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(54) **Device for tracking a maximum power point of a power source**

(57) The present invention concerns a device for tracking the maximum power point of a power source. The device comprises:
- means for measuring the electric power provided by the power source,
- means for modifying the voltage provided by the power source in a given direction,
- means for measuring a first and a second electric power values generated by the power source once the voltage is modified,
- means for modifying the voltage in the same direction or in an opposite direction according to the measured electric power values,
- means for waiting a first time period in order to enable the convergence of the current and of the voltage provided by the power source prior to measuring the first electric power value,
- means for performing, within a second time period different from the first time period, the measures of the first and second electric power values.

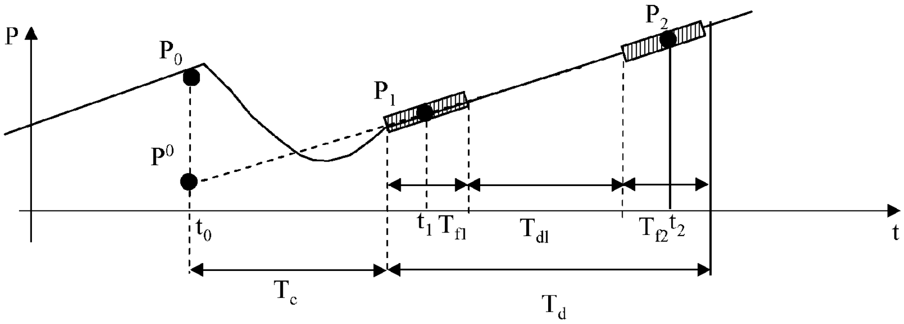

Fig. 5

EP 2 450 769 A1

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Description

[0001] The present invention relates generally to a device for tracking a maximum power point of a power source like a photovoltaic cell or an array of cells or a fuel cell.

[0002] A photovoltaic cell directly converts solar energy into electrical energy. The electrical energy produced by the photovoltaic cell can be extracted over time and used in the form of electric power. The direct electric power provided by the photovoltaic cell is provided to conversion devices like DC-DC up/down converter circuits and/or DC/AC inverter circuits.

[0003] However, the current-voltage characteristics of photovoltaic cells cause the output power to change nonlinearly with the current drawn from photovoltaic cells. The power-voltage curve changes according to climatic variations like light radiation levels and operation temperatures.

[0004] The near optimal point at which to operate photovoltaic cells or arrays of cells is at or near the region of the current-voltage curve where the power is greatest. This point is denominated as the Maximum Power Point (MPP).

[0005] The location of the Maximum Power Point is not known, but can be located, either through calculation models or by search algorithms.

[0006] Therefore Maximum Power Point Tracking techniques are needed to maintain the photovoltaic cells or arrays of cells operating point at its Maximum Power Point.

[0007] As the power-voltage curve changes according to climatic variations, the Maximum Power Point also changes according to climatic variations.

[0008] It is then necessary to be able to identify the Maximum Power Point at any time.

[0009] The most commonly used Maximum Power Point Tracking (MPPT) algorithm is Perturb and Observe (P&O) due to its ease of implementation in its basic form. The P&O algorithms are types of hill climbing methods which operate by periodically perturbing, i.e. incrementing or decrementing, the photovoltaic cells or arrays of cells voltage or current and comparing the photovoltaic cells or arrays of cells output power with that of the previous perturbation cycle. Thus, if the operating voltage of the photovoltaic cells or arrays of cells is perturbed in a given direction and the difference between the power after the perturbation and the power prior perturbation is positive, it is known that the perturbation moves the operating point toward the Maximum Power Point. The P&O algorithm would then continue to perturb the photovoltaic cells or arrays of cells voltage in the same direction. If the difference between the power after the perturbation and the power prior perturbation is negative, then the change in operating point moves the photovoltaic cells or arrays of cells away from the Maximum Power Point and the P&O algorithm reverses the direction of the perturbation.

[0010] A common problem with P&O is that the photovoltaic cells or arrays of cells voltage and/or current is perturbed every MPPT cycle; therefore when the Maximum Power Point is reached, the output power oscillates around the maximum, resulting in power loss in the photovoltaic cells or arrays of cells system. This is especially true in constant or slowly-varying climatic conditions.

[0011] Furthermore, P&O methods can fail under rapid changing climatic conditions.

[0012] **Fig. 1** shows two curves representing the power variations versus voltage of the photovoltaic cells or arrays of cells at two different climatic conditions.

[0013] The curve noted Cu1 represents the power variations versus voltage of the photovoltaic cells or arrays of cells at a first climatic condition and the curve noted Cu2 represents the power variations versus voltage of the photovoltaic cells or arrays of cells at a successive second climatic condition in which the irradiance is upper than the one of curve Cu1.

[0014] Starting from an operating point A of the curve Cu1, if atmospheric conditions stay approximately constant, a perturbation ΔV on the voltage V will bring the operating point to B of the curve Cu1 and the perturbation will be reversed due to a decrease in power.

[0015] However, if the irradiance increases and shifts the power curve from Cu1 to Cu2 within one cycle period, the operating point will move from point A of curve Cu1 to point C of curve Cu2. This represents an increase in power and the perturbation is kept the same. Consequently, the operating point diverges from the Maximum Power Point and will keep diverging if the irradiance continues to increase.

