(12)UK Patent Application (19)GB (11) 2 111 691 A

(21) Application No **8234384**
(22) Date of filing
**2 Dec 1982**
(30) Priority data
(31) **3149807**
(32) **16 Dec 1981**
(33) **Fed Rep of Germany (DE)**
(43) Application published
**6 Jul 1983**
(51) **INT CL³ G01R 31/36**
(52) Domestic classification
**G1U** BB
(56) Documents cited
**None**
(58) Field of search
**G1U**
**G1A**
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(54) **Apparatus for determining the power available from a solar generator**

(57) To enable the power, which is dependent upon the isolation at any time, to be determined directly, an apparatus is proposed which is provided with means for so loading the solar generator during a measurement e.g. to the left of load line R that the solar generator operates on a working point at which the generator voltage is less than the voltage at the working point for maximum power MPP, and a measuring system for measuring the current flowing during loading.

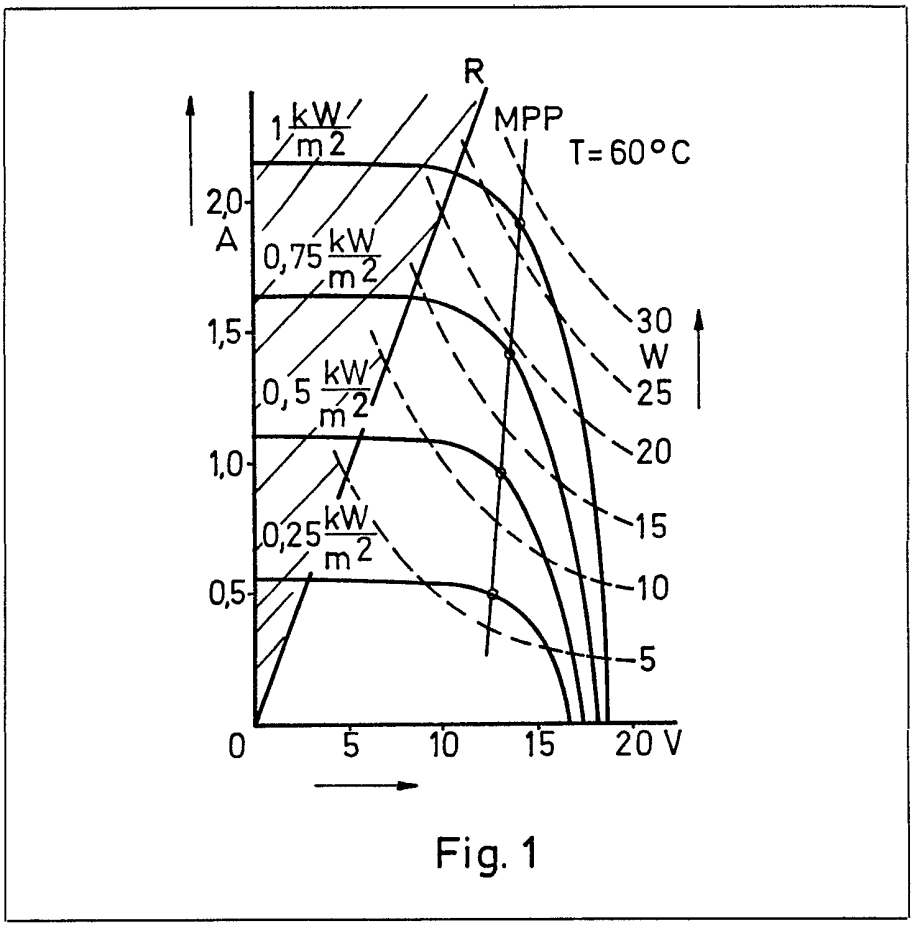


Fig. 1

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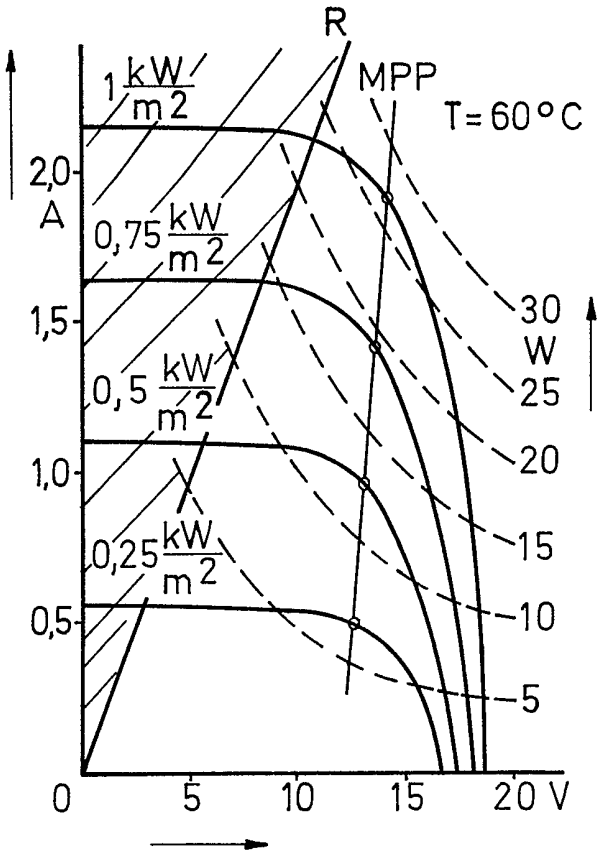
R
MPP
T = 60 °C
1 kW/m2
0,75 kW/m2
0,5 kW/m2
0,25 kW/m2
2,0
A
1,5
1,0
0,5
0
5
10
15
20 V
30
W
25
20
15
10
5

Fig. 1

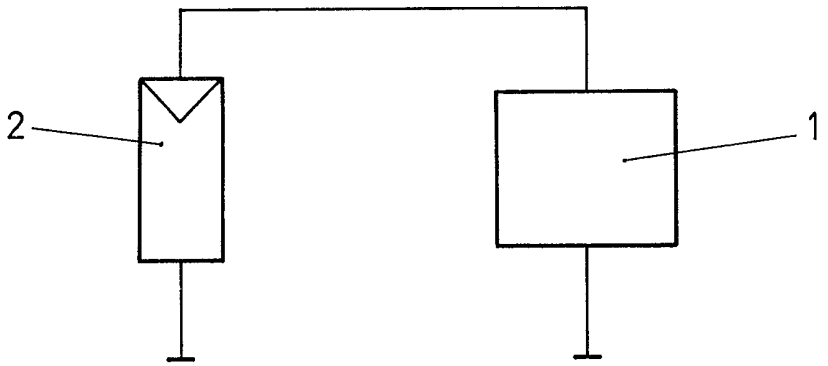
2
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Fig. 2

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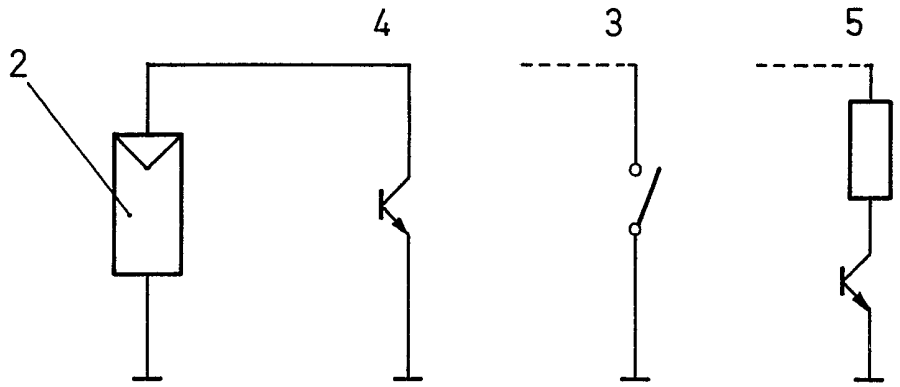


