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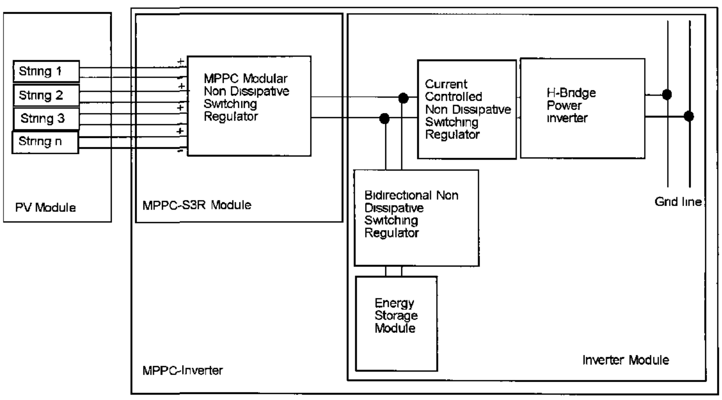

FIG. 2

(57) Abstract: The device consist of a Modular Non Dissipative Switching Regulator (MPPC-S3R) which delivers DC power at its maximum Power Point (MPP) and an Inverter Module, wherein the MPPC-S3R is modular allowing to get access to the power available from each of the n branches of the solar array as the voltage and the current from each branch is measured continuously; the inverter comprises a Current Controlled Non Dissipative Series Switching Regulator (CCSR) able to convert DC power supplied by the Modular Switching regulator into AC power, and a H-bridge Power Inverter, and it also comprises a Bidirectional switching series regulator which would allow the transfer for AC power to a storage module when the power provided is greater than the power demanded by the grid or transferring AC power from storage module to the Current controlled Switching regulator when the power demanded by grid is greater than the power supplied. This allows the highest possible efficiency maintaining the efficiency of the inverter as high as possible while detecting anomalies in any of the n-branches of a solar array.

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DEVICE TO EXTRACT MAXIMUM POWER FROM A SOLAR ARRAY AND PROCESS TO CARRY IT OUT

OBJECT OF THE INVENTION

The object of the present invention is a device able to extract the maximum of energy from a solar array and to transfer it, into a grid with the highest possible efficiency. It is also the object of the invention a process to extract the maximum energy from a solar array with the device of the invention.

The device object of the invention consist of a Modular Non Dissipative Switching Regulator which delivers DC power at its maximum Power Point (MPP) and an Inverter Module.

The Modular Non Dissipative Switching Regulator has as its mam feature the fact of being Modular, that is, it allows to get access to the power available from each of the n branches of the solar array as the voltage and the current from each branch is measured continuously.

The inverter module comprises a Current Controlled Non Dissipative Series Switching Regulator able to convert DC power supplied by the Modular Switching regulator into AC power, and a H-bridge Power Inverter.

Additionally the device it could comprise an additional module which would be a Bidirectional switching series regulator which would allow the transfer for AC power to a storage module when the power provided is greater than the grid power or transferring AC power from storage module to the Current controlled Switching regulator when the grid power is greater to the power supplied.

This Bidirectional Switching Regulator would be connected in parallel to the Modular Switching Regulator and the Current Controlled Switching Regulator.

Characterized the present invention the special features which the elements which form part of the object of the invention present m order to get at least a maximum extraction of energy from a solar array.

Thanks to the elements which form part of the device and the functions they performs some objectives are achieved, as the following:

- A solar array is operated to its MPP permanently and to it is got from it a DC power, without any AC ripple coming from a tracking process. This power is the sum of powers available from *n* solar panel branches mounted in parallel to form the solar array.

-Conversion of the DC power into into AC power in a suitable form to be inserted in a grid network with an efficiency the highest possible.

-Storing of the difference between the DC and the AC power in a non dissipative element and the difference power can be used to be injected into the grid or/and into another electrical network feeding non grid users. This module has the objective to maintain the power efficiency of the inverter as high as possible.

- Managing always the solar array to its optimum energy configuration in case where anomalies or failures are detected in the *n* solar panel branches.

- Informing a central control tower about the operational status of each branch of the solar array and identify the panels which may require maintenance.

- conversion of the DC maximum power available from a solar array into AC power to be injected into the grid with the highest efficiency.

BACKGROUND OF THE INVENTION

The state of the art is called MPPT-Inverter, which stands for Maximum Power Point Tracker and referred as MPPT, which is an electronic system that operates PV Modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically" moves the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power.

MPPT corresponds to a unit that transfers to the grid the maximum power possible from a solar array. This amount of power is the result of a tracking process, called MPPT (Maximum Power Point Tracking), which is achieved by measuring permanently, according to a sampling process kT, the voltage v_k and the current i_k of the solar array, make the product that is the power p_k at sampling time t_k and compare this result at time t_{k+1} by moving the operating point of a series regulator connected to the solar array. Depending on the sign of the difference $p_{k+1} - p_k$ the series regulator continue to move the operating point in one direction or its opposite. This power is supposed to be the maximum available from a solar array. It is exact if all panels of the solar array operate in the same conditions of light, temperature and ageing.

The general block diagram of a MPPT-Inverter, connected to a solar array of n sub panel modules, is represented on fig1. The n branches of the solar array are first paralleled before to be connected to a MPPT non dissipative series switching regulator. This regulator controls its input voltage and forces the PV module to operate at a voltage v_k and measures the available current i_k. It moves this voltage by steps until a change of sign in the measured power difference is detected. It is the MPPT process. The regulator delivers the power to the inverter module, under the form of a variable current as the inverter module imposes a DC voltage to the output of the MPPT regulator.

The inverter module is composed of two regulators. The first one is a series non dissipative regulator which behaves as a current source delivering an AC current, having the same phase as the AC grid voltage, to a H bridge power cell. This H bridge is connected to the grid via an insulating transformer for low power transfer or directly for high power transfer. In this last case, the insulation transformer is transferred into the current control regulator, generally under the form of a push-pull power cell.

One disadvantage of the MPPT-Inverter device is that does not allow to have access to the power from each of the n-branches of a solar array, happening sometimes that one or even more of the modules of the solar array, for instance, have a short-circuit, not being possible to know if the are contributing or not to the maximum power.

Another drawback which can be found in the devices used up to now and known as MPPT-Inverter is derived from the lack of correlation between the power supplied and grid power, lacking of any means for absorbing, or supplying the difference of power between the power supplied and the grid power.

Therefore it is an object of the present invention to overcome the drawbacks detected up to now, designing a device which would allow detection of any anomaly happened in any of the n-branches of a solar array and which would have means for absorbing or supplying the difference of power between the power supplied from the solar array and grid power.

EXPLANATION OF THE INVENTION

The object of the invention is to design a device able to extract the maximum of energy from a solar array and to transfer it, into a grid with the highest possible efficiency.

The device object of the invention consist of a Modular Non Dissipative Switching Regulator which delivers DC power at its maximum Power Point (MPP) , which will be referenced as MPPC (Maximum Power Point Control) and an Inverter Module.

The principle of the MPPC is to replace the MPPT process by the MPPC process in a first step. The modular feature of this process allows to get access to the power available from each of the *n* branches of the solar array as the voltage and the current from each branch is measured continuously. An anomaly happening to one of these *n* branches is immediately detected and corrective actions may be taken.

The main difference with the MPPT Inverter comes from the evaluation of the energy performance of each branch which are managed by a dedicated channel of a modular non dissipative sequential switching shunt regulator, called S3R. The *n* channels of the regulator force the solar array to operate at its MPP. If one branch is not contributing to the maximum power, due to a short circuit for instance, it can be disconnected from the rest and its status be sent to a central management controller. The efficiency of the S3R is almost 100% as only one channel is involved in the voltage regulation with a reduced duty cycle while the *n-1* other transfer the power to the inverter module.

Another difference with the state of the art represented by the combination MPPT-Inverter concerns the inverter module. A Current Controlled Series regulator (CCSR) is now connected to the MPPC-S3R module which delivers a DC power, the MPP power. A Current Controlled Series regulator able to convert this DC power into AC power is necessary and sufficient. In case such a regulator is not available it must be connected also to a Bidirectional Switching Series regulator mounted in parallel between the MPPC-S3R and the Current Contolled Series regulator. The task of this additional module is to allow the transfer of an AC power to the grid while a

DC power is available from the S3R. The power difference has an AC form, similar to the one transferred to the grid. It is transferred to an energy storage module, equivalent to a battery, when the MPP power is greater than the grid power. It is transferred to the Current Controlled regulator connected to the H bridge when the grid power is greater than the MPP power.

As for the MPPT inverter, an insulating transformer is inserted between the H bridge and the grid for low power application or inside the current controller, via a push-pull power cell for high power applications.