[0016] Solution has been proposed in order to overcome that problem. The paper of S Sera entitled "Improved MPPT method for rapidly changing environmental conditions" published in IEEE ISIE July 9-12 2006, Montreal proposes a modified MPPT Perturb and observe algorithm wherein one additional measurement of the solar arrays power is taken after a duration equal to half the duration of the perturbation cycle for the MPPT Perturb and observe algorithm. The additional measurement is used for estimating the power variation due to rapid change of climatic conditions during the perturbation cycle and for finally avoiding disturbances generated by rapid change of climatic conditions.

[0017] The problem of that technique is that making a power measurement at half the duration of the perturbation cycle can yield to some measurement error due to transient voltage and current behaviour after applying the perturbation ΔV.

[0018] This in turn can lead to some error on the estimation of the power variation due to rapid change of climatic conditions during the perturbation cycle.

[0019] Thus, disturbances generated by rapid change of climatic conditions may not be properly avoided, potentially bringing some loss in power production, depending on the convergence time of the transient voltage and current behaviour after applying the perturbation ΔV.

[0020] In order to avoid such measurement error, one alternative to the above mentioned state of the art is to double the duration of the perturbation cycle.

[0021] This effectively avoids disturbances generated by changes of climatic conditions. However, as perturbation cycle duration is increased, the changes of climatic condition which can be tracked are slow.

[0022] The present invention aims at providing a device which enables to provide a tracking of the MPP which is robust to climatic variations and with a limited increase of the duration of the perturbation cycle.

[0023] To that end, the present invention concerns a device for tracking the maximum power point of a power source, the device comprising:

- means for measuring the electric power provided by the power source,
- means for modifying the voltage provided by the power source in a given direction,
- means for measuring a first and a second electric power values generated by the power source once the voltage is modified,
- means for modifying the voltage in the same direction or in an opposite direction according to the measured electric power values,
  characterised in that the device further comprises :
- means for waiting a first time period in order to enable the convergence of the current and of the voltage provided by the power source prior to measureing the first electric power value,
- means for performing, within a second time period different from the first time period, the measures of the first and second electric power values.

[0024] The present invention concerns also a method for tracking the maximum power point of a power source, the method comprising the steps of:

- measuring the electric power provided by the power source,
- modifying the voltage provided by the power source in a given direction,
- measuring a first and a second electric power values generated by the power source once the voltage is modified,
- modifying the voltage in the same direction or in an opposite direction according to the measured electric power values,
  characterised in that the method further comprises the step of waiting a first time period in order to enable the convergence of the current and of the voltage provided by the power source prior to measuring the first electric power value and the measures of the first and second electric power values are performed within a second time period different from the first time period.

[0025] Thus, the tracking of the MPP which is robust to climatic variations and the duration of the perturbation cycle is reduced as much as possible as the periods of times correspond to the minimum values corresponding to their respective requirements.

[0026] A second time period larger than the first time period enables to get accurate estimation of time variation of power and then improves the robustness of the tracking of the MPP to rapid climatic variations.

[0027] A second time period smaller than the first time period reduces the duration of the perturbation cycle and thus reduces the loss in energy produced by the power source due to the setting of the input voltage away from optimum MPP voltage during the perturbation cycle.

[0028] As perturbation cycle duration is reduced, the tracking of the MPP may be conducted more often thus increasing in the same time the power efficiency of the system.

[0029] It is then possible to use smaller voltage value modifications during perturbation cycles, improving then the accuracy of the tracking of the MPP.

[0030] According to a particular feature, the first and second electric power values generated by the power source once the voltage is modified are each measured by sampling the current and the voltage provided by the power source during a first and second sub time periods of the second time period and samples are averaged.

[0031] Thus, an averaging can be applied on respective samples over the first and second sub time periods. The noise affecting the measured first and second electric power values is reduced and accuracy of measurement is improved.

[0032] According to a particular feature, the second time period further comprises a third sub time period which separates the first and second sub time periods.

[0033] Thus, an estimation of the time derivative of the power delivered by the power source at regulation voltage can be determined. Speed and accuracy of MPP tracking method can be optimised adjusting the duration of the third sub time period. The longer the third sub time period is, the better is the estimation of the derivative. The shorter the third sub time period is, the faster rapid changes of climatic conditions can be tracked.

[0034] According to a particular feature, the second time period varies according to at least one criterion.

[0035] Thus, MPPT algorithm can be optimised. The perturbation cycle is kept as minimum for any case.

[0036] According to a particular feature, the first and/or the second sub time periods of the second time period may vary according to at least one criterion.

[0037] Thus, MPPT algorithm can be optimised to noise levels and convergence time. The perturbation cycle is kept as minimum for any case.

[0038] According to a particular feature, the duration of first, second and third sub time periods are determined from the signal to noise ratio of the measurement samples of current and voltage provided by the power source.

[0039] Thus, a varying number N of samples are used for filtering. N may be equal to the duration of first and second sub time periods divided by the sampling duration. The error on the first and second measurements is reduced by square root of N. The duration of first and second sub time periods can be chosen so as to reach any target accuracy on the first and second measurements. The perturbation cycle can then be adapted to the noise condition.

[0040] According to a particular feature, the device is included in an energy conversion device.

[0041] Thus, the energy conversion system takes the form of a device and is compact.

[0042] According to a particular feature, the electric power values are measured on voltages and currents at the output of the energy conversion device.