Fig. 3

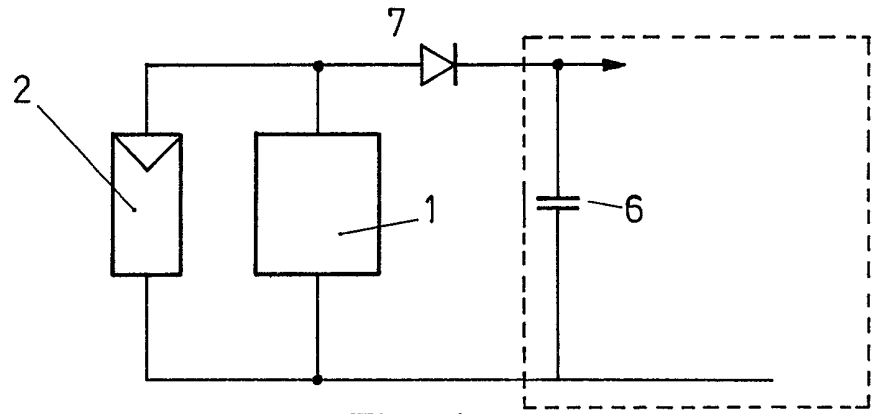


Fig. 4

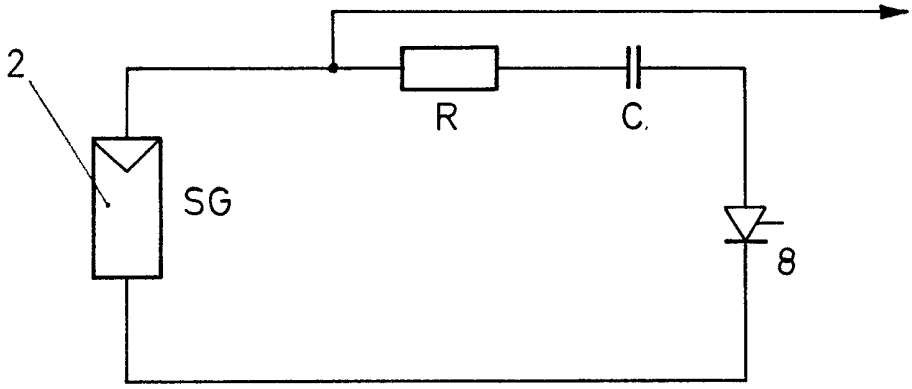


Fig. 5

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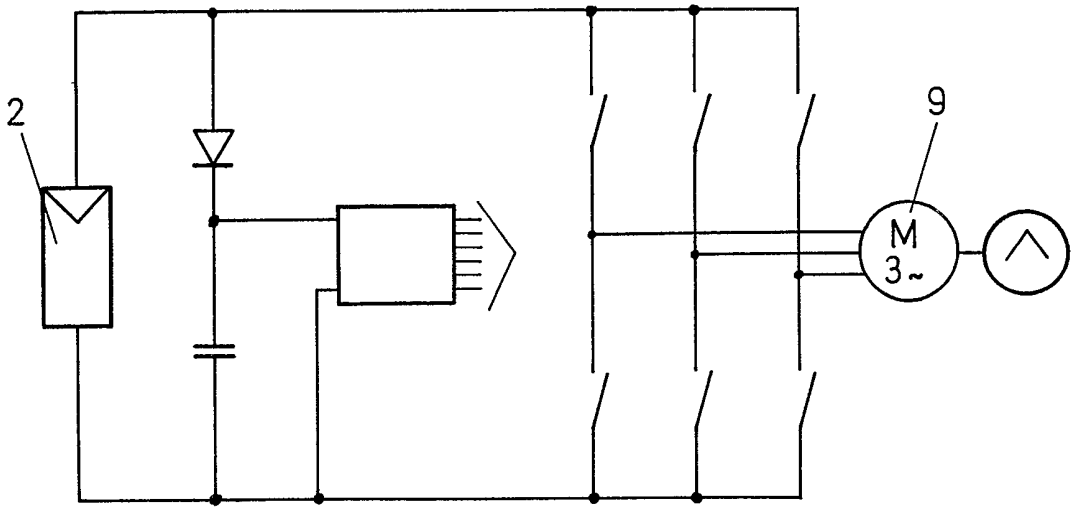


Fig. 6

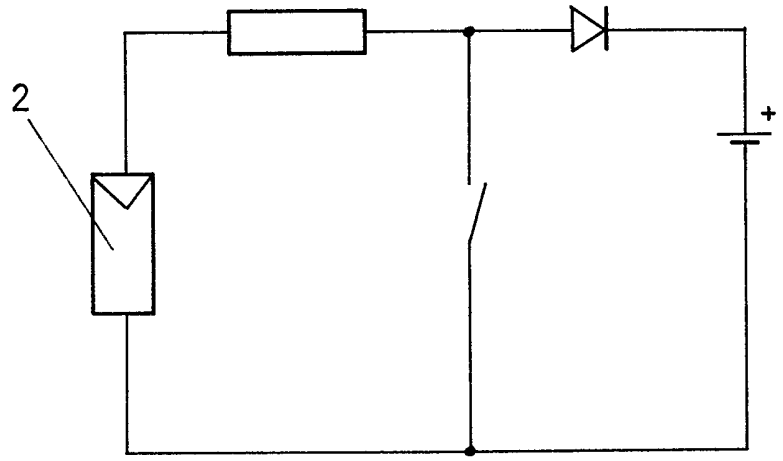


Fig. 7

SPECIFICATION

**Apparatus for determining the power available from a solar generator, and apparatus incorporating such power-determining apparatus.**

This invention relates to an apparatus for detecting the power available from a solar generator, such power being dependent upon the isolation at any time.

The invention also relates to apparatus incorporating a solar generator and such power-determining apparatus.