The device object of the invention consists of two modules a MPPC, referenced as MPPC-S3R module and an Inverter module.

The MPPC-S3R module is a modular shunt regulator with as many channels as they are solar panels to be managed. It is a S3R regulator with n channels, each channel connected to a solar panel via power cell composed of a shunt power switch Q_n and a series power diode D_n. The n power cells are connected to a common capacitive output filter c. This regulator regulates the *MPP* voltage of the solar array (or the n solar panels) according to a reference command *Vmpp* generated by a microprocessor. The microprocessor computes the MPP of the solar array using the measurements of the i_n current coming from each solar panel, the solar array voltage v and the status of the power switches Q_n.

The inverter module converts the DC voltage at the output of the MPPC-S3R module into AC current such as the MPP power is totally transferred to the grid. If i_{MPP} and v_{MPP} and are the delivered current and voltage delivered by the MPPC-S3R and i_{AC} is the AC current transferred to the grid at the imposed voltage v_{AC}, that is *220V rms* at the frequency $f= /2$ that is *50 Hz,* the MPP power P_{MPP} is such as:

$$P_{MPP} = \overline{v_{AC} i_{AC}} = \overline{v_{MPP} i_{MPP}}$$

EXPIANATION OF THE FIGUKES

Further characteristics and advantages of the invention will be explained in greater detail in the following detailed description of an embodiment thereof which is given by way of non-limiting example with reference to the appended drawings, in which:

Figure 1, shows a Block diagram of a MPPT-Inverter

Figure 2 represents a block diagram of the device object of the invention, that is, a MPPC- Inverter

Figure 3, represents a detailed circuit of this MPPC-S3R module

Figure 4, represents a theoretical block diagram of the inverter module of the MPPC-Inverter unit.

Figures 5A, 5B and 5C, represent the waveforms of the grid parameters at IkW MPP power.

Figure 6, represents power ripple at input of the Current Controlled Series Regulator.

Figure 7, shows a block diagram of the Current

Controlled Series Regulator CCSR.

Figure 8, shows a detailed block diagram of the MPPC-S3R Inverter with active filter.

PREFERRED EMBODIMENT OF THE INVENTION

The device of the invention basically consists of a MPPC module referenced as a MPPC-S3R and an inverter module, both combined seek to extract the maximum of energy from a solar array and to transfer it, into a grid with the highest possible efficiency.

In figure 2 it can be observed a block diagram of the device object of the invention wherein it is possible identified the MPPC-S3R module and the Inverter Module and the elements which form part of the same.

A detailed circuit of this MPPC-S3R module is shown on fig 3 where 3 solar panel modules are connected to a 3 channels switching shunt regulator. The load corresponds to the inverter module.

The MPPC-S3R module is a modular shunt regulator with as many channels as they are solar panels to be managed. It is a S3R regulator with n channels, each channel connected to a solar panel via power cell composed of a shunt power switch Q_n and a series power diode D_n. The n power cells are connected to a common capacitive output filter C. This regulator regulates the *MPP* voltage of the solar array (or the n solar panels) according to a reference command V_{RMPP} generated by a microprocessor. The microprocessor computes the MPP of the solar array using the measurements of the i_n current coming from each solar panel, the solar array voltage v and the status of the power switches Q_n.

The inverter module converts the DC voltage at the output of the MPPC-S3R module into AC current such as the MPP power is totally transferred to the grid. If i_{MPP} and v_{MPP} and are the delivered current and voltage delivered by the MPPC-S3R and i_{AC} is the AC current transferred to the grid at the imposed voltage v_{AC}, that is *220V rms* at the frequency $f=\omega/2\pi$ that is *50 Hz*, the MPP power P_{MPP} is such as:

$$\bar{P}_{MPP} = \overline{v_{AC} \dot{i}_{AC}} = \overline{v_{MPP} \dot{i}_{MPP}}$$

This transfer is represented by the block diagram given on fig4, wherein it can be observed that the inverter module is composed of a Current Controlled Series Regulator (CCSR) connected in series with a H-bridge power inverter.

In such a module, the grid voltage v_{AC} is imposed to the output of the Current Controlled Series Regulator. It is given by:

$$v_{AC} = V_M \cos \omega t$$

The voltage waveform is given on fig 5A. This maximum peak voltage V_M for a grid voltage where V_{rms} is 220V is given by the relationship:

$$V_M = V_{rms}\sqrt{2} = 220 * \sqrt{2} = 311.08$$

The Current Controlled Series Regulator (CCSR) has to deliver to the H bridge a variable current i_{Out} able to be transferred to the grid under a sinus waveform having the same phase as the voltage v_{AC}. Let us supposed that the MPP power is IkW_1 therefore the rms value I_{rms} of the i_{AC} current is $1kW/220=4.54\ A$. It corresponds a sinus current waveform with a peak value I_M (half of the peak to peak value) such as:

$$I_M = \frac{\sqrt{2}}{2} I_{rms} = 3.21$$

The current i_{out} to be delivered by the CCSR, as the H-Bidge is m charge to the transfer of power to the grid under a sinus waveform, corresponds to the absolute values of the grid current i_{AC} that is:

$$i_{out} = ABS/ I_{AC} \cos \omega t / = 3.H\cos \omega t$$

The waveform of the current i_{out} is shown on fig 5B. The power P_{AC} delivered to the grid is given on fig 5c. It corresponds to the relationship:

$$P_{AC} = V_M I_M \cos^2 \omega t = \frac{V_M I_M}{2} (1 + 2 \cos \omega t)$$

It is a sinus waveform around the averaged power that is the MPP power.

The variable delivered power P_{AC} is available at the input of the Current Controlled Series Regulator which receives a constant power, the MPP power P_{MPP}. The difference P_C between these both powers corresponds to the waveform given on fig 6, given by:

$$P_C = P_{MPP} - P_{AC} = P_{MPP} - -^(l+2\cos \omega t)$$

It is equivalent to a power ripple to be filtered at the input of the Current Controlled Series Regulator, as it is shown in figure 6.

The ripple shown in figure 6 may be filtered passively by a huge reactive filter composed by a capacitance C or an *LC* filter. It leads to a heavy and massive filter. It cannot be suppressed the voltage ripple v on the capacitance terminals. The worst case is given by:

$$\Delta v = \frac{1}{C}\frac{P_{MPP}}{V_{MPP}}\Delta t$$

A ripple of IV for an application where VW is around 400V and P_{MPP} is IkW will require a capacitance C of several thousands of F.

The Current Controlled Series Regulator is necessary to generate the current i_{out} as shown on fig 5B. Its output voltage V_{out} is imposed by the grid. Transferred by the H-Bridge this voltage is a positive half sinus waveform. This regulator can be buck or boost type such as the output current is controlled by a command v such as, if G is a constant and G_{MPP} a parameter dependent on VW and v_{out}:

$$i_{out} = Gv - G_{MPP}$$

The block diagram of this regulator, in the case of a buck power cell is given on fig 7. It is a classical current control buck where the sawtooth current waveform $i(t)$ of the switch Q_A is compared to an analogue command Gv using a Comparator. This current follows the relationship:

$$i(t) = i_m + \frac{V_{MPP} - V_{out}}{L} t$$

When at time t_c where this current reaches a maximum i_M value such as:

$$i_M = i_{out} = i_m + \frac{V_{MPP} - V_{out}}{L} t_C$$

the output of the Comparator changes sign and the Logic circuit which has switched on Q_A according to a clock generator, switches off Q_A and switches on Q_3. As:

$$i_{out} = i_M - \frac{V_{MPP} - V_{out}}{L} t_C = i_{out} - \frac{V_{MPP} - V_{out}}{L} t_C$$

In a buck, with a sampling period T, the switch on time t_c is given by:

$$t_C = T \frac{V_{MPP}}{V_{out}}$$

Therefore

$$i_{out} = i_{out} - \frac{V_{MPP} - V_{out}}{L} T \frac{V_{MPP}}{V_{out}}$$

The output current must have a half sinus positive waveform with a peak value I_M dependent on I_{MPP} in order that the same quantity of electricity is exchanged in the input of the regulator that is:

$$\int_0^{\frac{T_G}{2}} i_{out}(t)dt = \int_0^{\frac{T_G}{2}} I_M \cos\omega t dt = I_{MPP}\frac{T_G}{2}$$

which gives

$$I_M = \pi I_{MPP}$$

The command $Gv(t)$ is realised by a microprocessor which receives inputs from :

- the grid voltage to generate a waveform $Gv(t)$ in phase with v_{AC}
- the current I_{Mpp} to the maximum amplitude of the $Gv(t)$
- the output current i_o for the feedback control of this parameter.

