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(54) Title: METHODS AND SYSTEMS FOR MEASURING POWER OF AT LEAST A PHOTOVOLTAIC DEVICE

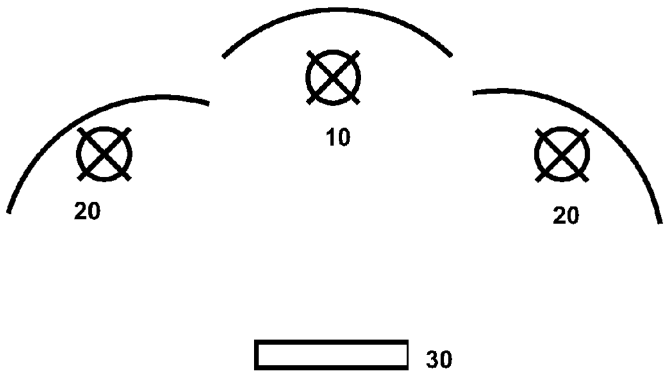

FIG. 2

(57) Abstract: Systems and methods for measuring power of at least a photovoltaic device (30). The method comprises the steps of: applying a first voltage to the photovoltaic device, conducting a first measurement of the photovoltaic device, conducting a second measurement of the photovoltaic device, and using a short measurement with the first voltage to calibrate the measurements with the second voltage. The first measurement of the photovoltaic device further comprises the step of illuminating the photovoltaic device with at least a first illumination source (10). The second measurement of the photovoltaic device further comprises the steps of: illuminating the photovoltaic device with at least a second illumination source (20), applying at least one of a first voltage and a second voltage during a second duration, and measuring an output current of the photovoltaic device.

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METHODS AND SYSTEMS FOR MEASURING POWER OF AT LEAST A PHOTOVOLTAIC DEVICE

FIELD OF THE INVENTION

[001] The present invention relates generally to processing of solar cells, and, more particularly to methods and systems for measuring electrical power of atleast a photovoltaic device in a cost effective, secure, environmentally safe, and efficient manner.

BACKGROUND OF THE INVENTION

[002] In the photovoltaic industry, sun simulators (also called 'flashers') are generally used in order to qualify the manufactured solar cells and solar modules. Sun simulators are artificial light sources capable of simulating the sunlight as closely as possible. In addition they apply a voltage or current to the photovoltaic device (also referred to as device under test or 'DUT').

[003] During the design process of such sun simulators, special care is taken to their light spectrum, light intensity and to the homogeneity of the light intensity on the photovoltaic device. The photovoltaic device may include a solar cell, a string, a matrix or modules of any type. The spectrum used depends on the way the photovoltaic device is tested, for example, normally a spectrum used for testing terrestrial application is AM1.5 and for space applications is AM0.

[004] For some solar cell technologies, for example the hetero-junction cells or dye-sensitized cells, the duration of illumination is an important parameter because accurate measurement of these devices may require from one tenth of a second to several seconds. For normal crystalline solar cells, the photovoltaic device is illuminated for some milliseconds to some tens of milliseconds. In both cases this period is the time needed to sweep thru a number of measurement points, for example, the voltage applied is varied from 0.0 to 0.6V and the current is measured. This sweep is done in a continuous way.

[005] The reason that these new technologies, for example, hetero-junction cells or dye-sensitized cells, need longer illumination times is that they have a higher electrical capacitance. Meaning that they can be interpreted as an RC-circuit that, when illuminated need some time to reach a stable output power. The reason why they have higher capacitance is currently debated in the scientific community.

[006] All actual testing equipments one single light source is used. This light source may consist of multiple types of light sources, but the point is that for all measurements the same light source is used.

[007] The normal approach to overcome the problem that the output power needs to stabilize is to increase the illumination duration or power or both. Since the life time of the light sources used, such as xenon lamps, is limited by the time they are turned on, longer illumination times reduces the number of photovoltaic devices that can be tested. Also higher output powers reduce life time of the photovoltaic devices because of the greater heat developed. Therefore it becomes difficult to provide light sources with long illumination times having long life times, making cost of ownership for the sun simulator higher.

[008] One possibility is to have long time-discharge xenon flashtubes, but this will lead to a spectrum that is very different from the sun's spectrum and therefore will require very strong optical filtering to get an acceptable light quality. Since a lot of light is filtered, this will increase the energy consumption.

[009] Another possibility is to design continuous-light systems wherein the light is turned on all the time. Usual light sources include xenon short-arc lamps, other gas-discharge lamps, Metal-Halide lamps, sulphur lamps, LEDs lamps, and tungsten incandescent lamps.

[0010] Another possibility would be to use usual tungsten-halogen lamps with strong filtering, but the amount of energy consumption by such system will become so high that such a system is not economically viable.

[0011] With such designs the light duration is not a problem, but the energy consumption is high because it is constant over time, the system doing measurements or not. Since continuous light sources normally need several minutes to reach steady state emission, they can not be turned off between measurements.

[0012] Also always, the life of the light source is limited, for example, continuous-light systems with usual (e.g. Xenon) lamps have a life time of ca. 1'000 hours, therefore, a lot of maintenance is needed and the cost for spare parts is high.

[0013] Some designs works with multiple xenon-flash strategies. One can sweep partially the I/V curve during one flash, and cover the full I/V curve by joining together the partial sweeps. This can be powerful for lab purposes, but time needed for such work is simply unacceptable for solar cell testing in production lines, because each partial sweep takes a certain time and the times for all sweeps have to be added.

[0014] Other methods may be considered as well like using a plurality of LEDs emitting at different wavelengths, the light from all LEDs together forming the spectrum of sun light. However, the availability of enough LEDs emitting different wave lengths and with sufficient power at reasonable price is not realistic at the moment.

[0015] In addition, the practical disposition of thousands of different LEDs will conduct to a large light source not suitable for accurate measurements since the optics to project all the light in a controlled manner onto the photovoltaic device becomes very difficult.

[0016] Accordingly, there exist needs for a cost effective sun simulator that can be used for solar cell technologies with high capacitance that has a longer life cycle and has lower energy consumption than the devices according to the state of the art.

SUMMARY OF THE INVENTION

[0017] In view of the foregoing disadvantages inherent in the prior arts, the general purpose of the present invention is to provide an improved combination of convenience and utility, to include the advantages of the prior art, and to overcome the drawbacks inherent therein.

[0018] The inventive system of the present invention provides a longer live cycle and has lower energy consumption than the devices according to the state of the art. Moreover the cost of ownership is also reduced.

[0019] In one aspect, the present invention provides a system for measuring efficiency of atleast a photovoltaic device, comprises atleast a first illumination source capable of closely mimicking a sun spectrum during a first illumination, the first illumination source having atleast a power output defined by a test done, atleast a second illumination source adapted to emit light within a sensitivity range of the photovoltaic device to be tested during a second illumination, means for applying atleast one of a voltage and a current to the photovoltaic device to be tested, means for measuring atleast one of a current and a voltage respectively during the first illumination and the second illumination, and means for calibrating the measurement made with the second illumination source to the first illumination source. Normally a series of measurements may be made with the second illumination source. The sun spectrum used depends on the way the photovoltaic device is tested, for example, normally a spectrum used for testing terrestrial application is AM1.5 and for space applications is AM0.

[0020] In another aspect, the present invention provides a method for testing atleast a photovoltaic device. The method comprises the steps of: applying atleast one of a first voltage and a first current to the photovoltaic device, conducting a first measurement of the photovoltaic device, applying atleast one of a second voltage and a second current to the photovoltaic device, conducting atleast a second measurement of the photovoltaic device, and using atleast a first illumination source that closely resembles a sun spectrum with atleast one of the first voltage and the first current to calibrate the second measurement. Normally atleast one of respectively the first voltage and the second voltage or the first current and the second current are identical to facilitate the calibration. The first measurement of the photovoltaic device further comprises the step of illuminating the photovoltaic device with atleast a first illumination source. The second measurement of the photovoltaic device further comprises the steps of: illuminating the photovoltaic device with atleast a second illumination source, applying atleast one of a first voltage, first current, a second voltage, and a second current during a second duration, and measuring atleast one of output currents and out put voltages of the photovoltaic device.