[0043] According to a particular feature, the electric power values are measured on voltages and currents at the input of the energy conversion device.

[0044] The characteristics of the invention will emerge more clearly from a reading of the following description of an example embodiment, the said description being produced with reference to the accompanying drawings, among which :

Fig. 1 shows two curves representing the power variations versus voltage of the photovoltaic cells or arrays of cells at two different climatic conditions;

Fig. 2 is an example of an energy conversion system wherein the present invention may be implemented;

Fig. 3 is an example of a curve representing the output current variations of a power source according to the output voltage of the power source;

Fig. 4 represents an example of a controller device according to the present invention;

Fig. 5 is an example of a curve representing the input power variations of the energy conversion device within a perturbation cycle;

Fig. 6 is an example of an algorithm for tracking the maximum power point of the power source according to the present invention ;

Fig. 7 is an example of an algorithm for adjusting at least one time period according at least one criterion.

Fig. 2 is an example of an energy conversion system wherein the present invention may be implemented.

[0045] The energy conversion system is composed of a power source PV like a photovoltaic cell or an array of cells or a fuel cell connected to an energy conversion device Conv like a DC-DC step-down/step-up converter and/or a DC/AC converter also named inverter, which output provides electrical energy to the load Lo.

[0046] The energy conversion device Conv comprises at least one switch S.

[0047] The power source PV provides current intended to the load Lo. The current I_{in} and the voltage V_{in} provided by the power source PV are converted by the energy conversion device Conv in output current I_{out} and output voltage V_{out} prior to be used by the load Lo.

[0048] According to the invention, the energy conversion system further comprises a controller device 20.

[0049] The controller device 20 comprises a maximum power point tracking controller MPPT and a duty cycle adjustment controller DCA.

[0050] The maximum power point tracking controller MPPT determines, from successive power measurements, a regulation voltage value. The regulation voltage value is an estimation of the input voltage value which maximizes the energy produced by the power source PV.

[0051] It has to be noted here that successive power measurements used by maximum power point tracking controller MPPT can be realised at the input or at the output of the energy conversion device Conv.

[0052] The duty cycle adjustment controller DCA controls the input voltage of the energy conversion device Conv, by controlling a duty cycle according to the regulation voltage value determined by maximum power point tracking controller MPPT.

[0053] The duty cycle drives the ON/OFF state of the at least one switch S of the energy conversion device Conv.

[0054] The duty cycle adjustment controller DCA brings some latency to regulate the input voltage of the energy conversion device Conv. Until convergence is reached after a duration Tc, power measurement can not be performed with high accuracy, due to transient behaviour in the energy conversion device Conv.

[0055] For example, the duty cycle adjustment controller DCA is a proportional-integral controller which drives the duty cycle D towards a new duty cycle value according to a regulation voltage value determined by maximum power point tracking controller MPPT.

[0056] The proportional-integral controller DCA is a feedback controller which determines the duty cycle to control the average input voltage V_{in} of the energy conversion device Conv towards a regulation voltage value. The proportional integer controller is defined by two coefficients. K_p is the proportional gain and K_i is the integral gain.

[0057] The duty cycle is built as a sum of the error between the input voltage and the regulation voltage weighted by coefficient K_p and the integral of that value weighted by coefficient K_i.

[0058] Coefficients K_p and K_i determine the system convergence time and the maximum voltage variation that is affordable. The convergence time of the voltage V_{in} at the input of the power converter Conv is dependent of the two gains K_p and K_I, where K_p is often a trade-off between decreasing overshoot and increasing convergence time.

[0059] Typically a rule of thumb, which links the K_p and K_I to the convergence time T_c sets T_c equal to five times the ratio of K_p over K_I.

[0060] For example, for K_p = 0,01 and K_i = 0,25, the current I_{in} and voltage V_{in} are stabilized over a duration T_c = 0,2 s.

[0061] According to the invention, the controller device 20 comprises:

- means for measuring the electric power provided by the power source,
- means for modifying the voltage provided by the power source in a given direction, i.e. increasing or decreasing the voltage provided by the power source,
- means for measuring a first and a second electric power values generated by the power source once the voltage is modified,
- means for modifying the voltage in the same direction or in an opposite direction according to the measured electric power values,

  characterised in that the device further comprises :
- means for waiting a first time period in order to enable the convergence of the current and of the voltage provided by the power source prior to measuring the first electric power value,
- means for performing, within a second time period different from the first time period, the measures of the first and second electric power values.

[0062] **Fig. 3** is an example of a curve representing the output current variations of a power source according to the output voltage of the power source.

[0063] On the horizontal axis of Fig. 3, voltage values are shown. The voltage values are comprised between null value and the open circuit voltage Voc.

[0064] On the vertical axis of Fig. 3, current values are shown. The current values are comprised between null value and the short circuit current I_{SC}.

[0065] At any given light level and photovoltaic array temperature, there is an infinite number of current-voltage pairs, or operating points, at which the photovoltaic array can operate. However, there exists a single MPP for a given light level and photovoltaic array temperature.

[0066] **Fig. 4** represents an example of a controller device according to the present invention.

[0067] The controller device 20 has, for example, an architecture based on components connected together by a bus 401 and a processor 400 controlled by the program related to the algorithm as disclosed in the Figs. 6 and 7.

[0068] It has to be noted here that the processor 400 is, in a variant, implemented under the form of one or several dedicated integrated circuits which execute the same operations as the one executed by the processor 400 as disclosed hereinafter.