The voltage $Gv(t)$ is the output voltage provided by a microprocessor which amplifies Ia difference between the current going to the inverter and the current coming from the S3R. It is a control command which defines the upper limit of the switching current entering the inverter. And as it can be observed in figure 7 depending of the difference between $Gv(t)$ and I_M, the CCSR will work as a buck or as a boost type regulator, activitmg either Q_A or Q_B .

In this figure 7, it is also possible to observe the inverter H-Bridge which is composed of 4 switches Q_1 Q_2 Q_3 Q_4 The switches Q_1 and Q_3 are activated by the same driver as well as the switches Q_2 and Q_4 by another driver. Both drivers are synchronised by the grid voltage.

In order to avoid a power ripple at the input of the regulator and reduce the voltage ripple by a huge reactive filter, an active filter has to be inserted between the MPPC-S3R and the regulator. The block diagram of this process is shown on fig 2, wherein it can be observed that a bidirectional non dissipative regulator connected to an energy storage device has been mounted at the interface between the MPPC-S3R and the Controlled Current Series Regulator.

The bidirectional non dissipative regulator connected to the energy storage device, a capacitance or a battery, mounted at the interface between the S3R and the Current Controlled Series Regulator has the objective to derive to the energy storage device the excess of power and restore it when it is required by the inverter. The following relationship is imposed at the interface, if P_C is the power involved in the energy storage device :

$$P_C = P_{MPP} - P_{AC} = P_{MPP} - \frac{V_M I_M}{2}(\backslash + 2cos\,\omega t)$$

On fig 8 is detailed the block diagram of the complete MPPC-S3R Inverter with the active filter. This filter is a bidirectional current controlled regulator. It operates as a buck to transfer power from the S3R to the capacitance C_5 and as a boost to send power to the inverter. The switches of the regulator are $Q_A\varepsilon$ and $Q_B\varepsilon$ .The principle is the same as the Current Controlled Series Regulator. The saw tooth current $2_S(t)$ flowing into switch Q_{AS} is sensed and compared to an analogue command Gv_S .This current is positive in the buck operation (power to the capacitance C_S) and negative in the boost mode (power to the CCSR) . The switch is activated by a clock via the Logic circuit and the driver, and switched off when the comparator changes state that is:

$$i_{MS} = Gv_S$$

The current m the inductance L_S is controlled by a feedback loop which compares it to a variable reference current via an Error Amplifier which generates the command Gv_S

This variable reference is the result of a comparison of the MPP current I_{MPP} with the inverter current I entering the Current Controlled Series Regulator via an Amplifier. In order to eliminates the sawtooth ripple, an LC filter is inserted between the S3R and the inverter.

The essential nature of this invention is not altered by variations in materials, form, size and arrangement of the component elements, described in a non-restrictive manner, sufficient for an expert to proceed to the reproduction of thereof.

CLAIMS

1.- Device able to extract the maximum of energy from a solar array and to transfer it, into a grid characterized in that it comprises:

- a Modular Non Dissipative Switching Regulator (MPPC-S3R) which delivers DC power at its maximum Power Point (MPP), and it has n dedicated channels being every channel connected to the n branches of the solar array.

- an Inverter Module comprising a Current Controlled Non Dissipative Series Switching Regulator CCSR able to convert DC power supplied by the Modular Switching regulator into AC power, and a H-bridge Power Inverter

- a Bidirectional switching series regulator connected to an energy storage device is mounted at the interface between the MPPC-S3R and the Current Controlled Series Regulator (CCSR).

2.- Device according to claim 1 characterized in that the Modular Non Dissipative Switching Regulator (MPPC-S3R) is composed of a microprocessor and means for generating a reference command v_{RMPP}

3.- Device according to claim 2 characterized in that every of the n channels the Modular Non Dissipative Switching Regulator (MPPC-S3R) is composed of a shunt power switch Q and a series power diode.

A.- Device according to claim 1 characterized in that the Current Controlled Non Dissipative Series Switching Regulator CCSR of the inverter module, comprises a micropressor a comparator a clock, a logic circuit and a driver, wherein the microprocessor generates a control command Gv(t) which defines the upper limit of the switching current entering in the inverter and compared with $I_{M/}$ the CCSR will work as a buck or as a boost type regulator, activating either of switches Q_A or Q_B the CCSR has.

5.- Device according to claim 1 characterized in that the H-Bridge of the Power Inverter is composed of 4 switches Q_i Q_2 Q_3 Q_4 The switches Q_1 and Q_3 are activated by the same driver as well as the switches Q_2 and Q_4 by another driver. Both drivers are synchronised by the grid voltage

6.- Device according to claim 1 characterized in that the Bidirectional Switching Series Regulator comprises a micropressor a comparator a clock, a logic circuit and a driver, and the Storage device is a Capacitance .

1.- Process to extract maximum energy from a solar array with the device previously claimed which is comprised of:

- a Modular Non Dissipative Switching Regulator (MPPC-S3R) which delivers DC power at its maximum Power Point (MPP) , and it has n channels being every channel connected to the n branches of the solar array.
- an Inverter Module comprising a Current Controlled Non Dissipative Series Switching Regulator CCSR able to convert DC power supplied by the Modular Switching regulator into AC power, and a H-bridge Power Inverter
- a Bidirectional switching series regula¬tor connected to an energy storage device is mounted at the interface between the MPPC-S3R and the

Current Controlled Series Regulator (CCSR).

And the processed comprises the following actions.

- the MPPC-S3R evaluates the energy performance of each branch of a solar array and it regulates the *MPP* voltage of the solar array (or the *n* solar panels) according to a reference command V_{RMPP} generated by a microprocessor which computes the MPP of the solar array using the measurements of the i_n current coming from each solar panel, the solar array voltage v and the status of power switches Q_n of every channel.
- The CCSR (Current Controlled Series Regulator) of the inverter module converts the DC voltage at the output of the MPPC-S3R module into AC current and can work as a buck or boost type such as the current output is controlled by a command $Gv_{(t)}$
- The Bidirectional switching series regulator operates as a buck to transfer power from the MPPC-S3R to a capacitance C_S and as a boost to send power to the inverter.

8.- Process to extract maximum energy from a solar array according to claim 7 characterized in that the command $Gv_{(t)}$ is realised by a microprocessor which receives inputs from :

-the grid voltage to generate a waveform $Gv_{(t)}$ in phase with v_{AC}

-the current I_{MPP} to the maximum amplitude of the $Gv_{(t)}$

-the output current x_o for the feedback control of this parameter

9.- Process to extract maximum energy from a solar array according to claim 7 characterized in that the The Bidirectional switching series regulator comprises two switches Q_{AS} and Q_{BS} wherein the saw tooth current $i_S(t)$ flowing into switch Q_{AS} is sensed and compared to an analogue command Gv_s this current is positive in the buck operation (power to the capacitance C_S) and negative in the boost mode (power to the CCSR) ; the switch is activated by a clock via the Logic circuit and the driver, and switched off when the comparator changes state

10.- Process to extract maximum energy from a solar array according to claim 7 characterized in that the storage device connected to the Bidirectional Switching Series Regulator is comprises by Capacitance C_S and an inductance L_S where the current m the inductance L_S is controlled by a feedback loop which compares it to a variable reference current via an Error Amplifier which generates the command Gv_s

AMENDED CLAIMS
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1.- Device able to extract the maximum of power from a solar array and to transfer it, into a grid characterized in that it comprises:

- a Modular Non Dissipative Switching Regulator (MPPC-S3R) which delivers DC power at the maximum Power Point (MPP) of the corresponding branch of the solar array it is connected to, and it has n dedicated channels wherein every channel is connected to a corresponding one of the n branches of the solar array.
- an Inverter Module comprising a Current Controlled Non Dissipative Series Switching Regulator (CCSR) able to convert DC power supplied by the Modular Switching regulator into AC power, and a H-bridge Power Inverter
- a Bidirectional switching series regulator connected to an energy storage device is mounted at the interface between the Modular Non Dissipative Switching Regulator (MPPC-S3R) and the Current Controlled Series Regulator (CCSR).

2.- Device according to claim 1 characterized in that the Modular,. Non Dissipative Switching Regulator (MPPC-S3R) comprises a microprocessor and means for generating a first reference command $(v_{RM}pp)$

3.- Device according to claim 2 characterized in that every of the n channels the Modular Non Dissipative Switching Regulator (MPPC-S3R) comprises a shunt power switch (Q) and a series power diode.

4.- Device according to claim 1 characterized in that the Current Controlled Non Dissipative Series Switching Regulator (CCSR) of the inverter module, comprises a micropressor a comparator a clock, a logic circuit and a driver, wherein the microprocessor generates a control command (Gv(t)) which defines the upper limit of the switching current entering in the inverter and compared with I_M, the Non Dissipative Series Switching Regulator (CCSR) is being used to either deliver power to the grid form DC-link capacitor C (supply mode) or to deliver power from the grid to DC-link capacitor C (storage mode), activating either of switches, a first switch (Q_A) or a second swithch (Q_B) the Non Dissipative Series Switching Regulator (CCSR) has.