[0021] In another aspect, the present invention provides a method for measuring electrical power of atleast a photovoltaic device through a test. The method comprises the steps of mimicking closely the spectrum of sun during a first illumination, emitting light within a sensitivity range of the photovoltaic device to be tested during a second illumination, applying one of a voltage and a current to the photovoltaic device to be tested, measuring one of a current and voltage respectively during the first illumination and the second illumination, and calibrating the measurement made with the second illumination source to the first illumination source.

[0022] These together with other objects of the invention, along with the various features of novelty that characterize the invention, are pointed out with particularity in the claims annexed hereto and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated exemplary embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] While the specification concludes with claims that particularly point out and distinctly claim the invention, it is believed the expressly disclosed exemplary embodiments of the present invention can be understood from the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify the same elements. The drawings and detailed description which follow are intended to be merely illustrative of the expressly disclosed exemplary embodiments and are not intended to limit the scope of the invention as set forth in the appended claims. In the drawings:

[0024] FIG. 1 illustrates exemplary I/V curves for different illumination strengths;

[0025] FIG. 2 illustrates a system for testing efficiency of atleast a photovoltaic device, according to an exemplary embodiment of the present invention;

[0026] FIG. 3 illustrates an exemplary light sequence;

[0027] FIG. 4 illustrates a method for testing efficiency of atleast a photovoltaic device, according to an exemplary embodiment of the present invention;

[0028] FIG. 5 illustrates an exemplary method for testing the photovoltaic device, according to an embodiment of the present invention;

[0029] FIG. 6 illustrates an exemplary equivalent circuit for a solar cell;

[0030] FIG. 7 illustrates an exemplary working sequence for mathematical adjustment, according to an embodiment of the present invention;

[0031] FIG. 8 illustrates an exemplary working sequence for comparison around Mpp, according to an embodiment of the present invention;

[0032] FIG. 9 illustrates an exemplary method for pre-illumination the photovoltaic device, according to an embodiment of the present invention; and

[0033] FIG. 10 illustrates a method for measuring efficiency of atleast a photovoltaic device through a test, according to an embodiment of the present invention.

[0034] Like reference numerals refer to like parts throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE DRAWINGS

[0035] The exemplary embodiments described herein detail for illustrative purposes are subject to many variations of structure and design. It should be emphasized, however that the following description should not be used to limit the scope of the present invention. The present invention is not limited to particular system for measuring or testing efficiency or power of the photovoltaic device as shown and described. Rather, the principles of the present invention may be used with a variety of photovoltaic device power measuring or testing methods and structural arrangements. It is understood that various omissions, substitutions of equivalents are contemplated as circumstances may suggest or render expedient, but the present invention is intended to cover the application or implementation without departing from the spirit or scope of the its claims.

[0036] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without these specific details.

[0037] As used herein, the term ‘plurality’ refers to the presence of more than one of the referenced item and the terms ‘a’, ‘an’, and ‘atleast’ do not denote a limitation of quantity, but rather denote the presence of atleast one of the referenced item. The term ‘device’ also includes ‘engine’ or ‘machine’ or ‘system’ or ‘apparatus’.

[0038] The terms ‘photovoltaic device’, ‘solar cell’, ‘photovoltaic cell’, ‘cell’ and ‘wafer’ may also be used herein interchangeably and may also denote part of such devices. The photovoltaic device may be of any technology such as thin film, crystalline, hetero junction (HIT), etc. The photovoltaic device also includes wafer and thin film module. A plurality of photovoltaic device may form a matrix. Further, a solar module may be made with photovoltaic devices with a protective such that the protective member may be suited for being part of the solar module.

[0039] The term ‘photovoltaic device’ includes solar cell, string, matrix, and solar module and may also be used herein interchangeably. The terms ‘first illumination source’, ‘first illumination’, ‘first illumination device’ and ‘reference illumination’ may also be used herein interchangeably to refer to the same thing. The terms ‘second illumination source’, ‘second illumination’, ‘second illumination device’ and ‘reference illumination’ may also be used herein interchangeably to refer to the same thing.

[0040] The terms ‘measuring’ and ‘testing’ may also be used herein interchangeably to refer to the same thing. The terms ‘power’ and ‘efficiency’ may also be used herein interchangeably to refer to the same thing.

[0041] The solar simulator apply a voltage or current to the photovoltaic device (also referred to as device under test or ‘DUT’) to test the efficiency of the photovoltaic device. During testing, the other quantity, for example, current or voltage respectively, is read out to obtain current versus voltage (I/V) points. These points may be formed into an I/V diagram from which a maximum power point (also referred to ‘Mpp’) is determined. The Mpp is a point on the curve where current multiplied by the voltage gives the highest value. The Mpp is a measure used for the efficiency of the photovoltaic device, so basically not all points on the I/V diagram are needed, only the Mpp.

[0042] Referring to FIG. 1 which shows an exemplary I/V curves for different illumination strengths. The vertical line connects the Mpp of the curves. Determining the Mpp is a part of the efficiency measurement, i.e., the maximum converted power. Efficiency is the converted power produced by the photovoltaic device 30 divided by the optical power impinging on the photovoltaic device30.

[0043] Referring to FIG. 2, which illustrates a system 100 for measuring efficiency of atleast a photovoltaic device 30 through atleast a test, according to an exemplary embodiment of the present invention. A first accurate testing (measurement) of the photovoltaic device 30 may be made with a first illumination source 10 that mimics the sun’s spectrum very exactly. Then further measurements may be made with atleast a second illumination source 20 whose spectrum only has to fall within the sensitivity range of the photovoltaic device 30. The first exact measurement may be used to calibrate the measurements made with less accurate spectrum.

[0044] Moreover, after the first exact measurement preferably near a short circuit current (herein after referred to as ‘Isc’), i.e., zero voltage applied to the photovoltaic device 30 and its terminals are short circuited, the illumination level of the lower quality ‘Direct Current (also known as ‘DC’) light source’ may be adjusted as to obtain the same short-circuit current as was measured with good spectral illumination conditions, for example, with a short pulse of a normal xenon lamp. This will mean that the same current as before is generated inside the solar cell junction, so it is now possible to sweep the I/V curve of the photovoltaic device 30 at any convenient, possibly very low speed, without shortening the life time of the (xenon) flashbulb.

[0045] Adjusting current under secondary (DC) illumination by adjusting radiated power is equivalent to compensate for spectral mismatch and light intensity for this particular illumination. The ‘DC light source’ may be a true DC light source that is turned on all the time or simply a light source suitable for longer light flashes.

[0046] The first, reference illumination has to be as exact as possible in terms of spectral content, intensity (as shown in FIG. 1: Mpp moves with intensity) and uniformity. For a xenon flashtube light source, spectral content is usually obtained by careful control of current inside the flashtube, i.e., by using of highly accurate current source), plus adding convenient spectral filters in the light path.

[0047] The capacitance of the solar cells is positively correlated to the applied voltage. The capacitance is relatively low when the solar cell is short circuited (i.e., the solar cell with zero volts applied) and increases with the voltage applied. The capacitance may increase by a factor of 10 or even more when the voltage increases to the maximum power point (herein after referred to as 'Mpp'). Therefore measuring around Isc is faster than around Mpp or Open collector voltage (herein after referred to as 'Voc'). The poles of the solar cell are not connected so that no current can flow, the duration of the flash for the accurate measurement may be further reduced.

[0048] The one of the advantages of the present invention is that the inventive system has a longer live cycle and has lower energy consumption. Moreover the cost of ownership is also reduced.