[0069] The bus 401 links the processor 400 to a read only memory ROM 402, a random access memory RAM 403, an analogue to digital converter ADC 406.

[0070] The read only memory ROM 402 contains instructions of the programs related to the algorithm as disclosed in the Figs. 6 and 7 which are transferred, when the controller device 20 is powered on to the random access memory RAM 403.

[0071] The RAM memory 403 contains registers intended to receive variables, and the instructions of the programs related to the algorithms as disclosed in the Figs. 6 and 7.

[0072] The analogue to digital converter 406 is connected to the input and the output of the energy conversion device Conv and converts voltages and currents at the input and the output of the energy conversion device Conv into binary information.

[0073] The controller device 20 comprises an interface module 405 which transfers the duty cycle D to be applied by the energy conversion device Conv.

[0074] It has to be noted here that in a variant of realization, the MPP tracking module 20 is included in the energy conversion device Conv.

[0075] According to a particular mode of realization, the RAM memory 403 memorises voltage and current values converted by the analogue to digital converter 406 during a time duration T_f.

[0076] The processor 400 averages the measurement samples of voltage and of the current values in order to obtain measurement values to be used for tracking the MPP.

[0077] **Fig. 5** is an example of a curve representing the input power variations of the energy conversion device within a perturbation cycle.

[0078] The vertical axis represents the power measured at the output of the energy conversion device Conv and the horizontal axis represents the time.

[0079] Fig. 5 represents the two time periods which have different values according to the invention. The first time period T_c is determined in order to enable the convergence of the input voltage V_{in}.

[0080] For example, T_c is determined as equal to five times the factor Kp divided by the factor K_I. Then, the first time period T_c is set as sufficiently long enough to enable the convergence of the input voltage towards the regulation input voltage.

[0081] The second time period value T_d is determined so as to enable that at least two measurements are obtained.

[0082] According to a particular feature, the second time period T_d is dependent of at least one criterion.

[0083] The parameter is for example, the noise level on measurements.

[0084] The second time period is decomposed into at least three sub time periods.

[0085] A first sub time period T_{f1} is dedicated to a first sampling of the input current I_{in} and the input voltage V_{in} in order to obtain a value P_1 of the input power.

[0086] A second sub time period T_{dl} is set so as to enable an accurate measurement of the slope of the curve between the first measurement of the power P_1 and second measurement of the power P_2.

[0087] A third sub time period T_{f2} is dedicated to a second sampling of the input current I_{in} and the input voltage V_{in} in order to obtain a value P_2 of the input power.

[0088] The first sub time period T_{f1} is a time period in which plural samples of measurements of the input voltage V_{in} and of the input current I_{in}. Samples are averaged in order to obtain the first measurement of the power P_1.

[0089] The third sub time period T_{f2} is a time period in which plural samples of measurements of the input voltage V_{in} and of the input current $I_{in.}$ Samples are averaged in order to obtain the second measurements measurement of the power P_2.

[0090] According to a particular mode of realization, the sub time periods T_{f1} and T_{f2} are variable according to noise level on measurements.

[0091] According to a particular mode of realization, the second sub time period T_{d1} is variable according to noise level on measurements.

[0092] **Fig. 6** is an example of an algorithm for tracking the maximum power point of the power source according to the present invention.

[0093] More precisely, the present algorithm is executed by the processor 400 of the controller device 20.

[0094] At step S600, a perturbation cycle is started.

[0095] At next step S601, the processor 400 commands the measurement of the power provided to the energy conversion device Conv. The power is noted P_0.

[0096] Plural samples of the input current I_{in} and the input voltage V_{in} may be performed over a time duration not shown in Fig. 5 in order to obtain an average value P_0 of the input power.

[0097] At next step S602, the processor 400 commands the transfer of a perturbation through the interface 405 to the energy conversion device Conv. The processor 400 commands the transfer of a duty cycle D which corresponds to an input voltage which is equal to a value V_{ref} defined in the previous perturbation cycle.

[0098] At next step S603, the processor 400 activates a timer which is equal to the first time period T_c. The first time period T_c enables the convergence of the input current I_{in} and the input voltage V_{in} within the perturbation cycle.

[0099] At next step S604, the processor 400 commands the measurement of the power provided to the energy conversion device Conv. The power is noted P_1.

[0100] Plural samples of the input current I_{in} and the input voltage V_{in} may be performed over the time duration T_{f1} in order to obtain an average value P_1 of the input power.

[0101] At next step S605, the processor 400 activates a timer which is equal to the second sub time period $T_{d1.}$ The second sub time period T_{d1} is set so as to enable an accurate measurement of the slope of the curve between the measurement of the input power P_1 and of the input power P_2.

[0102] At next step S606, the processor 400 commands the measurement of the power provided to the energy conversion device Conv. The power is noted P_2.

[0103] Plural samples of the input current I_{in} and the input voltage V_{in} may be performed over the time duration T_{f2} in order to obtain an average value P_2 of the input power.

[0104] At next step S607, the processor 400 determines the slope of the curve between the measurement of the input power P_1 and of the input power P_2.

[0105] After convergence, the proportional-integral controller stabilises the input voltage level to desired value. If the current has changed during the second time period T_d which is composed of the first, second and third sub periods of time, this means that the irradiance has also changed and the power curve changes respectively up or down depending on if irradiance has increased or decreased.