5.- Device according to claim 1 characterized in that the H-Bridge of the Power Inverter is composed of 4 switches, a first switch *(Q_1) a second switch (Q_2) a third switch (Q_3) and a fourth switch (Q_4)* The switches Q_1 and Q_3 are activated by the same driver as well as the switches Q_2 and Q_4 by another driver. Both drivers are synchronised by the grid voltage

6.- Device according to claim 1 characterized in that the Bidirectional Switching Series Regulator comprises a microprocessor a comparator a clock, a logic circuit and a driver, and the Storage device is a capacitor.

7.- Process to extract maximum energy from a solar array with the device previously claimed which is comprised of:

- a Modular Non Dissipative Switching Regulator (MPPC-S3R) which delivers DC power at its maximum Power Point (MPP), and it has n channels being every channel connected to the n branches of the solar array.
- an Inverter Module comprising a Current Controlled Non Dissipative Series Switching Regulator (CCSR) able to convert DC. power supplied by the Modular Switching regulator into AC power, and a H-bridge Power-Inverter -
- a Bidirectional switching series regulator connected to an energy storage device is mounted at the interface between the Modular Non Dissipative Switching Regulator (MPPC-S3R) and the Current Controlled Series Regulator (CCSR).

And the processed comprises the following actions.

- the Modular Non Dissipative Switching Regulator (MPPC-S3R) evaluates the energy performance of each branch of a solar array and it regulates the maximum Power Point *[MPP)* voltage of the solar array (or the *n* solar panels) according to a first reference command (VR_{MPP}) generated by a microprocessor which computes the maximum Power Point (MPP) of the solar array using the measurements of the (i_n) current coming from each solar panel, the solar array voltage *v* and the status of power switches (Q_n) of every channel.

- The Current Controlled Series Regulator (CCSR) of the inverter module converts the DC voltage at the output of the Modular Non Dissipative Switching Regulator (MPPC-S3R) module into AC current and can work as a buck or boost type such as the current output is controlled by a second reference command *(Gv(t))*
- The Bidirectional switching series regulator operates as a-buck to transfer power from the Modular Non Dissipative Switching Regulator (MPPC-S3R) to a capacitor (C_S) and as a boost to send power to the inverter.

8.- Process to extract maximum energy from a solar array according to claim 7 characterized in that the second reference command *(Gv(t))* is realised by a microprocessor which receives inputs from :

- the grid voltage to generate a waveform of a second reference command *(Gv(t))* in phase with grid voltage (v_{AC})
- the current entering the inverter module (IMP_P) to the maximum amplitude of the second reference command *(Gv(t))*
- the output current (i_0) for the feedback control of this parameter

9.- Process to extract maximum energy from a solar array according to claim 7 characterized in that the The Bidirectional switching series regulator comprises two switches, a first switch *(QAS)* and a second switch (Q_{BS}) wherein the saw tooth current (/s(t)) flowing into the first switch (Q_{AS}) is sensed and compared to an analogue command *(Gvs)* this current is positive in the buck operation (power to the capacitance *(Cs))* and negative in the boost mode (power to the CCSR); the switch is activated by a clock via the Logic circuit and the driver, and switched off when the comparator changes state

10.- Process to extract maximum energy from a solar array according to claim 7 characterized in that the storage device connected to the Bidirectional Switching Series Regulator is comprises by Capacitance (Csjand an inductance *(L_s)* where fhe current in the inductance *(L_s)* is controlled by a feedback loop which compares it to a variable reference current via an Error Amplifier which generates the analogue command *(Gv_8)*.

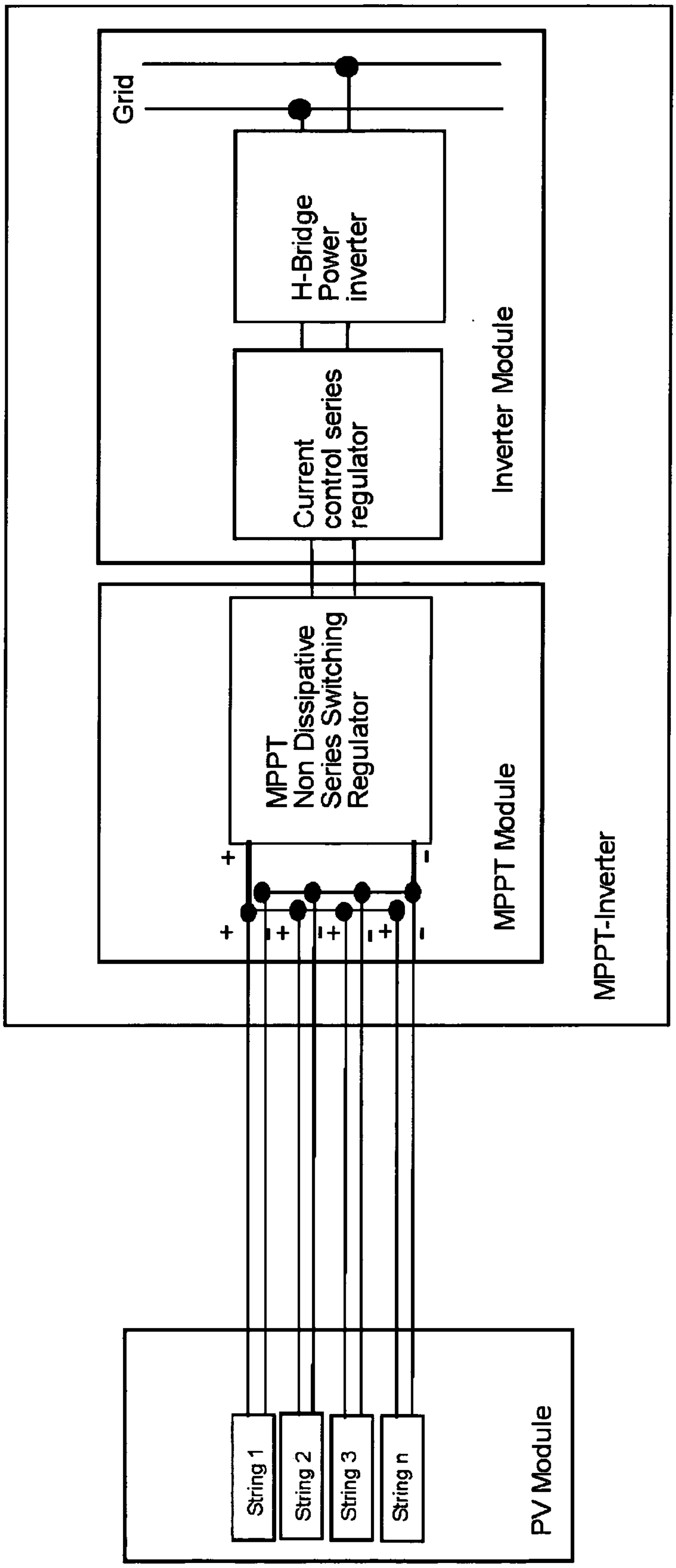

Grid
H-Bridge
Power
inverter
Current
control series
regulator
Inverter Module
MPPT
Non Dissipative
Series Switching
Regulator
MPPT Module
MPPT-Inverter
String 1
String 2
String 3
String n
PV Module