[0049] According to an exemplary embodiment of the present invention, other methods may be considered as well like using a plurality of LEDs and usual tungsten-halogen lamps with strong filtering.

[0050] In addition, the practical disposition of thousands of different LEDs will conduct to a large light source not suitable for accurate measurements since the optics to project all the light in a controlled manner onto the photovoltaic device 30 becomes very difficult. However, according to the present invention, the LEDs do not have to mimic the spectrum of sun light and therefore less LEDs may be used, i.e., only the LEDs emitting at a certain wave length such that the light from all LEDs may together form the spectrum of sun light, are needed and the LEDs that would have been necessary to form the sun light spectrum outside that range may not be used.

[0051] FIG. 2 illustrates a system 100 (also referred to as 'sun simulator') for measuring power (efficiency) of atleast a photovoltaic device 30 through atleast a test. The system 100 comprises atleast a first illumination source 10 capable of closely mimicking a sun spectrum during a first illumination, the first illumination source having atleast a power output defined by a test done, atleast a second illumination source 20 adapted to emit light within a sensitivity range of the photovoltaic device 30 to be tested during a second illumination; means (not shown) for applying atleast one of a voltage and a current to the photovoltaic device 30 to be tested; means (not shown) for measuring atleast one of a current and a voltage respectively during the first illumination and the second illumination, and means for calibrating the measurement made with the second illumination source to the first illumination source.

[0052] The first illumination source 10 having a power output defined by the test done. The test may be carried out to determine or measure Mpp, I/V curve, efficiency of the photovoltaic device. The sun spectrum used depends on the way the photovoltaic device 30 is tested, for example, normally a spectrum used for testing terrestrial application is AM1.5 and for space applications is AM0. Further, applying atleast one of the voltage and the current to the photovoltaic device 30 includes short circuiting (Voltage=0) the photovoltaic device 30. Normally a series of measurements may be made with the second illumination source.

[0053] An optical power may be defined for the test being carried out. The optical power may be changed according to the nature of the photovoltaic device 30 or other testing requirement. For example, an optical power output of the first illumination source 10 may includes 1kW/m2, 800W/m2, 200W/m2, or any other suitable etc.

[0054] The first illumination device 10 may have good spectral content and good uniformity characteristics. The second illumination devices 20 (auxiliary light sources) may have long duration characteristic.

[0055] Referring to FIG. 3 which illustrates an exemplary light sequence, wherein the numeral 11 depicts a first duration, i.e., a time/period of a first illumination (illumination by the first illumination source 10) and measurement of Isc. The numeral 12 depicts second duration, i.e., a first period of a secondary illumination (illumination by the second illumination source 20) for an adjustment of illumination to reach the same Isc than in the time 11 of the first illumination. The numeral 13 depicts a full I/V measurement period under the secondary illumination.

[0056] The second illumination source 20 may have a narrower power spectrum than that of the first illumination. Also mixing of multiple colours (not loosing huge amounts of light) is no problem. Only intensity and distribution on the photovoltaic device 30 has to be considered.

[0057] According to an exemplary embodiment of the present invention, one single type of LEDs, probably with on single peak in their power spectrum, may be used with any of the first illumination source 10 and the second illumination source 20.

[0058] Referring to FIG. 4 which illustrates a method 200 for measuring power of atleast the photovoltaic device 30, comprising the steps of: applying atleast a first voltage and a first current to the photovoltaic device 30, for example, preferably 0.0 Volts are applied and the photovoltaic device 30 is short circuited, at a step 212, conducting atleast a first measurement of the photovoltaic device 30 at a step 214, applying atleast one of a second voltage and a second current to the photovoltaic device 30 at a step 215, conducting a second measurement of the photovoltaic device 30 at a step 216, and using a short measurement with the first voltage to calibrate the measurements with the second voltage at a step 218.

[0059] The second measurement may per measurement take just as long as the first measurement. The main difference is that not the complete spectrum is used and that normally the second measurement is repeated to record (part) of the IV curve to find Mpp. Preferably 0.0 Volts are applied and the photovoltaic device 30 is short circuited. Normally atleast one of respectively the first voltage and the second voltage or the first current and the second current are identical to facilitate the calibration.

[0060] The first measurement of the photovoltaic device 30 may comprises the steps of illuminating the photovoltaic device 30 with atleast a first illumination source 20 which is adapted to closely mimicking the sun's power spectrum for a first duration 11 and measuring the current.

[0061] The second measurement of the photovoltaic device 30 may comprises the steps of illuminating the photovoltaic device 30 with atleast a second illumination source 20 with a power spectrum overlapping with the sensitivity range of the photovoltaic device 30 for a second duration 12, applying atleast one of a first voltage, a first current, a second voltage, and a second current during the second duration 12, and measuring atleast one of an output currents and out put voltages of the photovoltaic device 30.

[0062] According to an exemplary embodiment of the present invention, the testing of the photovoltaic device 30 may also be carried out by applying a current and measure the voltage. However, the measurement may stabilise much quickly in case of applying a voltage to the photovoltaic device 30 and measuring the current than doing the reverse. The reason is that when applying a voltage, the current may flow freely up to reach the stabilization point. When applying a current, the voltage may adapt slowly as the internal capacitor has to charge or discharge with the difference of internal and external currents. That may take quite long.

[0063] The first duration 11 (duration of the first measurement of the photovoltaic device 30) may be shorter than atleast one of 20, 10 or 5ms. The second duration 12 (duration of the second measurement of the photovoltaic device 30) being longer than 50, 100, 500 ms.

[0064] Referring to FIG. 5 which illustrates an exemplary method 300 (working sequence - adjustment of voltage) for testing the photovoltaic device 30, according to an embodiment of the present invention. The method 300 may comprises the steps of: installing the photovoltaic device 30 on a tester at a step 312, switching-on reference/first illumination (e.g. xenon flash) at a step 314, performing current measurement (preferably Isc) and recording the measured current at a step 316, switching-off reference/first illumination 10 and switching-on auxiliary/second illumination at a step 318, adjusting the auxiliary illumination to obtain the same current as under reference illumination and keeping the auxiliary illumination to this value at a step 322, sweeping atleast partially an I/V curve of the photovoltaic device 30 at a step 324 while keeping optical output of the second (auxiliary) illumination constant, recording as many points as desired at a step 326, switching-off the auxiliary illumination at a step 328, performing additional tests like dark reverse or other measurements, if required at a step 332, applying corrections means(Voc, Isc, Mpp, FF, Rseries, Rshunt, classification, etc.) extraction on atleast a measured data point at a step 334, storing the desired values and transmit useful information to other equipments (e.g. sorting equipments) at a step 336, and removing the photovoltaic device 30 from the tester 70 at a step338.

[0065] Sweeping I/V curve means that the output current or voltage of the photovoltaic device 30 is controlled. Setting the voltage may result in a certain output current. The voltage and the current then for one point on the I/V curve of the photovoltaic device 30. Normally the goal is to obtain the complete I/V curve of the photovoltaic device 30. From this curve the Mpp point may be found. As, reference illumination 10 may be not exactly at the desired irradiance, so a correction is needed. In addition, correction may also be needed to correct for temperature differences.

[0066] According to an exemplary embodiment of the present invention, atleast one of a dark reverse voltage and current may be adapted. The dark reverse a test to check the resistance of the solar cell to reverse voltage without being illuminated. Dark reverse may be used to prevent hot-spots when the solar cell is into modules. It is also a measure of the shunt resistance of a solar cell.

[0067] The additional test may be any test ranging from, for examples, dark direct (resistance of the solar cell to a voltage without being illuminated), capacitance measurement, colour determination, electroluminescence, etc.

[0068] Parameters that are of interest are: Voc, Isc, Mpp, FF, Rseries, Rshunt, classification according to efficiency, etc. Shunt and series resistance as shown in the FIG. 6 equivalent circuit for a solar cell.