[0106] The voltage variation per perturbation cycle is controlled by the proportional-integral controller. It is noted ΔV and is equal to $V(t) - v(t + T_c + T_d)$.

[0107] The input power is a linear function of the time over one perturbation cycle and is expressed as:

$$p = at + b$$

Where *a* is the slope, $a = U\dfrac{di}{dt}$, $\dfrac{di}{dt}$ is the variation of the current over time and b = P^0 is the theoretical power level at $t=t_0$ at time to at the beginning of the perturbation cycle if no convergence time is necessary.

[0108] The variation of the current over the perturbation cycle needs to be estimated. The estimation is done over the duration T_d .

[0109] Current estimation over the time:

$$\frac{d\hat{I}_{in}}{dt} = \frac{I_1 - I_2}{T_d}$$

Where I_1 is the current at $t = t_1$ in Fig. 5 and I_2 the current at time t_2 in Fig. 5.

[0110] At next step S608, the processor 400 commands the determination of P^0 which corresponds to an input power value that should be at the input of the energy conversion device Conv at time t_0 just after application of perturbation realised at step S602 in an ideal case where no convergence time exists.

[0111] Current estimation over the voltage variation is:

$$\frac{d\hat{I}_{in}}{dU} = \frac{I^0 - I_0}{\Delta V}$$

Where I_0 is the current at $t = t_0$ and I^0 the theoretical current at $t = t_0$ a at the beginning of the perturbation cycle if no convergence time is necessary.

[0112] Since at time t_2, the input power is equal to P_2 and putting *a* and b in the equation p = *at + b* we get:

$$P_2 = U\frac{I_2 - I_1}{T_d}\left(T_c + T_d\right) + P^0$$

$$P^0 = P_2 - U\frac{I_2 - I_1}{T_d}\left(T_c + T_d\right)$$

[0113] At next step S609, the processor 400 determines an output power variation, which would have been ideally observed at time to just after application of perturbation, in an ideal case where no convergence time exists.

[0114] The variation of the power during the total perturbation cycle is:

$$\Delta P = P^0 - P_0$$

[0115] The variation ΔP can then be expressed as follows:

$$\Delta P = P^0 - P_0 = P_2 - P_0 - U\left(I_2 - I_1\right)\left(\frac{T_c + T_d}{T_d}\right)$$

[0116] At next step S610, the processor 400 checks if the variation ΔP is positive or equals to null value.

[0117] If the variation ΔP is positive or equals to null value, the processor 400 moves to step S612. Otherwise, the processor 400 moves to step S611.

[0118] At step S611, the processor 400 decides to go in opposite direction for next perturbation cycle. The sign of voltage step ΔV is modified.

[0119] After that, the processor 400 moves to step S612.

[0120] At step S612, the processor 400 updates the voltage value V_{ref} by ΔV. If sign of voltage step ΔV is negative, the processor 400 decreases the voltage value V_{ref} by absolute value of ΔV. If sign of voltage step ΔV is positive, processor 400 increases the voltage value V_{ref} by absolute value of ΔV. For example absolute value of ΔV is defined as to be between 0.5 to 5 Volts.

[0121] After that, the processor 400 returns to step S600.

[0122] **Fig.** 7 is an example of an algorithm for adjusting at least one time period according to at least one criterion.

[0123] The present algorithm will be disclosed in an example wherein the criterion is the noise on the measurements of the input current I_{in} and input voltage V_{in}.

[0124] More precisely, the present algorithm is executed by the processor 400 of the controller device 20.

[0125] The present algorithm is executed periodically and in parallel with the algorithm disclosed in Fig. 6.

[0126] At first step S700, the processor 400 evaluates the noise on the measurements of the input current I_{in} and input voltage V_{in}. For example the noise is determined using samples obtained during at least one sub time interval T_{f1} and/or T_{f2} on at least one previous perturbation cycle.

[0127] At next step S701, the processor 400 determines at least one sub time period T_{f1} and/or T_{f2} of the second time duration T_d according to the evaluated noise.

[0128] The at least one sub time period T_{f1} and/or T_{f2} of the second time duration T_d is determined from the level signal to noise ratio of the samples of measures of current and voltage provided by the power source.

[0129] If the noise level is low in comparison with the measured power, less samples are necessary to get an accurate measure of the power. The processor 400 sets then the sub time period T_{f1} and/or T_{f2} to a small value, for example to 10ms.

[0130] If the noise level is high, more samples are necessary to get an accurate measure of the power. The processor 400 sets then the sub time period T_{f1} and/or T_{f2} to a large value, for example to 100ms.

[0131] At next step S702, the processor 400 applies the modified time periods in at least one next perturbation cycle.

[0132] It has to be noted here that other criterion may be used for modifying the time duration.

[0133] For example available RAM memory size may be a criterion for modifying the sub time periods T_{f1} and/or T_{f2}.

[0134] For example, if the slope of the curve linking the power P_1 and P_2 in Fig. 5 is equal to null value during plural consecutive perturbation cycles, the duration T_d may be decreased.

[0135] If the slope of the curve linking the power P_1 and P_2 in Fig. 5 varies a lot during plural consecutive perturbation cycles, the duration T_d may be increased.

[0136] Naturally, many modifications can be made to the embodiments of the invention described above without departing from the scope of the present invention.