FIG.1

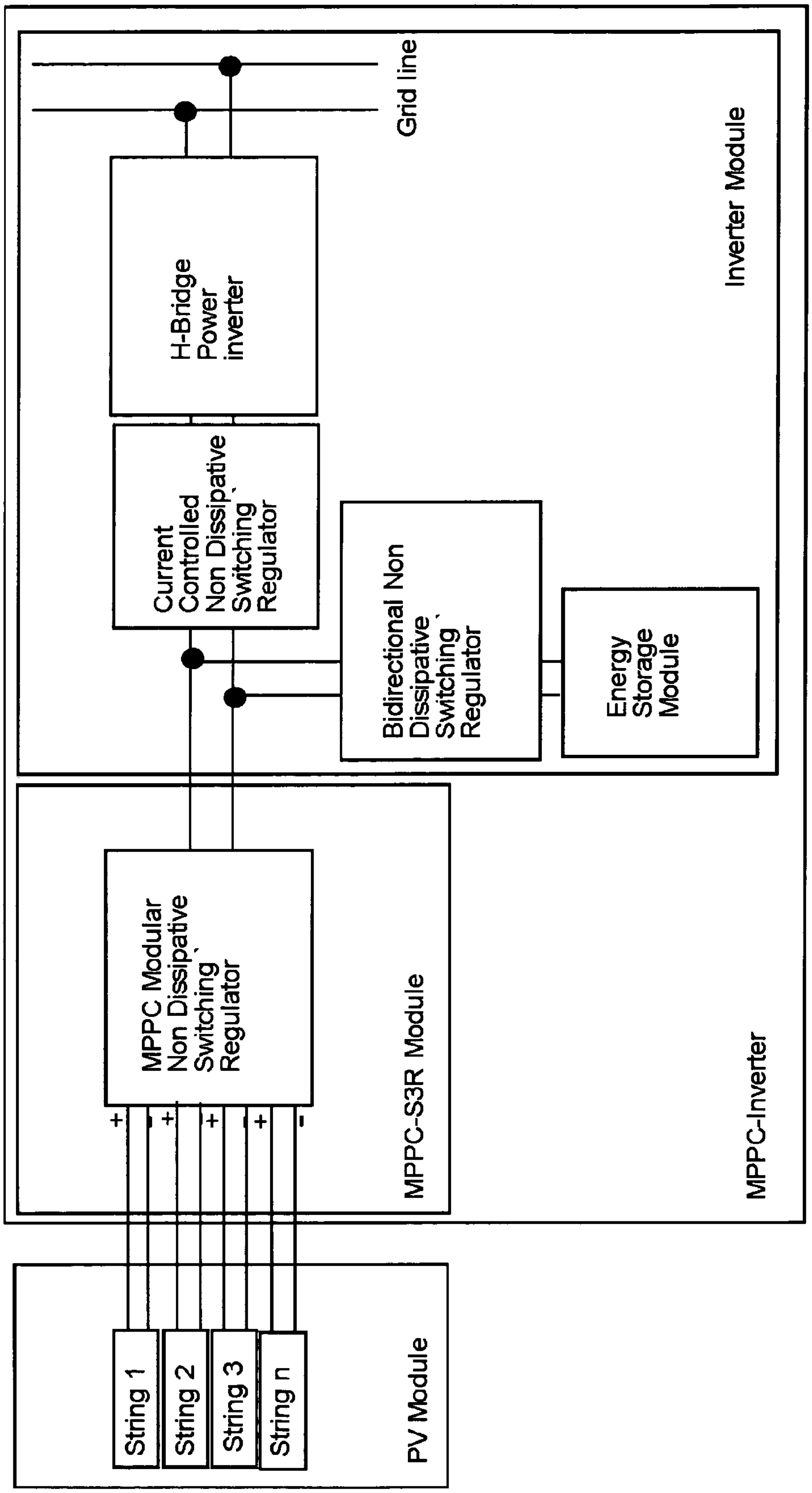
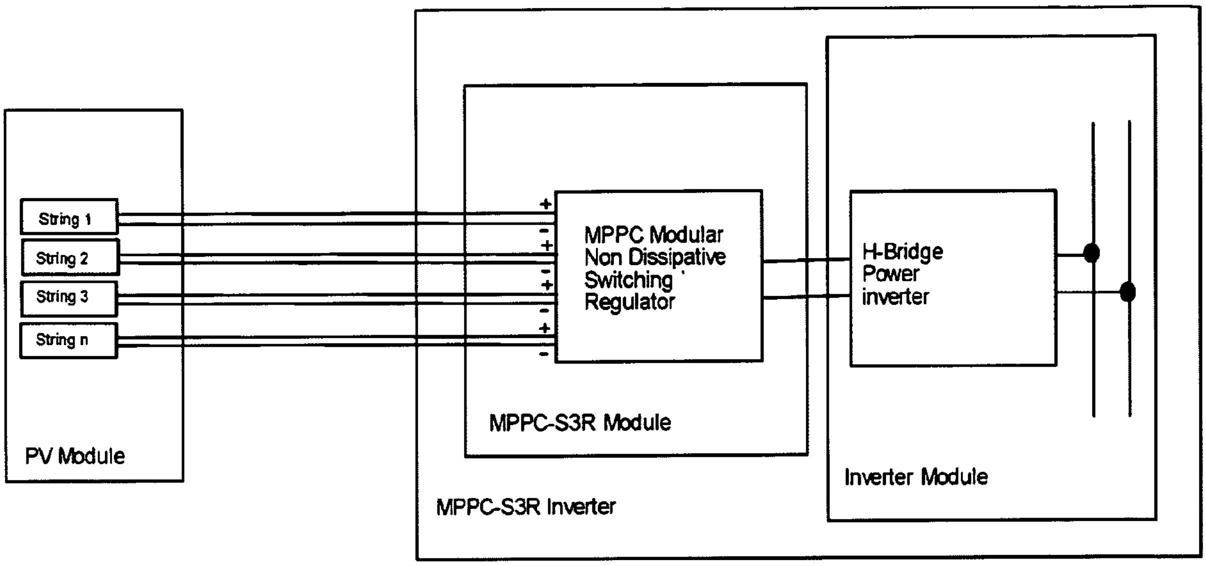

Grid line
H-Bridge Power inverter
Inverter Module
Current Controlled Non Dissipative Switching Regulator
Bidirectional Non Dissipative Switching Regulator
Energy Storage Module
MPPC Modular Non Dissipative Switching Regulator
MPPC-S3R Module
MPPC-Inverter
String 1
String 2
String 3
String n
PV Module

FIG.2


String 1
String 2
String 3
String n
PV Module
MPPC Modular Non Dissipative Switching Regulator
MPPC-S3R Module
MPPC-S3R Inverter
H-Bridge Power inverter
Inverter Module

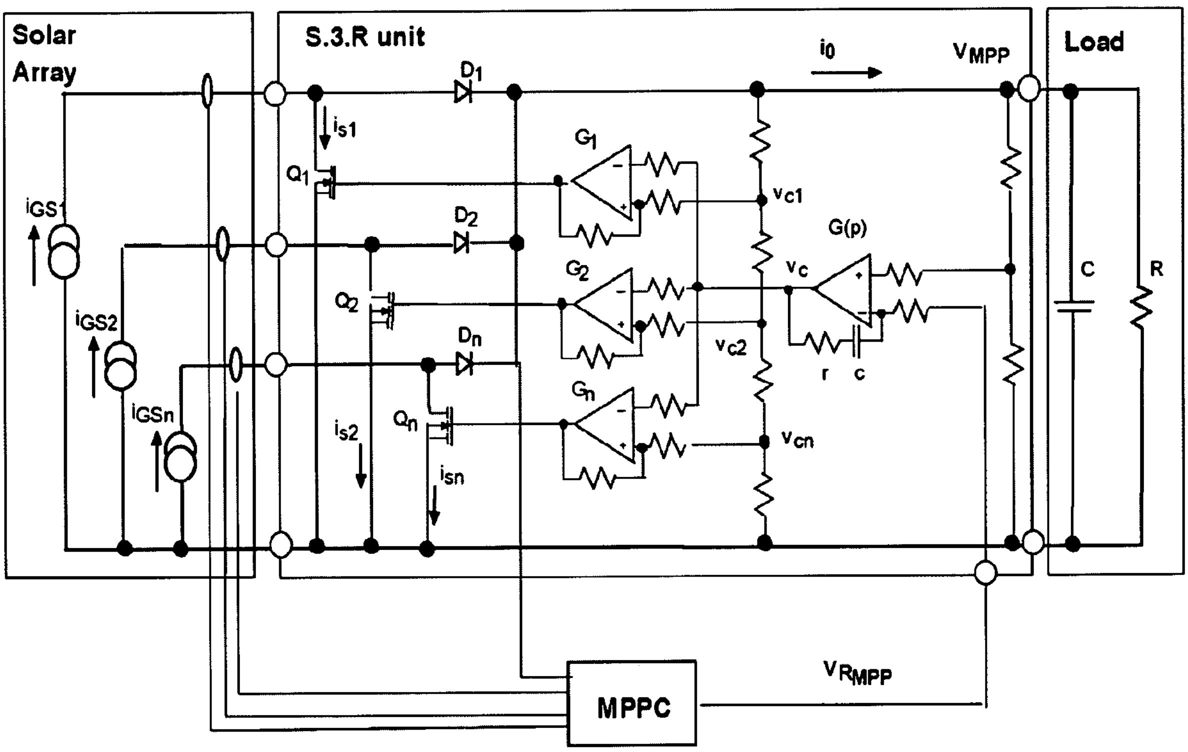

Solar Array
S.3.R unit
Load
D_1
D_2
D_n
Q_1
Q_2
Q_n
G_1
G_2
G_n
G(p)
i_{s1}
i_{s2}
i_{sn}
i_{GS1}
i_{GS2}
i_{GSn}
i_0
V_{MPP}
v_{c1}
v_{c2}
v_{cn}
v_c
r
c
C
R
MPPC
V_{RMPP}