[0069] Referring to FIG. 7 which illustrates an exemplary method 400 (working sequence- mathematical adjustment) for testing the photovoltaic device 30, according to an embodiment of the present invention. The method 400 may comprises the steps of: switching-on the first illumination source 10 at a step 412, applying atleast one of a voltage and a current to the photovoltaic device 30 at a step 414, measuring atleast one of the current and the voltage respectively under the first illumination source 10 at a step 416, switching-on the auxiliary illumination 20 at a step 418, sweeping atleast partially the I/V curve at a step 422, and correcting the full I/V curve mathematically according to the measured Isc under reference illumination 10 at a step 424. Preferably this measurement may be done at the Isc. The measured difference between the two measured Isc may be used to correct auxiliary illumination for the next solar cell (adaptative adjustment).

[0070] Here the order/steps the illuminations are used in may be reversed as well: (steps 702, 704, 706 – steps 708, 712) -> (steps 708, 712 – steps 702, 704, 706).

[0071] Referring to FIG. 8 which illustrates an exemplary method 500 (working sequence) for testing the photovoltaic device 30, according to an embodiment of the present invention. The method 500 may comprises the steps of: applying or sweeping around atleast one of an expected voltage and expected current around Mpp to the photovoltaic device 30 at a step 512, switching-on reference illumination 10 at a step 514, recording atleast one of a corresponding current and voltage respectively at a step 516, while keeping atleast one of the voltage and the current constant on the photovoltaic device 30, switching-off reference illumination 10 at a step 518, switching-on auxiliary illumination 20 at a step 522, adjusting irradiance on auxiliary illumination 20 at a step 524 to reach the same current as with reference illumination 10 while keeping voltage constant on the photovoltaic device 30 and identical to the step 516, fixing the auxiliary illumination 20 level at a step 526, and sweeping the full I/V curve under auxiliary illumination 20 at a step 528. This is quite the same sequence as of the method 300. The only difference is that the comparison of currents is made at a defined voltage across the photovoltaic device 30 that may be close to Mpp voltage.

[0072] According to an exemplary embodiment of the present invention, preferential sweep may be adapted, i.e., the sweep may be performed around where the Mpp is expected. Predictor may be previous photovoltaic device or a theoretical value. In production batches, good photovoltaic devices 30 have the same properties within a dispersion of say 10 %. Only bad photovoltaic devices 30 may differ largely. Sweeping on a 15 to 20 % range of the full I/V curve may cover all good photovoltaic devices 30 cases.

[0073] Referring to FIG. 9 which illustrates a method 600 for pre-illumination of the photovoltaic device 30, according to an exemplary embodiment of the present invention. The method 600 may comprises the steps of: switching-on the auxiliary illumination 20 in order to perform a 'light-soaking' function at a step 612, switching-off or keeping turned on the auxiliary illumination 20 and immediately switch-on the reference illumination 10 at a step 614, recording the Isc under reference illumination 10 at a step 616, switching-off or keeping turned on the reference illumination 10 and immediately switch-on the auxiliary illumination 20 at a step 618, adjusting Isc under auxiliary illumination 10 by varying illumination at a step 812, and sweeping the full I/V curve under adjusted auxiliary illumination 20 at a step 814. Light soak means the capacitance of the photovoltaic device is already charged before the measurement starts.

[0074] The order the light sources reference and auxiliary illumination sources used in may be reversed.

[0075] Continuous adjustment: Since form testing or measurement of one Photovoltaic device 30 to a next photovoltaic device 30, normally the Mpp may not change too much, therefore when using the second light source, the same power as used for the previous photovoltaic device 30 may be applied for the next photovoltaic device 30.

[0076] Referring to FIG. 10 which illustrates a method 700 for measuring electrical power of atleast a photovoltaic device 30 through a test. The method comprises the steps of mimicking closely the spectrum of sun during a first illumination at a step 712, emitting light within a sensitivity range of the photovoltaic device 30 to be tested during a second illumination at a step 714, applying one of a voltage and a current to the photovoltaic device 30 to be tested at a step 716, measuring one of a current and voltage respectively during the first illumination and the second illumination at a step 718, and calibrating the measurement made with the second illumination source to the first illumination source at a step 722.

[0077] In other instances, well-known methods, procedures, components, and circuits have not been described herein so as not to obscure the particular embodiments of the present invention. Further, various aspects of embodiments of the present invention may be performed using various means, such as integrated semiconductor circuits, computer-readable instructions organized into one or more programs, or some combination of hardware and software.

[0078] Although a particular exemplary embodiment of the invention has been disclosed in detail for illustrative purposes, it will be recognized to those skilled in the art that variations or modifications of the disclosed invention, including the rearrangement in the configurations of the parts, changes in sizes and dimensions, variances in terms of shape may be possible. Accordingly, the invention is intended to embrace all such alternatives, modifications and variations as may fall within the spirit and scope of the present invention.

[0079] The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is understood that various omissions, substitutions of equivalents are contemplated as circumstance may suggest or render expedient, but is intended to cover the application or implementation without departing from the spirit or scope of the claims of the present invention.

CLAIMS

What is claimed is:

1. A system for measuring power of atleast a photovoltaic device, comprising:

atleast a first illumination source capable of closely mimicking a sun spectrum during a first illumination, the first illumination source having atleast an optical power output defined by a test done;

atleast a second illumination source adapted to emit light within a sensitivity range of the photovoltaic device to be tested during a second illumination;

means for applying one of a voltage and a current to the photovoltaic device to be tested;

means for measuring one of a current and voltage respectively during the first illumination and the second illumination; and

means for calibrating the measurement made with the second illumination source to the first illumination source.

2. The system of claim 1, wherein the second illumination source having a power spectrum narrower than that of the first illumination.

3. The system of claim 1, wherein atleast a single type of LEDs with on single peak in their power spectrum are adapted as atleast one of the first illumination source and the second illumination source. .

4. The system of claim 1, wherein an optical power of atleast one of the first illumination source and second illumination source is defined according to the nature of the photovoltaic device for a test being carried out.

5. A method for testing atleast a photovoltaic device, comprising the steps of:

applying atleast one of a first voltage and a first current to the photovoltaic device;

conducting a first measurement of the photovoltaic device;

applying atleast one of a second voltage and a second current to the photovoltaic device;

conducting a second measurement of the photovoltaic device; and

using a first illumination source that closely resembles a sun spectrum with atleast one of the first voltage and the first current to calibrate the second measurement,

wherein normally atleast one of respectively the first voltage and the second voltage or the first current and the second current are identical to facilitate the calibration.

6. The method of the previous claim, wherein the second measurement of the photovoltaic device further comprising the steps of: illuminating the photovoltaic device with atleast a second illumination source; applying atleast one of a first voltage, a first current, a second voltage, and a current during a second duration; and measuring atleast one of output currents and out put voltages respectively of the photovoltaic device.

7. The method of previous claims, wherein a duration of the first measurement of the photovoltaic device is shorter than atleast one of 20, 10, 5ms, wherein the duration of the second measurement is longer than atleast one of 50, 100, 500 ms.

8. The method of previous claims, wherein a working sequence for adjustment of voltage for testing the photovoltaic device comprising the steps of:

installing the photovoltaic device on a tester;

switching-on reference/first illumination;

performing current measurement and recording the measured current;

switching-off the first illumination source and switching-on the second illumination source;

adjusting the second illumination source to obtain the same current as under first illumination source and keeping the second illumination source to this value;

sweeping atleast partially a I/V curve of the photovoltaic device while keeping the optical output of the second illumination constant;

recording atleast a desired point;

switching-off the second illumination source; and

removing the photovoltaic device from the tester.

9. The method of previous claims, wherein atleast one of a dark reverse voltage and a current is adapted to check the resistance of the photovoltaic device to reverse voltage without being illuminated.