Claims

1. Device for tracking the maximum power point of a power source, the device comprising:

- means for measuring the electric power provided by the power source,
- means for modifying the voltage provided by the power source in a given direction,
- means for measuring a first and a second electric power values generated by the power source once the voltage is modified,

- means for modifying the voltage in the same direction or in an opposite direction according to the measured electric power values,

characterised in that the device further comprises :

- means for waiting a first time period in order to enable the convergence of the current and of the voltage provided by the power source prior to measuring the first electric power value,

- means for performing, within a second time period different from the first time period, the measures of the first and second electric power values.

2. Device according to claim 1, **characterised in that** the first and second electric power values generated by the power source once the voltage is modified are each measured by sampling the current and the voltage provided by the power source during a first and second sub time periods of the second time period and samples are averaged.

3. Device according to claim 2, **characterised in that** the second time period further comprises a second sub time period which separates the first and second sub time periods.

4. Device according to claim 3, **characterised in that** the second time period varies according to at least one criterion.

5. Device according to claim 4, **characterised in that** the first and/or the second sub time periods of the second time period may vary according to at least one criterion.

6. Device according to claim 5, **characterised in that** the duration of first, second and third sub time periods are determined from the signal to noise ratio of the measurement samples of current and voltage provided by the power source.

7. Device according to claim 6, **characterised in that** the device is included in an energy conversion device.

8. Device according to claim 7, **characterised in that** the electric power values are measured on voltages and currents at the output of the energy conversion device.

9. Device according to claim 7, **characterised in that** the electric power values are measured on voltages and currents at the input of the energy conversion device.

10. Method for tracking the maximum power point of a power source, the method comprising the steps of:

- measuring the electric power provided by the power source,

- modifying the voltage provided by the power source in a given direction,

- measuring a first and a second electric power values generated by the power source once the voltage is modified,

- modifying the voltage in the same direction or in an opposite direction according to the measured electric power values,

characterised in that the method further comprises the step of waiting a first time period in order to enable the convergence of the current and of the voltage provided by the power source prior to measuring the first electric power value, and **in that** the measures of the first and second electric power values are performed within a second time period different from the first time period.

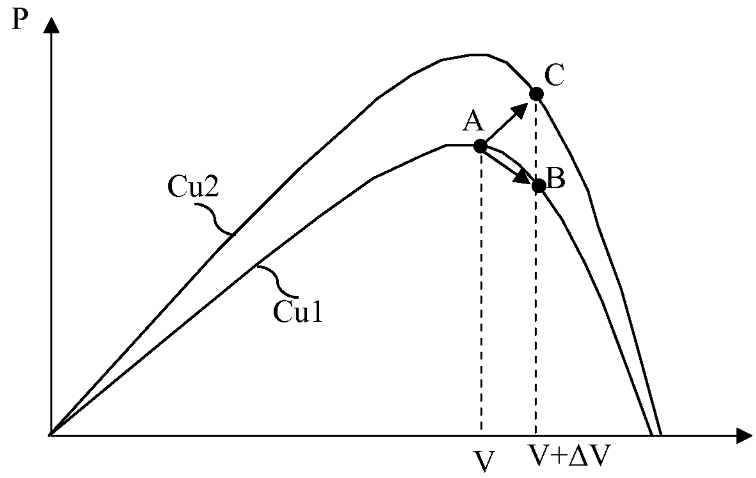

P
C
A
B
Cu2
Cu1
V
V+ΔV

Fig. 1

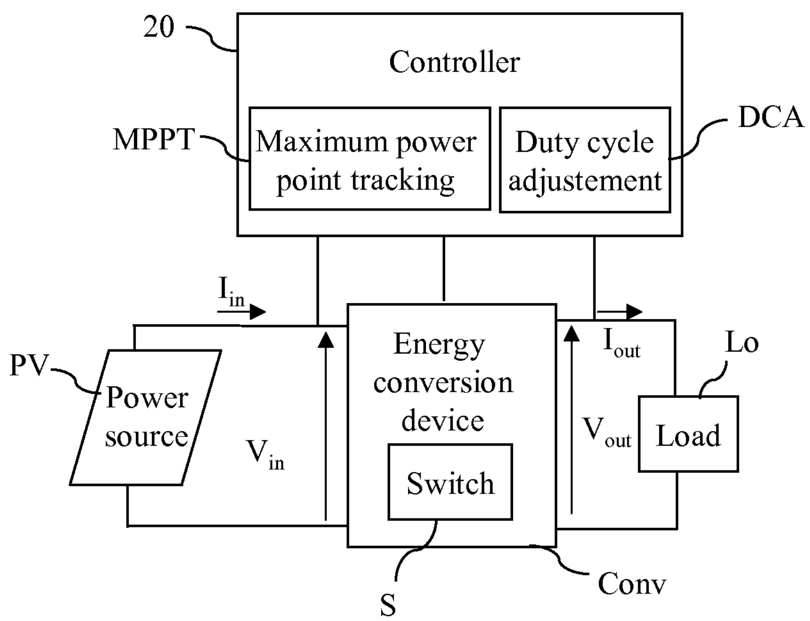
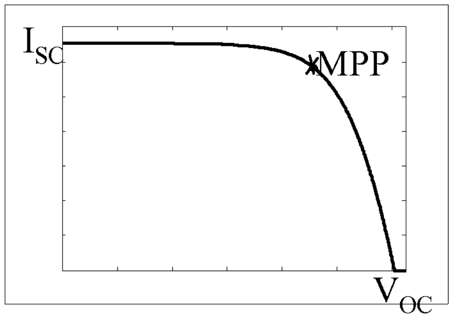
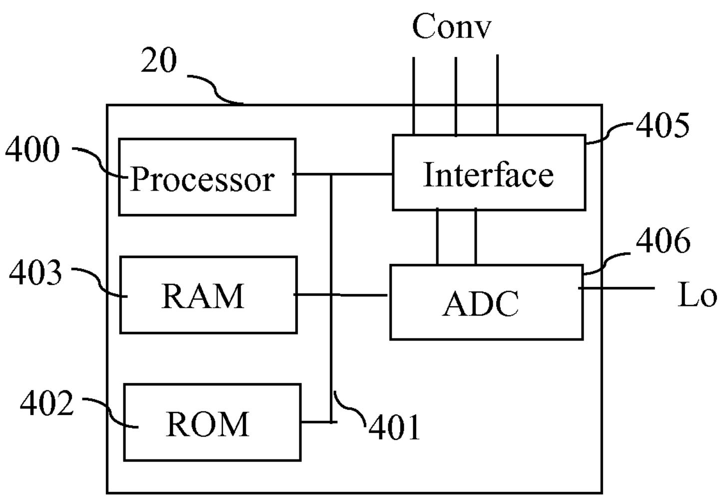

