the reference pattern of the artistic style comprises: a third dot array formed by a plurality of isolated dots arranged in a six-armed asterisk configuration; or comprises: two fourth dot arrays formed by a plurality of isolated dots arranged in a V-shaped configuration and symmetrically arranged, and a fifth dot array formed by a plurality of isolated dots and located on a symmetry axis of the two fourth dot arrays; and/or,

the reference pattern of the natural style comprises:

a sixth dot array symmetrically arranged on left and right sides, and a seventh dot array symmetrically arranged on upper and lower sides;

wherein the sixth dot array comprises:

a first fan-shaped region formed by a plurality of isolated dots, and second fan-shaped regions symmetrically arranged on two sides of the first fan-shaped region, the first fan-shaped region comprises a plurality of first dot array curves arranged at intervals along a radial extension direction from a center point, wherein curvature of the first dot array curves gradually increases in a direction away from the center point;

the second fan-shaped regions comprise a plurality of second dot array curves arranged at intervals from a distal end toward a center point of the first fan-shaped region, wherein curvature of the second dot array curves gradually increases in a direction toward the center point of the first fan-shaped region; and/or,

wherein the seventh dot array comprises:

a first fan-shaped region formed by a plurality of isolated dots, and second fan-shaped regions symmetrically arranged on two sides of the first fan-shaped region,

the first fan-shaped region comprises a plurality of first dot array curves arranged at intervals along a radial extension direction from a center point, wherein curvature of the first dot array curves gradually increases in a direction away from the center point;

the second fan-shaped regions comprise a plurality of second dot array curves arranged at intervals from a top end of the first fan-shaped region toward an arc endpoint of the first fan-shaped region, wherein curvature of the second dot array curves gradually increases from the top end of the first fan-shaped region toward the arc endpoint of the first fan-shaped region.

4. The method according to any one of claims 1 to 3, wherein the preset parameters further comprise a preset viewing distance, and step S102 further comprises the steps of:

S1024 obtaining the preset viewing distance;

when the preset viewing distance is less than or equal to a preset first distance threshold, performing step S1025;

when the preset viewing distance is greater than the first distance threshold but less than or equal to a preset second distance threshold, performing step S1026;

when the preset viewing distance is greater than the second distance threshold but less than or equal to a preset third distance threshold, performing step S1027;

S1025 adjusting the size of the isolated dots based on a graphics-oriented rule;

S1026 adjusting the size of the isolated dots based on a balance-oriented rule;

S1027 adjusting the size of the isolated dots based on an energy-oriented rule.

5. The method according to any one of claims 1 to 3, wherein step S102 further comprises the steps of:

S1028 obtaining adjustment parameters, and performing randomization adjustment on a size and/or a number of isolated dots in a designated local region based on the adjustment parameters;

wherein the adjustment parameters comprise a size of the designated local region; and/or,

S1029 performing color adjustment on a designated region based on preset color adjustment parameters.

6. A method for designing a colored photovoltaic module, wherein the method comprises:

obtaining a dot-vectorized pattern applicable to the photovoltaic module according to the design method according to any one of claims 1 to 5;

S103 forming, by using an opaque material, dots of the dot-vectorized pattern on a light incident surface of the photovoltaic module, and aligning the dot-vectorized pattern with the photovoltaic module, such that, for each photovoltaic cell in the photovoltaic module, a shielding area of the photovoltaic cell that is covered by isolated light-blocking regions in the dots is identical;

wherein light-transmitting regions for light penetration are formed between the dots and between the isolated light-blocking regions.

7. A colored photovoltaic module, wherein the colored photovoltaic module comprises a pattern layer disposed on a light incident surface of a photovoltaic module, and the pattern layer comprises:

at least one base dot-vectorized unit disposed on each photovoltaic cell, wherein the base dot-vectorized unit comprises a plurality of isolated light-blocking regions arranged according to a preset base pattern of a specified style;

wherein part or all of the isolated light-blocking regions form a specified pattern on the photovoltaic module, such that an energy conversion efficiency of the photovoltaic module is greater than or equal to a

preset energy conversion efficiency Q_0, or an energy loss rate of the photovoltaic module is less than or equal to a preset energy loss rate P_0;

wherein the isolated light-blocking regions are formed by using an opaque material;

wherein the specified style comprises an architectural style, an artistic style, or a natural style, and each style comprises at least one base pattern formed by a plurality of isolated light-blocking regions.