10. The method of previous claims, wherein a working sequence for a mathematical adjustment for testing the photovoltaic device further comprising the steps of:

switching-on the first illumination source;

applying atleast one of a voltage and current to the photovoltaic device;

measuring atleast one of the current and the voltage respectively under the first illumination source;

switching-on the second illumination source;

sweeping atleast partially the I/V curve; and correcting the recorded I/V curve mathematically according to atleast one of the measured current and voltage under first illumination source.

11. The method of previous claims further comprising the step of preferential sweep adapted to be performed around where the Mpp is expected.

12. The method of previous claims further comprising the step of switching-on the second illumination source in order to perform a light-soaking function.

13. A method for measuring electrical power of atleast a photovoltaic device through a test, comprising the steps of:

mimicking closely the spectrum of a sun spectrum during a first illumination;

emitting light within a sensitivity range of the photovoltaic device to be tested during a second illumination;

applying one of a voltage and a current to the photovoltaic device to be tested;

measuring one of a current and voltage respectively during the first illumination and the second illumination; and

calibrating the measurement made with the second illumination source to the first illumination source.

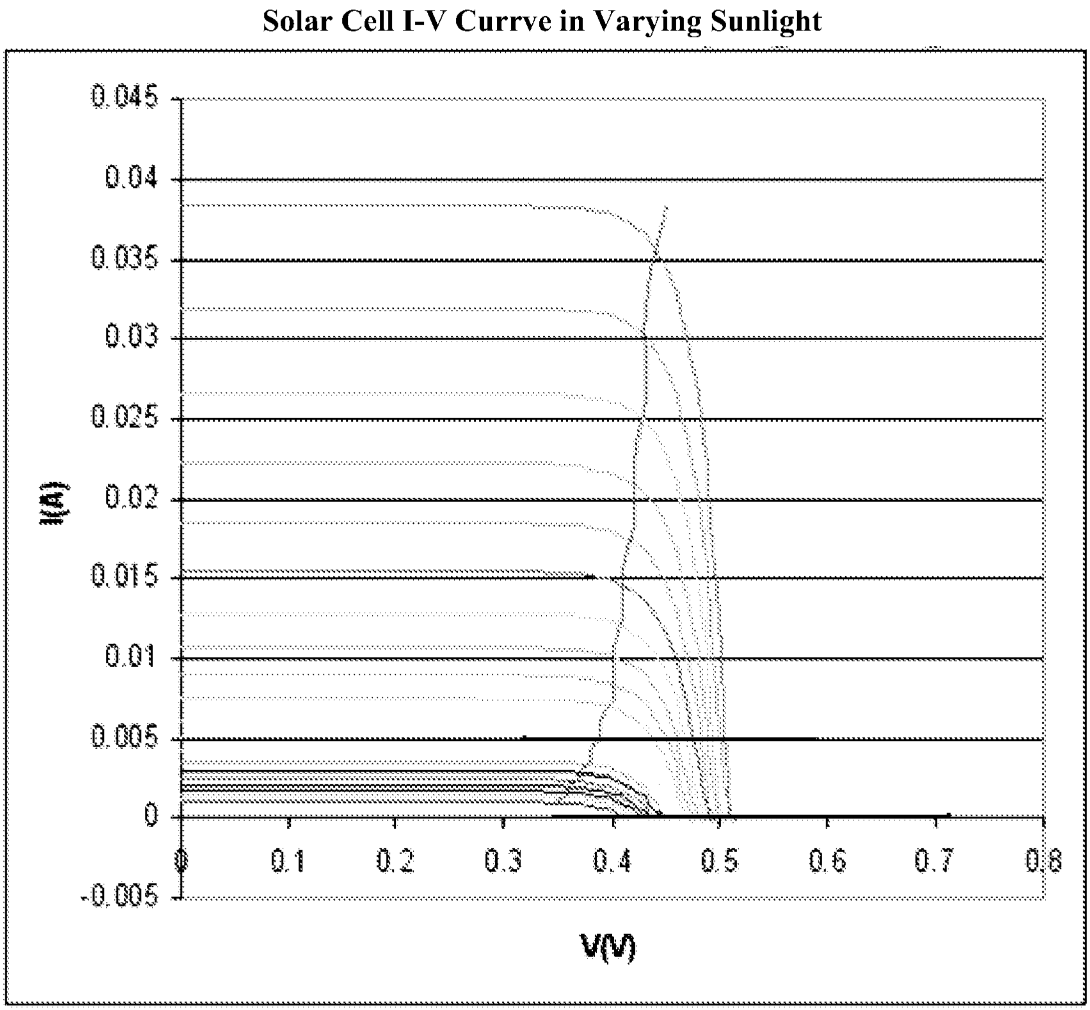
Solar Cell I-V Currve in Varying Sunlight
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
I(A)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
V(V)