FIG.3

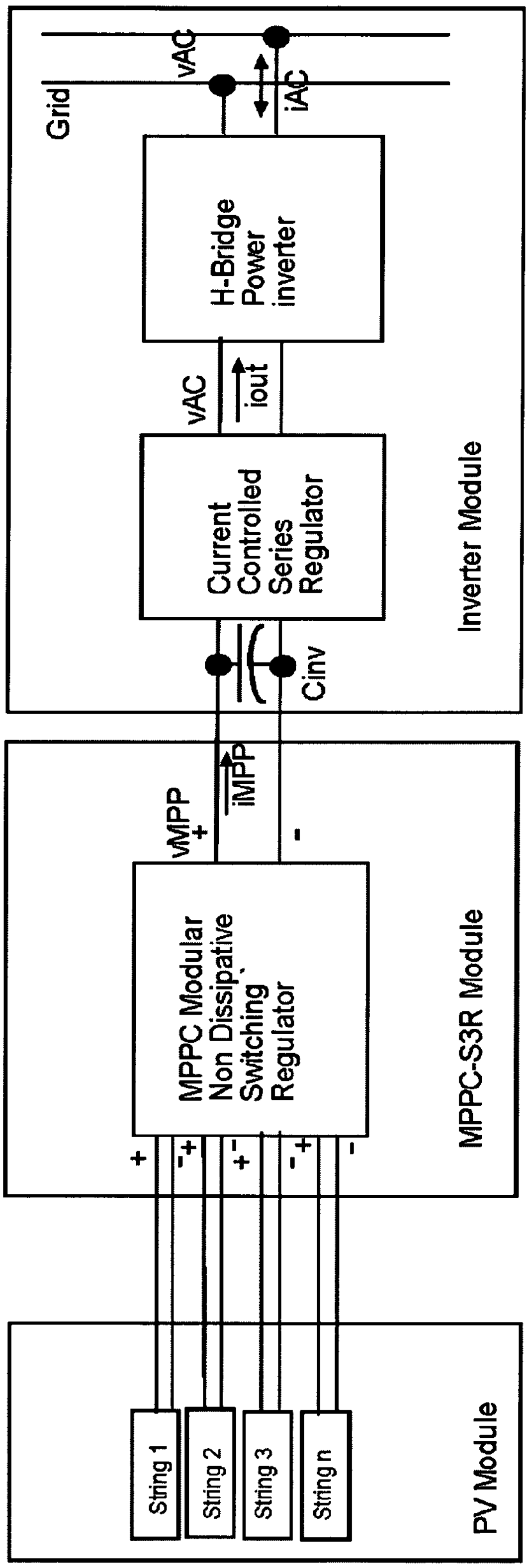

Grid
vAC
iAC
H-Bridge
Power
inverter
vAC
iout
Current
Controlled
Series
Regulator
Inverter Module
Cinv
vMPP
+
iMPP
-
MPPC Modular
Non Dissipative
Switching
Regulator
MPPC-S3R Module
String 1
String 2
String 3
String n
PV Module

FIG.4

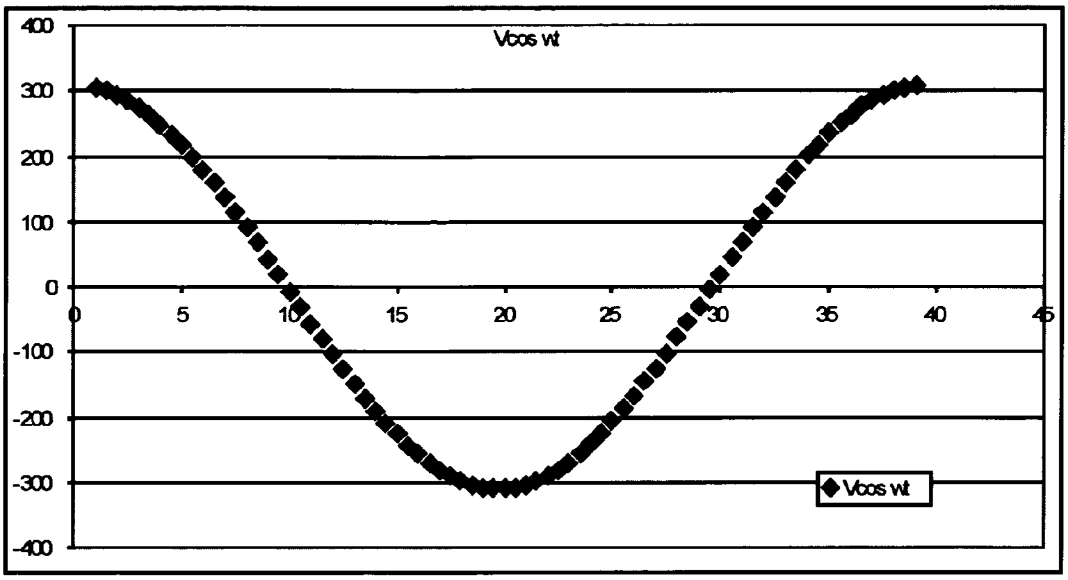

Vcos wt
400
300
200
100
0
-100
-200
-300
-400
0
5
10
15
20
25
30
35
40
45
Vcos wt

FIG.5A

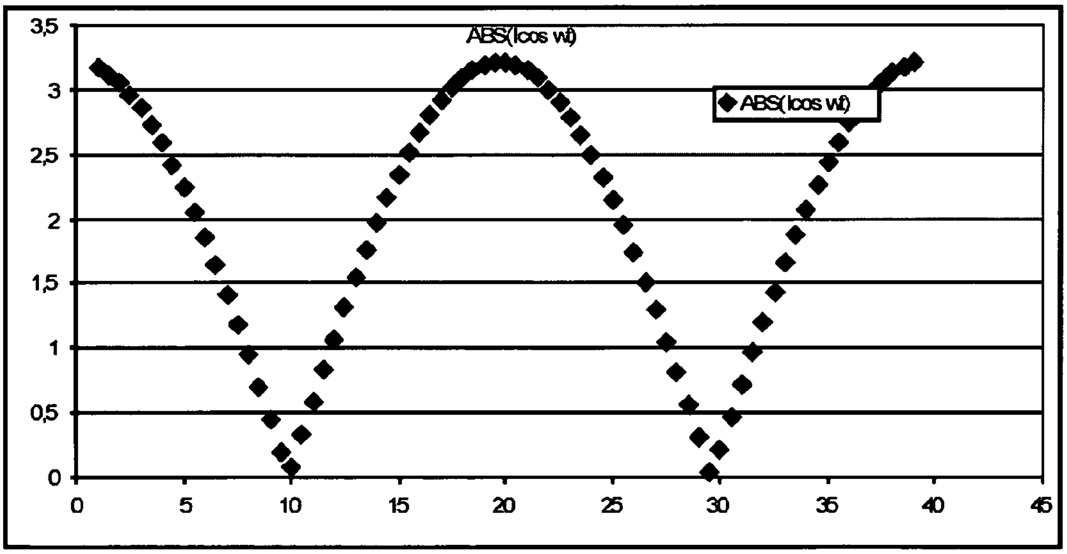

ABS(Icos wt)
3,5
3
2,5
2
1,5
1
0,5
0
0
5
10
15
20
25
30
35
40
45
ABS(Icos wt)

FIG.5B

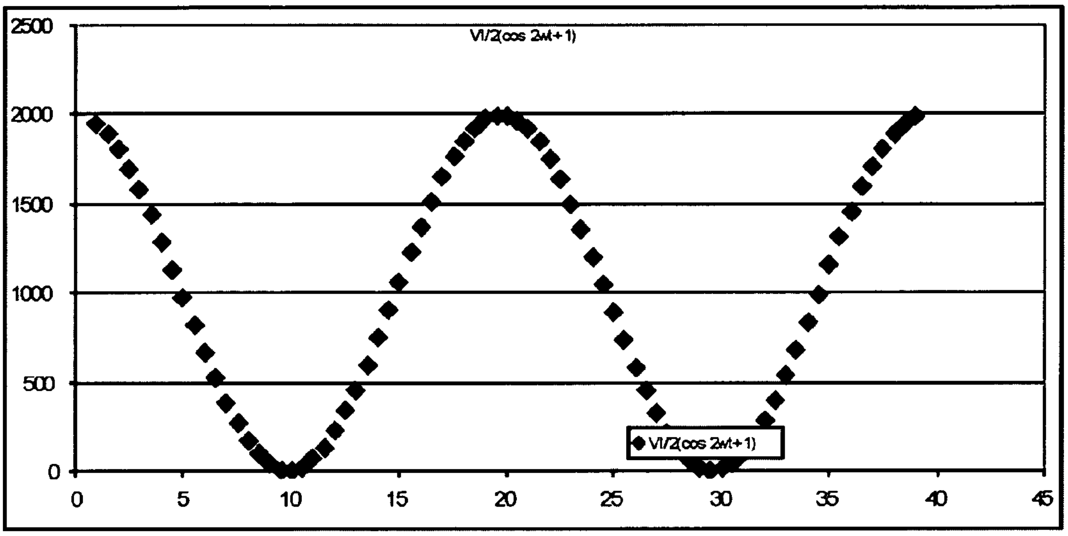

VI/2(cos 2wt+1)
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
VI/2(cos 2wt+1)