20
Controller
MPPT
Maximum power point tracking
Duty cycle adjustement
DCA
I in
PV
Power source
V in
Energy conversion device
Switch
I out
V out
Lo
Load
S
Conv

Fig. 2



I_{SC}
MPP
V_{OC}

Fig. 3



Conv
20
400
Processor
Interface
405
403
RAM
ADC
406
Lo
402
ROM
401

Fig. 4

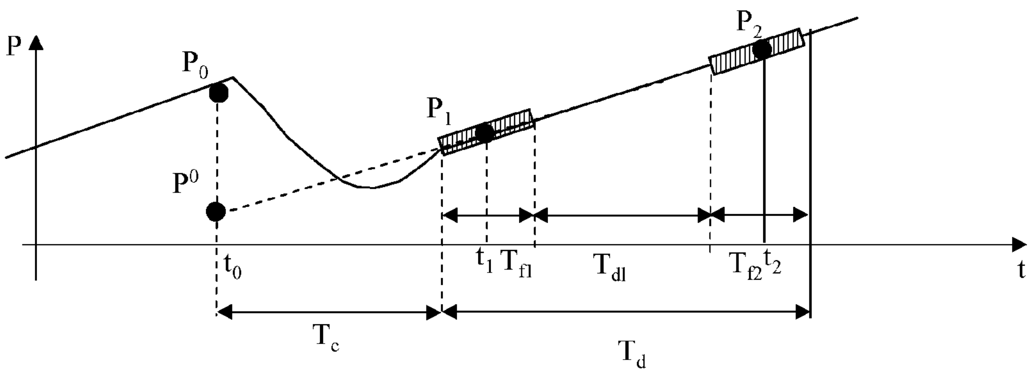

P
P_0
P^0
P_1
P_2
t_0
t_1 T_{f1}
T_{dl}
T_{f2} t_2
t
T_c
T_d

Fig. 5

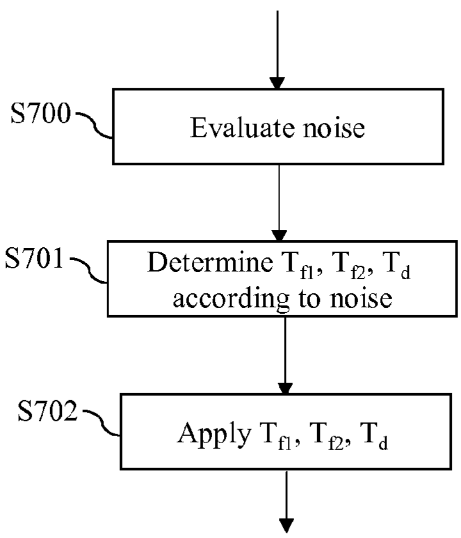

S700
Evaluate noise
S701
Determine T_{f1}, T_{f2}, T_d according to noise
S702
Apply T_{f1}, T_{f2}, T_d