FIG. 1

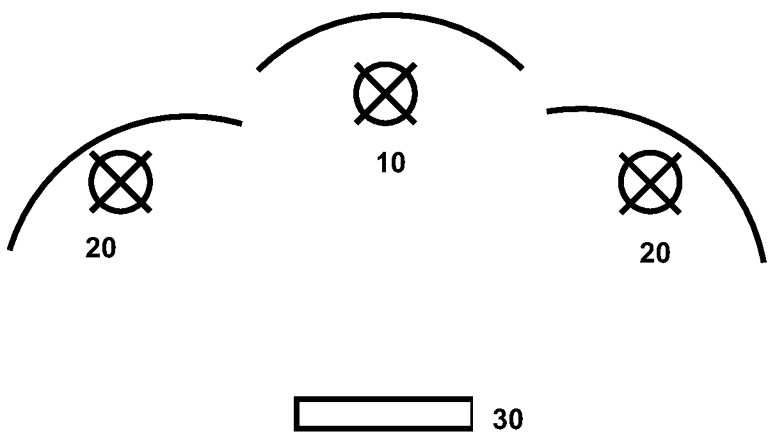
10
20
20
30

FIG. 2

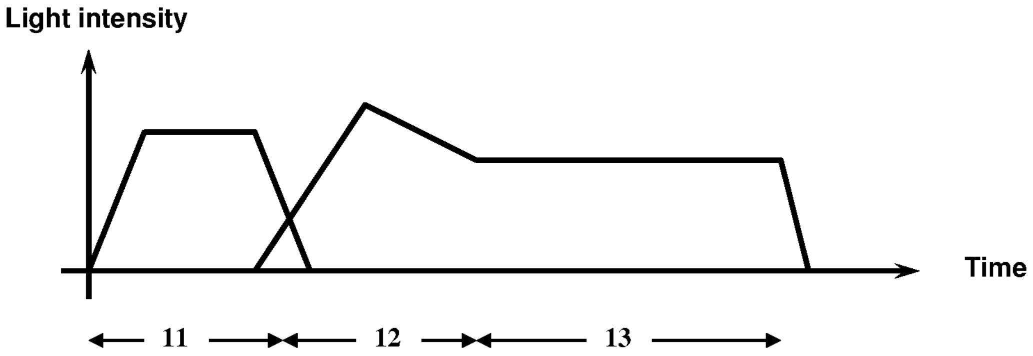
Light intensity
Time
11
12
13

FIG. 3

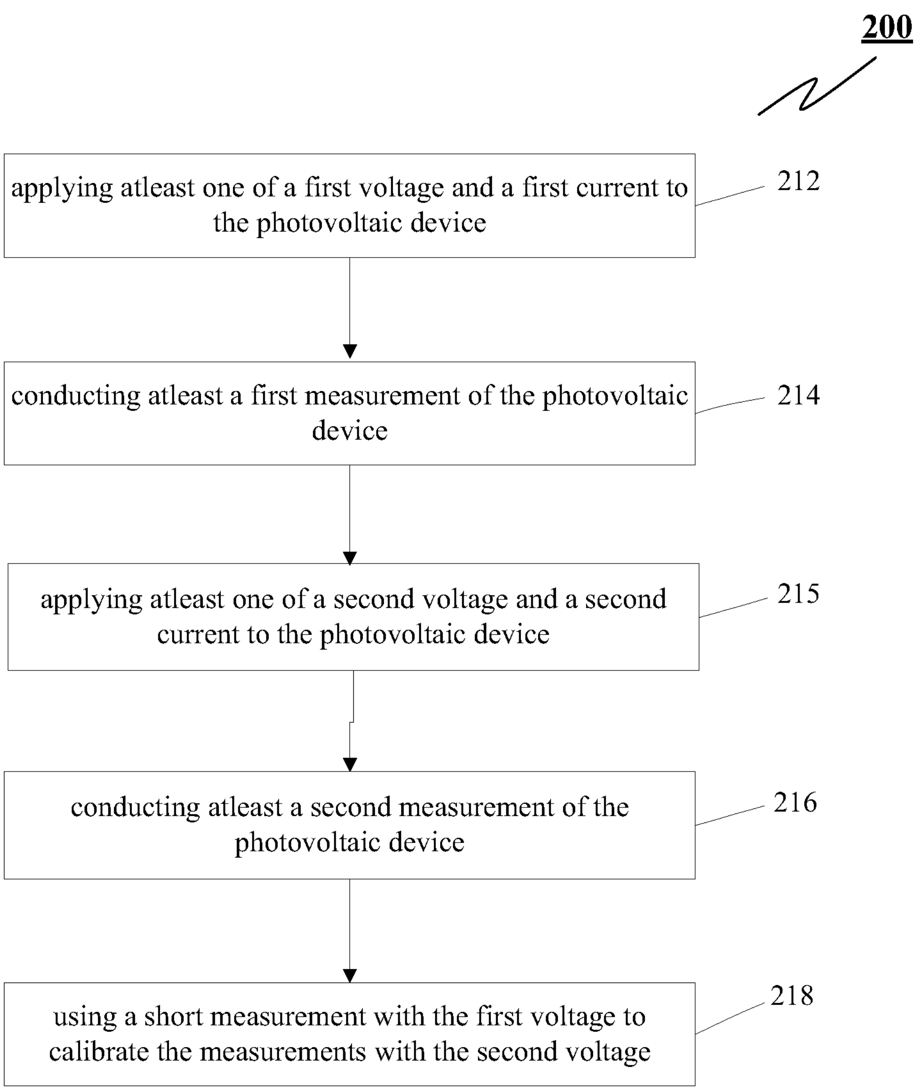
200
applying atleast one of a first voltage and a first current to the photovoltaic device
212
conducting atleast a first measurement of the photovoltaic device
214
applying atleast one of a second voltage and a second current to the photovoltaic device
215
conducting atleast a second measurement of the photovoltaic device
216
using a short measurement with the first voltage to calibrate the measurements with the second voltage
218

FIG. 4

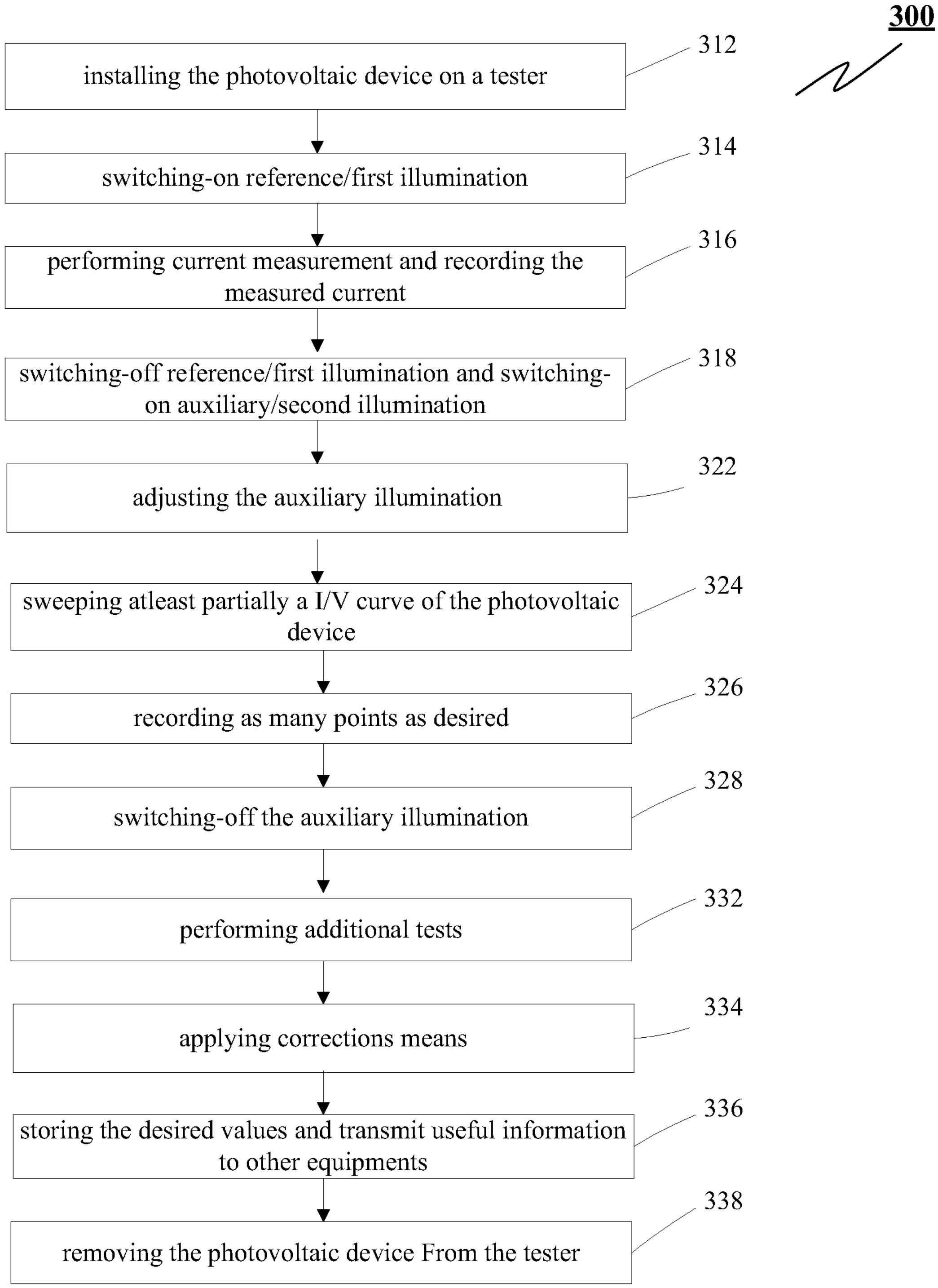
300
installing the photovoltaic device on a tester
312
switching-on reference/first illumination
314
performing current measurement and recording the measured current
316
switching-off reference/first illumination and switching-on auxiliary/second illumination
318
adjusting the auxiliary illumination
322
sweeping atleast partially a I/V curve of the photovoltaic device
324
recording as many points as desired
326
switching-off the auxiliary illumination
328
performing additional tests
332
applying corrections means
334
storing the desired values and transmit useful information to other equipments
336
removing the photovoltaic device From the tester
338