FIG.5C

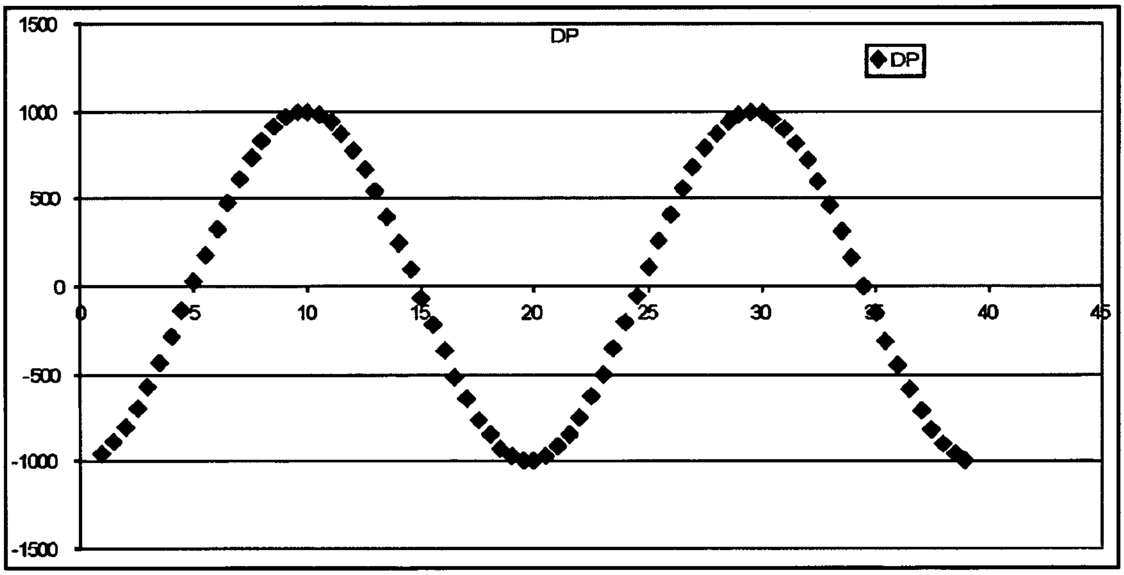

DP
DP
1500
1000
500
0
-500
-1000
-1500
0
5
10
15
20
25
30
35
40
45

FIG.6

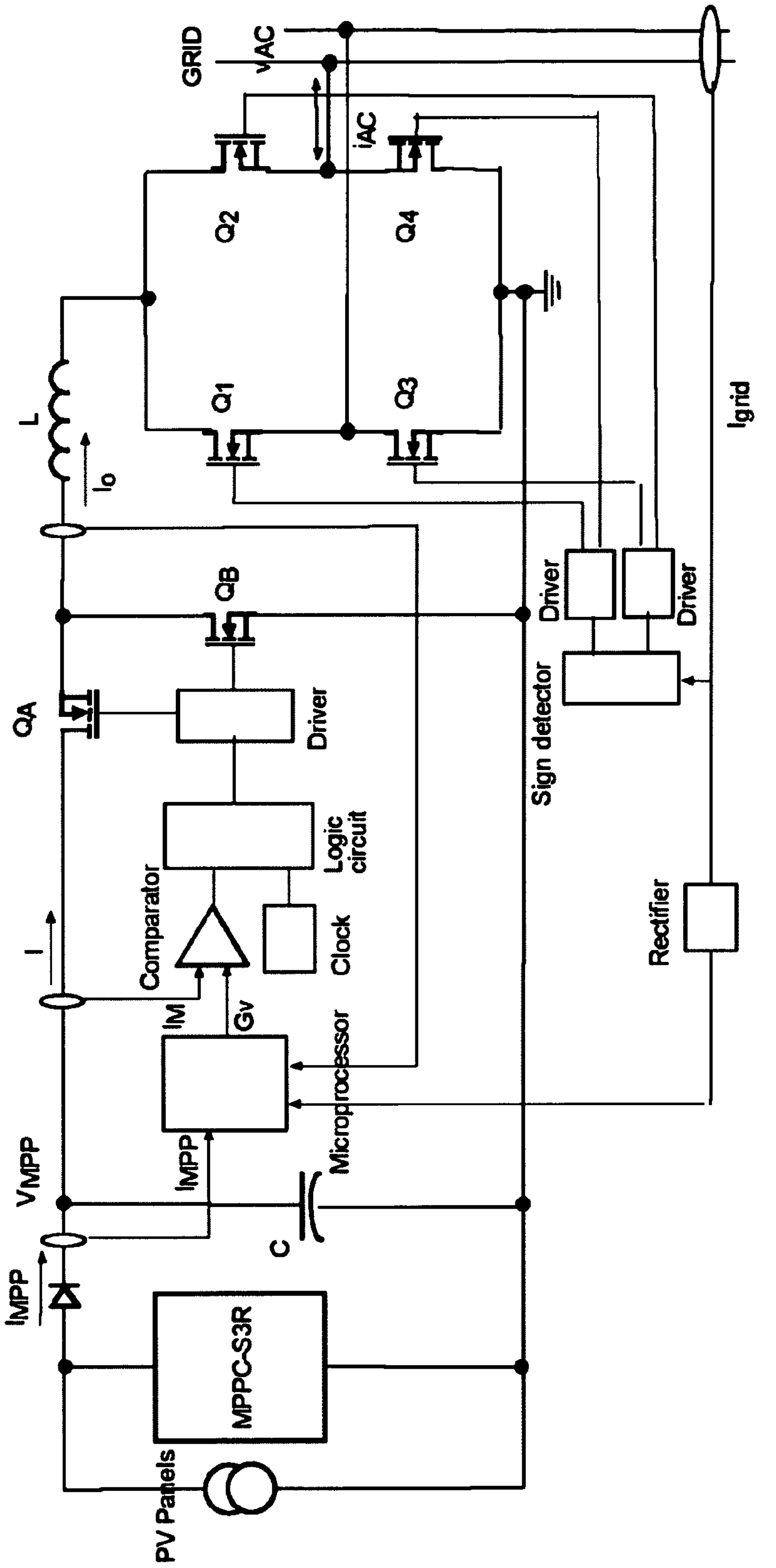

GRID
VAC
iAC
Q1
Q2
Q3
Q4
L
Io
QA
QB
Driver
Logic circuit
Comparator
Clock
I
IM
Gv
Microprocessor
VMPP
IMPP
C
MPPC-S3R
PV Panels
Driver
Driver
Sign detector
Rectifier
Igrid