Fig. 7

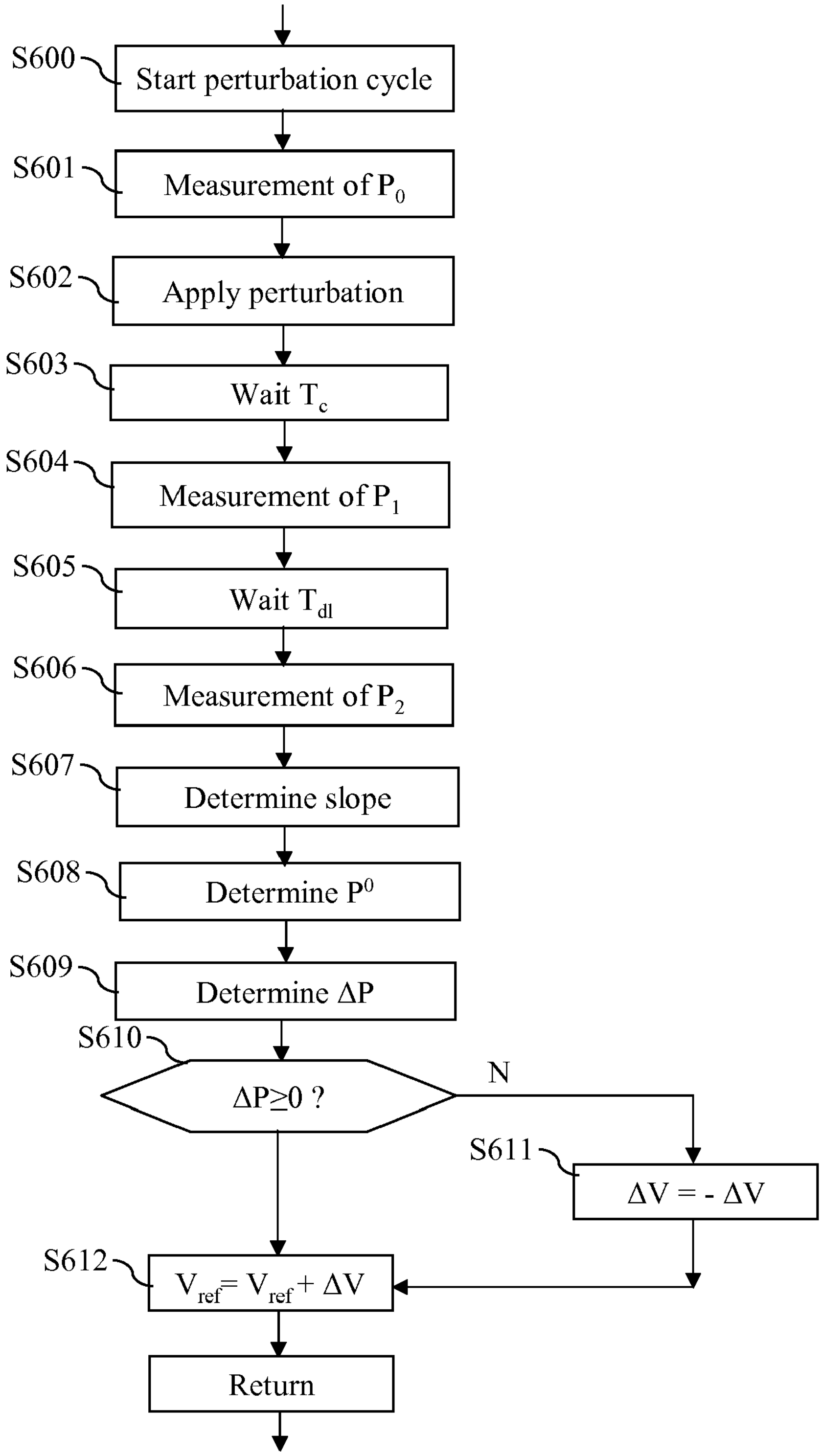

S600
Start perturbation cycle
S601
Measurement of P_0
S602
Apply perturbation
S603
Wait T_c
S604
Measurement of P_1
S605
Wait T_{dl}
S606
Measurement of P_2
S607
Determine slope
S608
Determine P^0
S609
Determine ΔP
S610
$\Delta P \geq 0$?
N
S611
$\Delta V = - \Delta V$
S612
$V_{ref} = V_{ref} + \Delta V$
Return

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 10 19 0495

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	SERA D ET AL: "Optimized Maximum Power Point Tracker for Fast-Changing Environmental Conditions", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, IEEE SERVICE CENTER, PISCATAWAY, NJ, USA, vol. 55, no. 7, 1 July 2008 (2008-07-01), pages 2629-2637, XP011226628, ISSN: 0278-0046, DOI: DOI:10.1109/TIE.2008.924036	1-5,10	INV. G05F1/67
A	* the whole document *	6-9	

Y	FEMIA N ET AL: "Optimization of Perturb and Observe Maximum Power Point Tracking Method", IEEE TRANSACTIONS ON POWER ELECTRONICS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 20, no. 4, 1 July 2005 (2005-07-01), pages 963-973, XP011135789, ISSN: 0885-8993, DOI: DOI:10.1109/TPEL.2005.850975	1-5,10	
A	* the whole document *	6-9	TECHNICAL FIELDS SEARCHED (IPC)
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A	US 2010/176771 A1 (FIELDHOUSE JEFFREY ALAN [CA] ET AL) 15 July 2010 (2010-07-15) * abstract; figures 5A,5B *	1-10	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	27 May 2011	Arias Pérez, Jagoba

1

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EUROPEAN SEARCH REPORT

Application Number
EP 10 19 0495

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	YING-TUNG HSIAO ET AL: "Maximum power tracking for photovoltaic power system", CONFERENCE RECORD OF THE 2002 IEEE INDUSTRY APPLICATIONS CONFERENCE : 37TH IAS ANNUAL MEETING ; 13 - 18 OCTOBER 2002, PITTSBURGH, PENNSYLVANIA, USA; [CONFERENCE RECORD OF THE IEEE INDUSTRY APPLICATIONS CONFERENCE. IAS ANNUAL MEETING], IEEE SERVICE CE, vol. 2, 13 October 2002 (2002-10-13), pages 1035-1040, XP010610008, DOI: DOI:10.1109/IAS.2002.1042685 ISBN: 978-0-7803-7420-1 * the whole document * -----	1-10	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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Non-patent literature cited in the description

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