FIG. 5

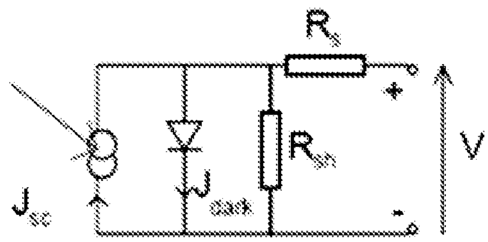
R
R
V
J
J
+
-

FIG. 6

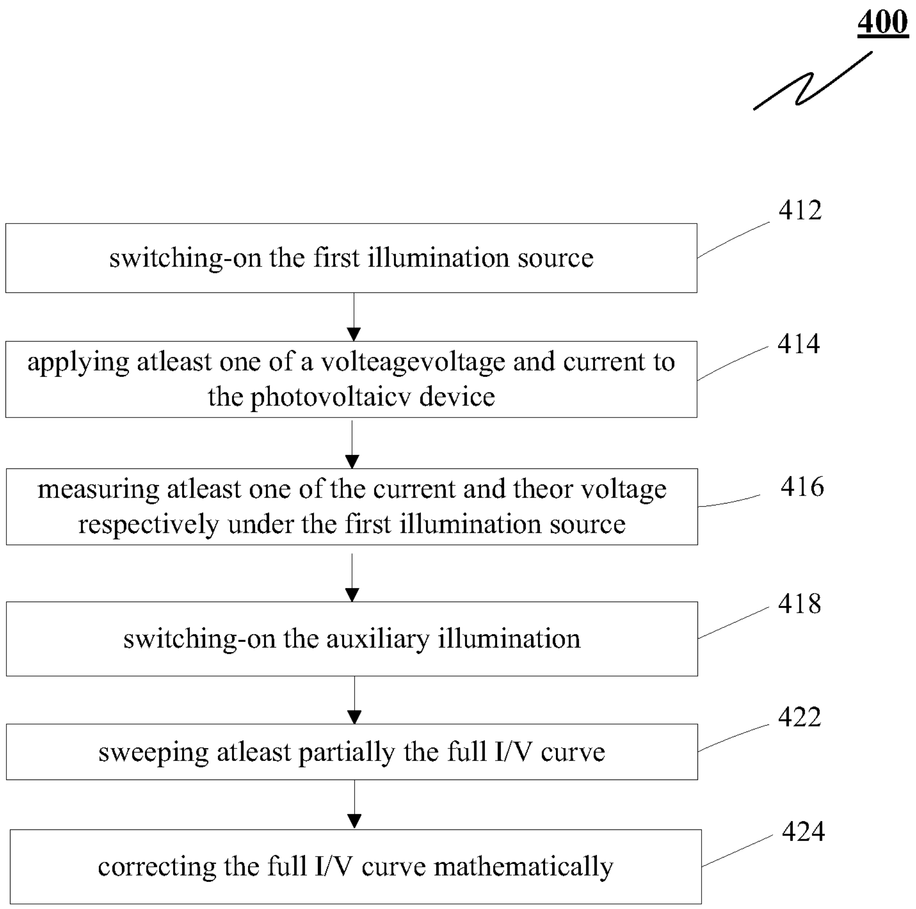
400
412
switching-on the first illumination source
414
applying atleast one of a volteagevoltage and current to the photovoltaicv device
416
measuring atleast one of the current and theor voltage respectively under the first illumination source
418
switching-on the auxiliary illumination
422
sweeping atleast partially the full I/V curve
424
correcting the full I/V curve mathematically

FIG. 7

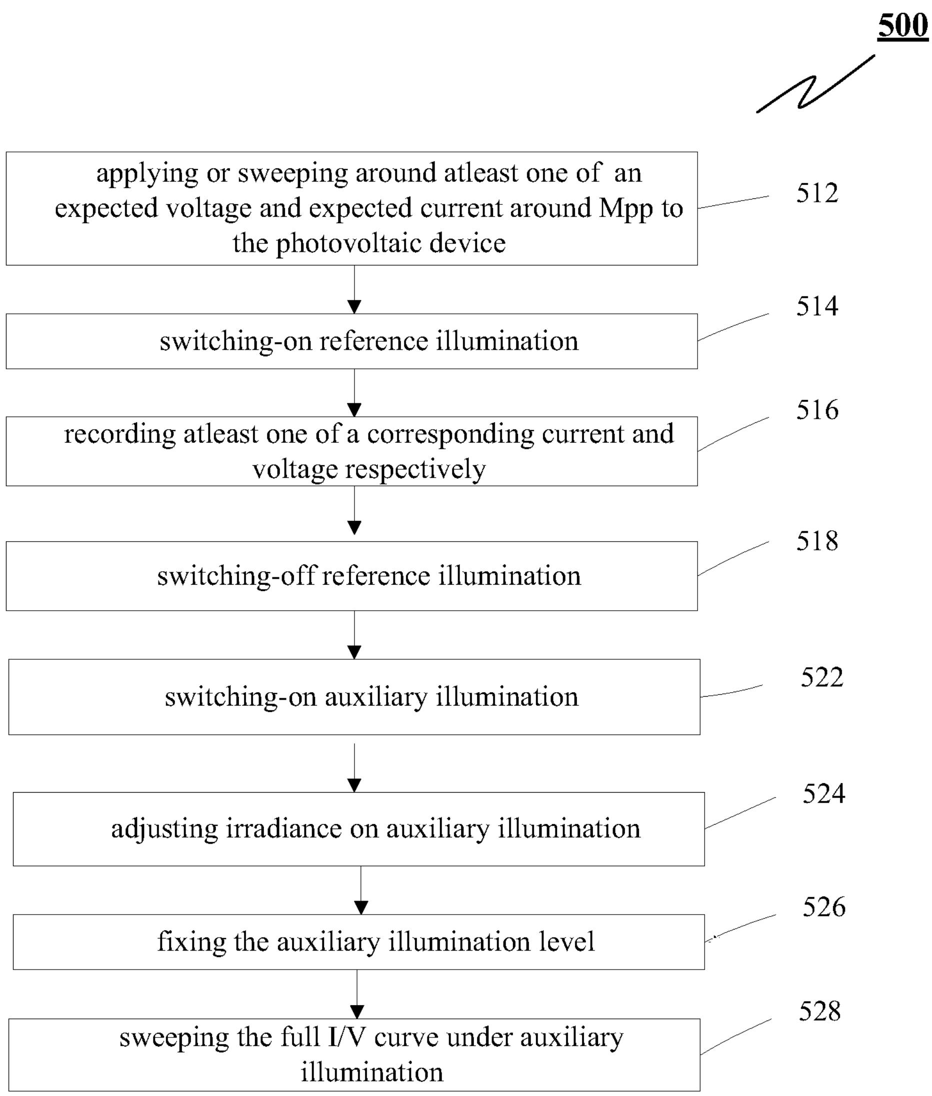
500
applying or sweeping around atleast one of an expected voltage and expected current around Mpp to the photovoltaic device
512
switching-on reference illumination
514
recording atleast one of a corresponding current and voltage respectively
516
switching-off reference illumination
518
switching-on auxiliary illumination
522
adjusting irradiance on auxiliary illumination
524
fixing the auxiliary illumination level
526
sweeping the full I/V curve under auxiliary illumination
528