In supplying electricity to a load such as a battery charger, electrical pumping system, etc., from a solar generator or solar cells, e.g. comprising photovoltaic electrical energy producers, it is often advantageous or even necessary to switch the load on only when the power that the solar generator can deliver has a value equal to or greater than a specific minimum value.

The value of this minimum power depends upon the nature and operation of the electrical load. For example, a battery charger would not be switched on until the solar generator output was higher than the power loss of the appliance. This ensures that the appliance power loss need not be fully or partially covered by the accumulator during periods of low insolation. As another example, an underwater pump powered by a solar generator incorporating photovoltaic energy producers would advantageously not be switched on until the electrical power delivered by the solar generator was sufficient for pumping water,i.e. when the pump power was sufficient to overcome the geodetic head.

Apart from its size (area) and its direction of erection, the power that a solar generator can deliver depends primarily on the insolation at any time and on the temperature of the solar generator. One way of measuring the insolation at any time is to use a separate measuring system having the same direction of erection as the solar generator. Such a system may, for example, be a separate solar cell. A disadvantage of this method of measuring insolation is that the measuring system must be constructed and evaluated separately. Since the measuring system is independent of the solar generator it is not the power actually available at any time from the solar generator that is detected, by only the value provided by the separate measuring system, and this value does not give a direct reading. Fouling, ageing, shading, etc., of the solar generator is also disregarded by this method.

An object of the invention is to provide an apparatus which directly detects the power delivered by a solar generator.

According to the invention, there is provided apparatus for determining the power available from a solar generator, such power being dependent upon the insolation at any time, including means for so loading such solar generator during a measurement that the solar generator operates at a working point at which the voltage provided by the generator is less than the voltage provided at the working point affording the maximum power for the insolation then obtaining, and a measuring system for measuring the current flowing whilst the solar generator is so loaded.

The apparatus according to the invention utilizes the solar generator itself for detecting the power actually available. The invention makes use of the fact that the current produced by a solar generator when operating near the short-circuit point is substantially directly proportional to the insolation at any time.

The no-load voltage of a solar generator, on the other hand, would not provide reliable information as to the insolation or available power, because the no-load voltage varies only little with different degrees of insolation and because the no-load voltage is very dependent upon the temperature. The temperature-dependency of a solar generator current produced near the short-circuit point is low on the other hand.

The invention will be explained in detail with reference to a number of exemplified embodiments illustrated in the drawing wherein:

*Figure 1* is a graph showing the current-voltage characteristics of a solar generator for different values of the insolation.

*Figure 2* is a schematic diagram illustrating a means of loading a solar generator comprising a switch which short-circuits the solar generator for the measurement of available power.

*Figure 3* comprises schematic diagrams which show another three possible ways of loading the solar generator for the measurement of available power.

*Figure 4* illustrates schematically an apparatus operating by means of an electrical appliance connected to a solar generator.

*Figure 5* illustrates schematically a loading means operating by means of a capacitor.

*Figure 6* illustrates schematically a loading means consisting of parts of the connected load circuit and

*Figure 7* illustrates schematically an embodiment using the switch of a power transformer as a loading means.

The diagram shown in Fig. 1 illustrates four current-voltage characteristics of a solar generator (solar cell) as determined with insolations of 0.25 to 1 kW/m2. The characteristics show the maximum power points (MPP). The cross-hatched area to the left of the line R denotes the zone in which the solar generator working point should be situated during the measurement of the available power so that the generator current should provide a good

indication of the available power. It will be noted that the open-circuit voltage of the generator varies but little with the available power.

*Figure 2* shows the simplest method of loading the solar generator. An electrical or mechanical switch 1 is used which short-circuits the solar generator 2 for the period required for the measurement.

If a resistor is connected in series with the switch 1, the voltage drop across this register can be used directly as a measurement of the current flowing and of the possible generator output. Fig. 3 shows three possible ways of loading the solar generator 2, i.e. at 4, a transistor, at 3, a switch, or, at 5, a transistor in series with a resitor.

It is advantageous that the measurement of available power can be performed with a very short measuring time (less than 1 msec), since the solar generator is substantially inductance-free. The measurement can therefore also be carried out during the operation of a connected electrical appliance, (e.g. in order to evaluate breaking conditions in the event of inadequate insolation), by disconnecting the solar generator electrically from the appliance for a very short period during which the short-circuit current, or near-short-circuit current of the generator is measured, after which the appliance is connected to the generator again, and such measurement may, of course, be carried out repeatedly e.g. at regular intervals.