8. The colored photovoltaic module according to claim 7, wherein the base pattern of the architectural style comprises:

a first dot array formed by a plurality of dots arranged at equal intervals, and a plurality of second dot arrays formed by a plurality of dots arranged at equal intervals and surrounding the first dot array, wherein gaps between the isolated light-blocking regions form light-transmitting regions of the photovoltaic module; and/or,

the base pattern of the artistic style comprises:

a third dot array formed by a plurality of dots arranged in a six-armed asterisk configuration, wherein gaps between the isolated light-blocking regions form light-transmitting regions of the photovoltaic module; or,

the base pattern of the artistic style comprises:

two fourth dot arrays formed by a plurality of dots arranged in a V-shape and symmetrically disposed, and a fifth dot array formed by a plurality of dots arranged along a symmetry axis of the two fourth dot arrays, wherein gaps between the isolated light-blocking regions form light-transmitting regions of the photovoltaic module; and/or,

the base pattern of the natural style comprises:

a sixth dot array symmetrically disposed on left and right sides and a seventh dot array symmetrically disposed on upper and lower sides; wherein,

the sixth dot array comprises:

a first fan-shaped region formed by a plurality of dots, and second fan-shaped regions symmetrically disposed on both sides of the first fan-shaped region,

wherein the first fan-shaped region comprises a plurality of first dot-array curves arranged at intervals along a radial extension direction from a central point, and curvatures of the first dot-array curves gradually increase in a direction away from the central point; and

the second fan-shaped regions comprise a plurality of second dot-array curves arranged at intervals from a distal end toward the central point of the first fan-shaped region, and curvatures of the plurality of

second dot-array curves gradually increase in a direction toward the central point of the first fan-shaped region; and/or

the seventh dot array comprises:

a first fan-shaped region formed by a plurality of isolated dots, and second fan-shaped regions symmetrically disposed on both sides of the first fan-shaped region,

wherein the first fan-shaped region comprises a plurality of first dot-array curves arranged at intervals along a radial extension direction from a central point, and curvatures of the first dot-array curves gradually increase in a direction away from the central point; and

the second fan-shaped regions comprise a plurality of second dot-array curves arranged at intervals from a top end of the first fan-shaped region toward arc endpoints of the first fan-shaped region, and curvatures of the plurality of second dot-array curves gradually increase in a direction from the top end of the first fan-shaped region toward the arc endpoints.

9. The colored photovoltaic module according to claim 8, wherein, when sizes of the isolated light-blocking regions are identical, a density ρ_1 of the isolated light-blocking regions in the base pattern of the architectural style is greater than a density ρ_2 of the isolated light-blocking regions in the base pattern of the artistic style, and the density ρ_1 of the isolated light-blocking regions in the base pattern of the architectural style is less than a density ρ_3 of the isolated light-blocking regions in the base pattern of the natural style; or, each photovoltaic cell is provided with one base pattern of the natural style.

10.A system for designing a dot vectorized pattern, wherein the system comprises:

a base pattern library configured to store different types of base dot vectorized units; wherein types of the base dot vectorized units comprise architectural style, artistic style, and natural style, and each style comprises at least one base pattern formed by dot arrays to produce different visual effects;

a data acquisition module configured to acquire an image to be converted and preset parameters; wherein the preset parameters comprise one or more of: a type of the base dot vectorized unit, a base pattern of the base dot vectorized unit, a preset energy conversion efficiency Q_0 and/or a preset energy loss rate P_0, and a preset dot density ρ_0;

a pattern conversion module connected to the data acquisition module and the base pattern library, and configured to convert the image to be converted into a corresponding dot vectorized pattern based on the preset parameters;

wherein the dot vectorized pattern enables an energy conversion efficiency of a photovoltaic module to be greater than or equal to the preset energy conversion efficiency, or enables an energy loss rate of the photovoltaic module to be less than or equal to the preset energy loss rate, and ensures that a shading area of each photovoltaic cell in the photovoltaic module is identical.