FIG. 8

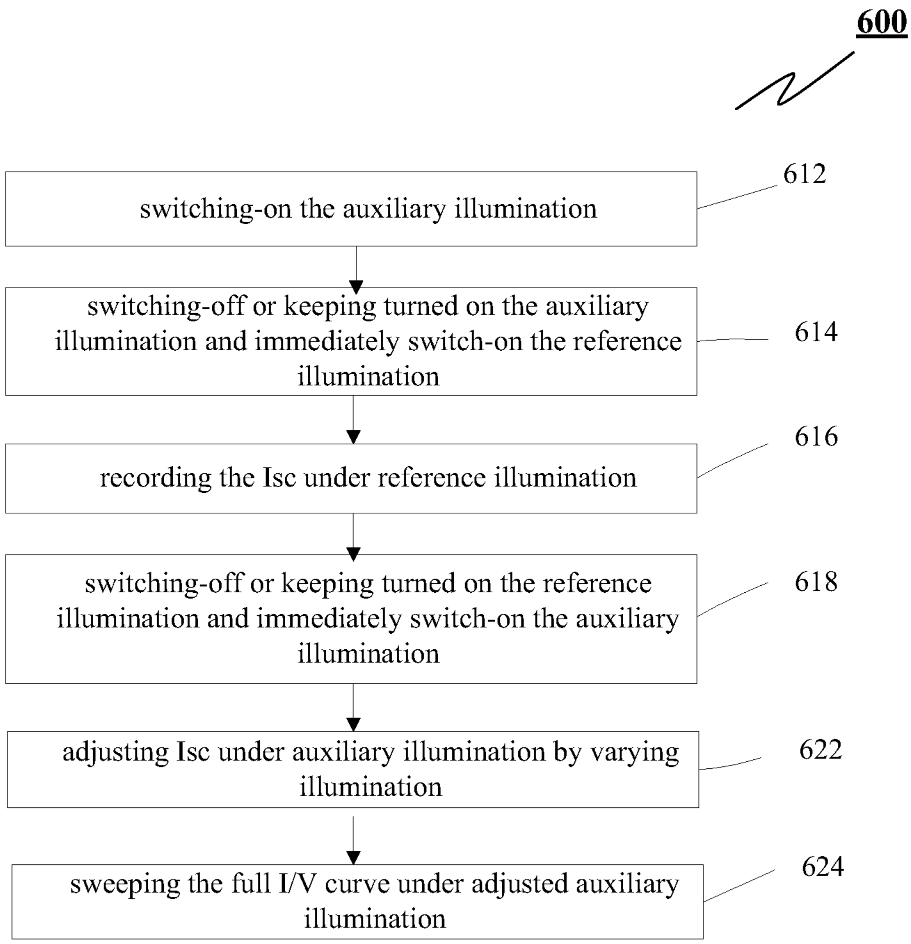
600
switching-on the auxiliary illumination
612
switching-off or keeping turned on the auxiliary illumination and immediately switch-on the reference illumination
614
recording the Isc under reference illumination
616
switching-off or keeping turned on the reference illumination and immediately switch-on the auxiliary illumination
618
adjusting Isc under auxiliary illumination by varying illumination
622
sweeping the full I/V curve under adjusted auxiliary illumination
624

FIG. 9

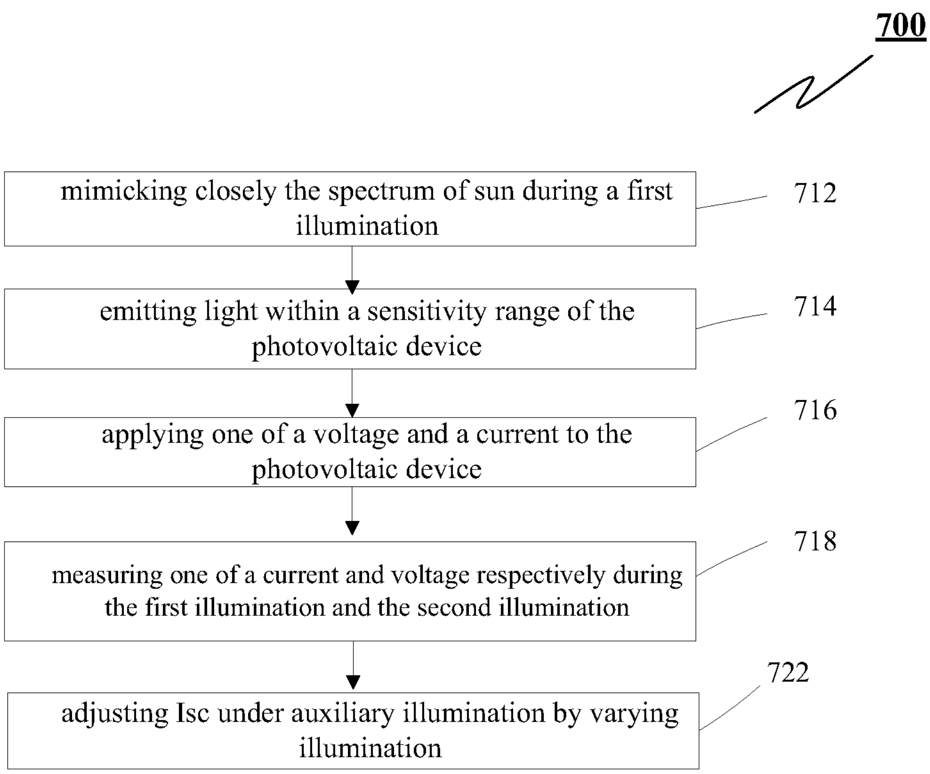
700
mimicking closely the spectrum of sun during a first illumination
712
emitting light within a sensitivity range of the photovoltaic device
714
applying one of a voltage and a current to the photovoltaic device
716
measuring one of a current and voltage respectively during the first illumination and the second illumination
718
adjusting Isc under auxiliary illumination by varying illumination
722

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/051975

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21S8/00 G01R31/26
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F21S G01R G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2004/056648 A1 (MATSUYAMA JINSHO [JP]) 25 March 2004 (2004-03-25) figures 1, 5, 6 paragraphs [0002], [0007], [0010] paragraph [0014] - paragraph [0197] paragraph [0226] -----	1,2,4-13 3
X	JP 2008 171897 A (NAT INST OF ADV IND & TECHNOL) 24 July 2008 (2008-07-24) figures 1-7 abstract paragraph [0019] - paragraph [0038] ----- -/--	1,2,4-13

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 September 2012	12/09/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Höller, Helmut

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GLATFELTER T ET AL: "A method for determining the conversion efficiency of multiple-cell photovoltaic devices", CONFERENCE RECORD OF THE IEEE PHOTOVOLTAIC SPECIALISTS CONFERENCE, XX, XX, 4 May 1987 (1987-05-04), pages 1187-1193, XP009055414, the whole document -----	1,2,4-13
X	EP 1 179 857 A2 (CANON KK [JP]) 13 February 2002 (2002-02-13) figures 1-7 paragraph [0001] - paragraph [0033] -----	1,2,4-13
X	ADELHELM R ET AL: "Performance and parameter analysis of tandem solar cells using measurements at multiple spectral conditions", SOLAR ENERGY MATERIALS AND SOLAR CELLS, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL, vol. 50, no. 1-4, 1 January 1998 (1998-01-01), pages 185-195, XP004102509, ISSN: 0927-0248, DOI: 10.1016/S0927-0248(97)00143-8 the whole document -----	1,2,4-13
A	NAGAMINE F ET AL: "New solar simulator for multi-junction solar cell measurements", PROCEEDINGS OF THE PHOTOVOLTAIC SPECIALISTS CONFERENCE. LOUISVILLE, MAY 10 - 14, 1993; [PROCEEDINGS OF THE PHOTOVOLTAIC SPECIALISTS CONFERENCE], NEW YORK, IEEE, US, vol. CONF. 23, 10 May 1993 (1993-05-10), pages 686-690, XP010113171, DOI: 10.1109/PVSC.1993.347009 ISBN: 978-0-7803-1220-3 the whole document -----	1-13
Y	ALI M BAZZI ET AL: "Solid-state light simulator with current-mode control", APPLIED POWER ELECTRONICS CONFERENCE AND EXPOSITION (APEC), 2011 TWENTY-SIXTH ANNUAL IEEE, IEEE, 6 March 2011 (2011-03-06), pages 2047-2053, XP032014161, DOI: 10.1109/APEC.2011.5744878 ISBN: 978-1-4244-8084-5	3
A	abstract page 2047, right-hand column, last paragraph - page 2048, left-hand column, paragraph 1 -----	1,2,4-13
	-/--	

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006 135196 A (KANEKA CORP) 25 May 2006 (2006-05-25) figures 1-5 abstract -----	1-13
A	JP 2005 011958 A (CANON KK) 13 January 2005 (2005-01-13) figures 1, 9, 10-12 abstract -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/051975

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