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## (54) A METHOD AND DEVICE FOR MEASURING THE SOLAR ENERGY RECEIVED AT A PARTICULAR PLACE


(71) We, CENTRE NATIONAL D'ETUDES SPATIALES of 129, Rue de l'Universite, 75 Paris 7, France, a Corporate Body administered by the State do hereby declare this invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:


The invention relates to the measurement of solar energy received at a particular place.

In most applications of solar energy, there is a need for statistical data regarding the distribution of energy in time and space.

The knowledge available at present is either inaccurate or unsuitable for utilising solar energy.

There is therefore a need for an easily transportable, inexpensive measuring instrument which can measure the energy received during a given period, using the same type pick-ups that would be used for the utilisation of the solar energy.

In one aspect the invention provides a method of measuring the solar energy received at a particular place, using a voltage-frequency converter for converting the intensity of energy received at the place into a representative frequency signal adapted to be counted, the signal being sent as an input signal to a counting input of a counter, wherein the counter is switched on by connecting it to an electric supply circuit as soon as the input signal reaches a first preset minimum value corresponding to a morning threshold and the counter is switched off by disconnecting it from the supply circuit when the input signal falls below a second preset value corresponding to an evening threshold which is below the first preset minimum value so that the counter sums the intensity of energy received from the moment when the input signal has reached the first minimum value to the moment when the signal has decreased to the second value.

In a further aspect the invention provides a device for measuring the solar energy received at a particular place, comprising a pick-up which is arranged to receive solar energy and supply an electric signal corresponding to the intensity of the received energy, a converting circuit connected to receive said corresponding signal and convert it to a representative frequency signal, a threshold circuit connected to receive said corresponding signal and arranged to provide a dawn signal corresponding to a morning threshold of energy intensity falling on said pick-up and a dusk signal corresponding to an evening threshold of energy intensity falling on said pick-up, and a counter circuit connected to said converting circuit and to said threshold circuit to count under the control of the threshold circuit the cycles of said representative frequency signal, between the occurrance of said dawn and dusk signals.

In an embodiment of the invention, the converting circuit comprises a voltage controlled-frequency oscillator. Advantageously the ratio of the frequency to the voltage is such that the frequency supplied to the counter is 1 Hz when the solar energy is received at ground level is 1 $W/m^2$.

Advantageously, according to another feature of the invention, the device comprises a printer connected (a) to the counter and (b) to the threshold circuit, to record the contents of the counter, the printer being actuated by the dusk signal.

We shall now, by way of example, describe a preferred embodiment of an aforementioned device, with reference to the accompanying drawings in which:

*Figure 1* is a general block diagram of the device;

*Figure 2* is a more detailed diagram of the device;

*Figure 3* shows a detail of the threshold circuit of the device, and
*Figure 4* is a graph illustrating the operating conditions of the device.

The device shown in Figure 1 comprises:

A solar energy pick-up 1;

an electronic assembly 2 comprising *inter alia* a printer and counter 3 and an independent power supply 9.

The pick-up 1 is for example a photovoltaic solar cell of known type *per se* mounted on a steerable holder.

The photocell is secured to a one-piece holder. It is protected by a plate of glass (not shown) secured by adhesion. The assembly is connected to the electronic assembly 2 by a screened two-wire cable. The cell is electrically energised through a resistor having a value such that the following relation is obtained between the current through the cell and the solar flux falling on the cell: 1 mA $\rightarrow$ 1W/cm$^2$.

The electronic assembly 2 comprises:

A voltage/frequency converter 4, frequency dividers 5 and adaptor means 6 for actuating the printer and counter 3.

A threshold device 7 giving a day/night signal for switching the printer and counter on and off, and an interface 8 between device 7 and the printer counter 3. The printer is a 6-digit electromechanical printer which prints on paper tape. The read-out given by the printer is directly in Wh/m$^2$/day (Watt hours/square metre/day); and

An electrical supply system 9 comprising a panel containing a set of solar cells arranged to charge a storage battery, followed by a converter delivering supply voltages suitable for operating the electronic assembly (alternatively the panel of solar cells is replaced by a device for deriving suitable voltages from the mains).

A more detailed explanation of the operation and structure of the instrument will now be given with reference to Figures 2 - 4.

The aim is to integrate the energy received during a day and record a value for the total.