FIG.7

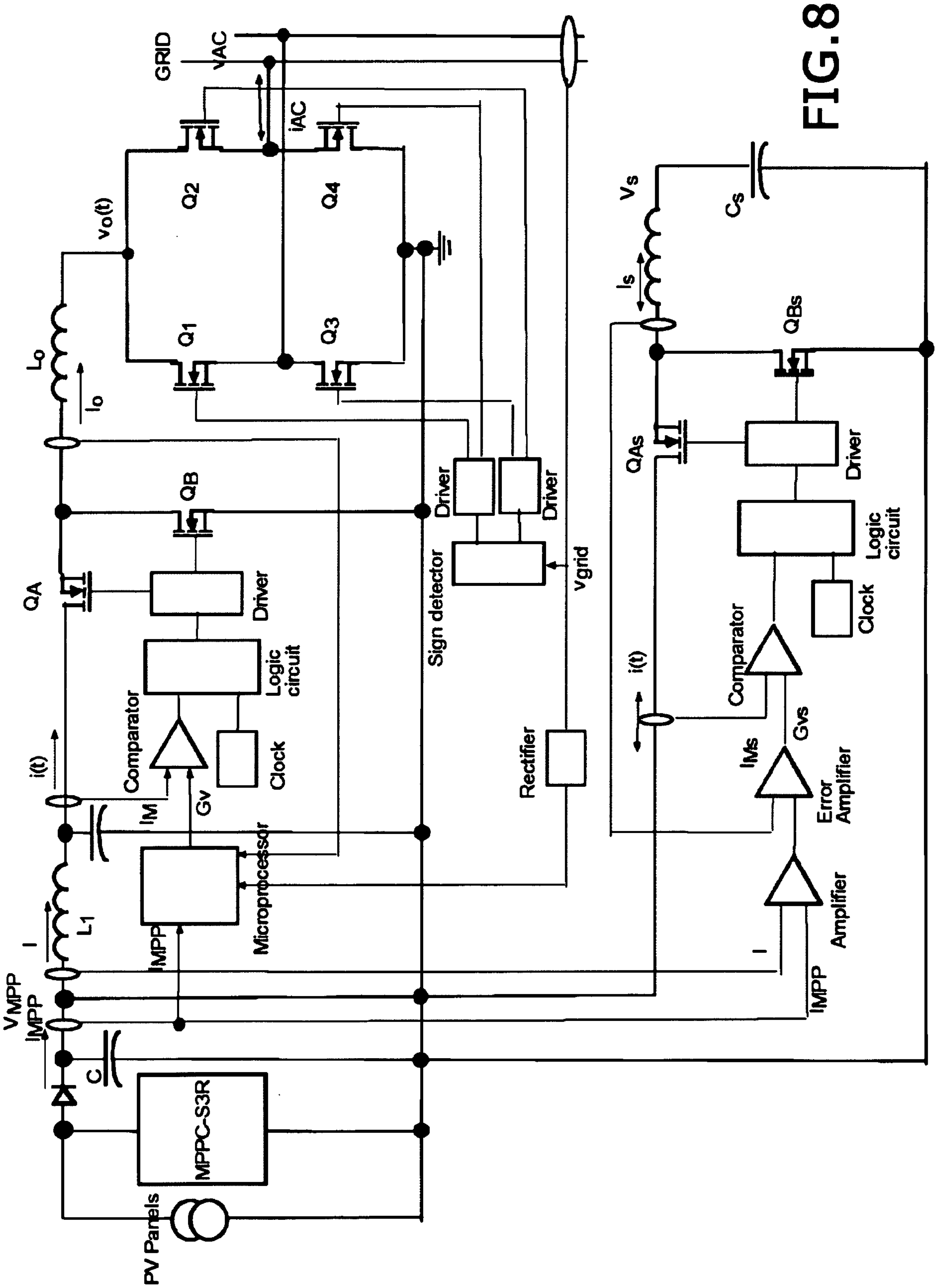

GRID
VAC
iAC
vo(t)
Q2
Q4
Q1
Q3
Lo
Io
QB
QA
Driver
Logic circuit
Comparator
Clock
i(t)
IM
Gv
L1
I
VMPP
IMPP
C
Microprocessor
MPPC-S3R
PV Panels
Sign detector
Driver
Driver
Vgrid
Rectifier
Vs
Cs
Is
QBs
QAs
Driver
Logic circuit
Clock
Comparator
i(t)
Gvs
IMs
Error Amplifier
Amplifier
I
IMPP

FIG.8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/003376

A. CLASSIRCATION OF SUBJECT MATTER
INV. H02J3/38
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)
H02J

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

Electronic data base consulted dumg the international search (name of data base and where practical search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document with indication where appropriate of the relevant passages	Relevant to claim No
X	BANGYIN LIU ET AL: "Design considerations and topology selection for dc-module-based building integrated photovoltaic system" INDUSTRIAL ELECTRONICS AND APPLICATIONS, 2008. ICIEA 2008. 3RD IEEE CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 3 June 2008 (2008-06-03), pages 1066-1070, XP031293888 ISBN: 978-1-4244-1717-9 page 1066, right-hand column page 1067, left-hand column page 1069, left-hand column figures 1,9,13 -----	1,5

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[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 document but published on or after the international filing date

'L' document which may throw doubts on priority ctaim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

'P' document published pπor to the international filing date but later than the pnonty dale 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

'X' document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

'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
29 June 2010	06/07/2010
Name and mailing address of the ISA/ European Patent Office, P B 5818 Patentlaan 2 NL - 2280 HV RI|SWIjk Tel (+31-70) 340-2040, Fax (+31-70) 340-3016	Authorized officer Rocha, Daniel

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/003376

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X	EDELMOSER K H ET AL: "Bi-directional DC-to-DC converter for solar battery backup applications" POWER ELECTRONICS SPECIALISTS CONFERENCE, 2004. PESC 04. 2004 IEEE 35T H ANNUAL AACHEN, GERMANY 20-25 JUNE 2004, PISCATAWAY, NJ, USA 5 IEEE, US LNKD- DOI:10.1109/PESC.2004.1355437, vol. 3, 20 June 2004 (2004-06-20), pages 2070-2074, XP010739590 ISBN: 978-0-7803-8399-9 page 2070 page 2074, left-hand column figures 1,2	1,2,5,6
X	GULES R ET AL: "A Maximum Power Point Tracking System With Parallel Connection for PV Stand-Alone Applications" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, IEEE SERVICE CENTER, PISCATAWAY, NJ, USA LNKD- DOI:10.1109/TIE.2008.924033, vol. 55, no. 7, 1 July 2008 (2008-07-01), pages 2674-2683, XP011226625 ISSN: 0278-0046	1,2
Y	Section III page 2676, right-hand column page 2677, right-hand column page 2678, left-hand column page 2680, right-hand column page 2681, left-hand column figures 3,6,7-9,11,12,14,16	4,9,10
X	HUAN YANG ET AL: "A power conditioning system for a hybrid energy system with photovoltaic and sodium-sulfur battery" ELECTRICAL MACHINES AND SYSTEMS, 2007. ICEMS. INTERNATIONAL CONFERENCE ON, IEEE, PI, 1 October 2007 (2007-10-01), pages 244-247, XP031197240 ISBN: 978-89-86510-07-2	1,5,7
Y	pages 245-246 figure 2	4,8-10
X	IMHOFF J ET AL: "DC-DC converters in a multi-string configuration for stand-alone photovoltaic systems" POWER ELECTRONICS SPECIALISTS CONFERENCE, 2008. PESC 2008. IEEE, IEEE, PISCATAWAY, NJ, USA, 15 June 2008 (2008-06-15), pages 2806-2812, XP031300387 ISBN: 978-1-4244-1667-7 page 2807 figure 2	1,3,5

-/--

C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
Y	JUNG-MIN KWON ET AL: "Grid-Connected Photovoltaic Multistring PCS With PV Current Variation Reduction Control" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, IEEE SERVICE CENTER, PISCATAWAY, NJ, USA LNKD- DOI: 10.1109/TIE.2008.2010293, vol. 56, no. 11, 2 December 2008 (2008-12-02), - 9 October 2009 (2009-10-09) pages 4381-4388, XP011266932 ISSN: 0278-0046 page 4386, left-hand column figure 7	8
Y	ALI KHAJEHODDIN S ET AL: "A Novel topology and control strategy for maximum power point trackers and multi-string grid-connected PV inverters" APPLIED POWER ELECTRONICS CONFERENCE AND EXPOSITION, 2008. APEC 2008. TWENTY-THIRD ANNUAL IEEE, IEEE, PISCATAWAY, NJ, USA, 24 February 2008 (2008-02-24), pages 173-178, XP031253244 ISBN: 978-1-4244-1873-2 figures 2,4,5	8
A	MEINHARDT M ET AL: "Multi-string-converter with reduced specific costs and enhanced functionality" SOLAR ENERGY, PERGAMON PRESS. OXFORD, GB LNKD- DOI:10.1016/S0038-092X(01)00067-6, vol. 69, 1 July 2001 (2001-07-01), pages *ZYl-111*, XP004303022 ISSN: 0038-092X the whole document	1-10
A	DE 199 19 766 Al (SMA REGELSYSTEME GMBH [DE]) 2 November 2000 (2000-11-02) the whole document	1-10

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/003376

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	ALONSO 0 ET AL: "Cascaded h-bridge multilevel converter for grid connected photovoltaic generators with independent maximum power point tracking of each solar array" PESC '03. 2003 IEEE 34TH. ANNUAL POWER ELECTRONICS SPECIALISTS CONFERENCE. CONFERENCE PROCEEDINGS. ACAPULCO, MEXICO, JUNE 15 - 19, 2003; [ANNUAL POWER ELECTRONICS SPECIALISTS CONFERENCE], NEW YORK, NY :; IEEE, US LNKD- DOI:10.1109/PESC.2003.1218146, vol. 2, 15 June 2003 (2003-06-15), pages 731-735, XP010648900 ISBN: 978-0-7803-7754-7 **the whole document** -----	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2009/003376

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19919766 A1	02-11-2000	NONE	