As shown in Fig. 4, an energy store such as a capacitor 6 may be provided for maintaining the power supply to the appliance during such measurement, the energy store, (capacitor 6), being connected across the input of the appliance, and thus across the output of the apparatus powering the appliance, and being decoupled from the solar generator 2, e.g. by means of a diode 7. The capacitor 6 thus provides the energy for the connected appliance during the measuring period.

Fig. 5 shows another advantageous embodiment. In this embodiment the solar generator 2 is loaded, for measurement of the available power, by means of a mechanical or electrical switch 8, a resistor R and a capacitor C, all connected in series across the output terminals of the solar generator. When the switch is closed, a current initially flows in the capacitor C, which is then discharged. This current is determined only by the resistor R and the instantaneous output of the solar generator 2. This current charges up the capacitor C. For measurement purposes it is now possible to utilize, as a measure of the available power, either the current flowing immediately after the switch is closed or the time elapsing, after closure of the switch, until the capacitor C has charged up to a given voltage. An advantage of this arrangement is that the switch may be in the form of a thyristor 8 which cuts off itself when the capacitor is fully charged.

It may also be advantageous not to use a separate loading means but arrange for parts of the connected load circuit of the appliance powered by the solar generator to act as the loading means. Figs. 6 and 7 show two examples:

In the case of electrically powered pumps the solar generator load can be via the electric motor 9, which is powered, for example, via an inverter (Fig. 6). In this case the auxiliary voltage is decoupled from the power stage.

A power transformer, e.g. a step-up transformer, will generally be used in battery chargers etc. The switch of this transformer is used as a loading means in the exemplified embodiment shown in Fig. 7.

CLAIMS

1. Apparatus for determining the power available from a solar generator, such power being dependent upon the insolation at any time, including means for so loading such solar generator during a measurement that the solar generator operates at a working point at which the voltage provided by the generator is less than the voltage provided at the working point affording the maximum power for the insolation then obtaining, and a measuring system for measuring the current flowing whilst the solar generator is so loaded.

2. Apparatus according to claim 1, including a switch adapted for connection to a solar generator and operable, when so connected, to short-circuit the solar generator during the measurement, said measureming system being arranged to measure the short-circuit passing through said switch.

3. Apparatus according to claim 1, wherein said means for loading the solar generator includes a resistor connected in series with a switch and with conductors connectable with a solar generator, the arrangement being such that, with said conductors connected to a solar generator, when said switch is closed, the resistor is connected across the solar generator, said measuring system being arranged to use the volage drop across the resistor as a measurement of the current flowing and of the available generator output.

4. An apparatus including a solar generator, an output, connected with the solar generator, for connection with an input of an appliance, and apparatus according to any of claims 1 to 3 connected with the solar generator for determining the power available therefrom.

5. Apparatus according to claim 4, in which an electrical energy storing device is disposed at said output for connection with the input of such an appliance, such store being decoupled from the solar generator, by decoupling means and being adapted to supply the energy required by a said appliance connected with said output during the mea-

surement of the power available from the solar generator.

6. Apparatus according to claim 5 wherein said de-coupling means is a diode.

7. Apparatus according to claim 1 wherein said means for loading the solar generator includes a switch, a resistor and a capacitor connected in series with conductors for connection to a said solar generator.

8. Apparatus according to claim 7 wherein said measuring system is arranged to use the current which flows immediately after the switch is closed as a measure of the available power.

9. Apparatus according to claim 7 wherein said measuring means is arranged to use the time elapsing after the switch is closed until the capacitor is charged to a predetermined voltage as a measure of the power available.

10. Apparatus according to claim 7 or claim 8 in which the switch used is a thyristor which cuts itself off after the capacitor has fully charged.

11. Apparatus including a solar generator, an appliance connected with the solar generator to be powered thereby, and apparatus according to claim 1 for determining the power available from the solar generator, and wherein parts of the load circuit of said appliance or machine connected to the solar generator are used as said loading means.

12. Apparatus according to claim 11 in which the means for loading the solar generator comprises said machine powered by the solar generator, preferably via an inverter, and in which an auxiliary voltage is branched from the power stage for measurement purposes.

13. Apparatus according to claim 11 in which said appliance is a power transformer used for charging accumulators and the like and a switch of said power transformer is used as loading means.

14. Apparatus for determining the power available from a solar generator, substantially as hereinbefore described with reference to, and as shown in any of Figs. 2 to 7 of the accompanying drawings.

15. Apparatus including a solar generator, an appliance or machine connected therewith to be powered thereby, and means for determining the power available from the solar generator, substantially as hereinbefore described with reference to, and as shown in any of Figs. 4 to 7 of the accompanying drawings.

16. Any novel feature or combination of features described herein.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1983.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.