Pick-up 1 supplies a voltage (useful range 1 mV to 200 mV approx.) proportional to the solar flux received at any instant; this voltage is amplified by an amplifier A1 (Figure 2).

The amplified voltage is used as a parameter for controlling a variable-frequency oscillator, which thus delivers a frequency proportional to the input voltage (e.g. 10 Hz/mV). The amplifier gain and the frequency/voltage ratio are chosen so that the frequency is e.g. 1Hz when the solar energy received at the ground is 1 W/m$^2$. The frequency is divided by 3 600 in frequency divider 5 and the resulting cycles are counted by a counter 10 in the printer and counter unit 3 over a period of time. As a result of the division by 3 600 the summed energy can be counted in Wh/m$^2$ units.

A threshold circuit 11 with hysteresis is provided for detecting the dawn (approx. 15 to 20 W/m$^2$) and dusk approx. 5 W/m$^2$.

Circuit 11 shown in more detail in Figure 3 comprises a differential amplifier A2 having an inverting (−) input and a non-inverting (+) input and wired so as to act as a comparator. Circuit 11 receives the output voltage of amplifier A1, via a resistor R1.

The output of amplifier A2 is either at the level −9V (e.g. by day) or at the level +9v (at night).

At night, therefore, the voltage at its positive input is

$$\frac{R4\ (R2\ +\ R3)}{R2R3} \times\ 9v;$$

if the output of amplifier A1 rises above this value (the first threshold), the output of A2 abruptly changes to −9v, defining a new voltage at the positive input, i.e.

$$\frac{R2R4\ -\ R3R4}{R2R4+R3R4+R2R3} \times\ 9v$$

(the second threshold value).

By day, the voltage at the positive input remains at the same value until, at nightfall, the voltage at the input falls below this value and again flips over the output of amplifier A2.

The threshold is given hysteresis to ensure a clean transition from a "night" state to a "day" state without vacillation on approaching the change-over level.

The output of amplifier A2 is followed by two transistors connected so as to deliver a day signal or a night signal at two separate outputs. During the day the day output is at 9v and the night output is at 0, and vice versa during the night. Consequently, the threshold circuit delivers either a day signal or a night signal.

A monostable 12 (Figure 2) detects the transition from day to night and from it provides an output pulse:

(1) to reset counter 10 to zero and thus start the measuring operation;

(2) to reset to zero the device for dividing by 3 600, and
(3) to energize the controlled oscillator 4 in order to trigger the counting operation by connecting it to the supply 9.

After the zero setting operations have been carried out, counting begins and each incoming pulse is added to the total in the counter.

At night, the threshold circuit detects the corresponding threshold ($5W/m^2$) which, because of the hysteresis, is lower than the dawn threshold.

A monostable 13 detects the day/night transition and provides an output pulse to actuate the printer, which thereupon prints out the contents summed in the counter.

Monostable 13 is also connected to disconnect the oscillator, to prevent the counter from changing state during the recording operation (since this may result in faulty printing).

Consequently, the counter sums the number of $Wh/m^2$ received during the day or, more precisely, the number of $Wh/m^2$ received from the moment $H_D$ when the received energy reaches the minimum morning threshold to the moment $H_A$ when the energy has decreased to the minimum evening threshold.

By way of example, the curve in Figure 4 shows the variation with time in the current 1 supplied by the pick-up during a day.

If we take the nominal value of the solar illumination received at ground level in fine weather with an ambient temperature of 25°C, the day threshold discussed above is chosen to correspond to 2% of this value and the night threshold $H_A$ to correspond to 0.5% of this value. Of course, the values can be modified as required.

Apart from its simplicity, a measuring instrument according to the invention has the advantage of operating at very low power cost, since its operation is limited to the useful recording periods.

WHAT WE CLAIM IS:

1. A method of measuring the solar energy received at a particular place, using a voltage-frequency converter for converting the intensity of energy received at the place into a respresentative frequency signal adapted to be counted, the signal being sent as an input signal to a counting input of a counter, wherein the counter is switched on by connecting it to an electric supply circuit as soon as the input signal reaches a first preset minimum value corresponding to a morning threshold and the counter is switched off by disconnecting it from the electric supply circuit when the input signal falls below a second preset value corresponding to an evening threshold which is below the first preset minimum value so that the counter sums the intensity of energy received from the moment when the input signal has reached the first minimum value to the moment when the signal has decreased to the second value.

2. A method as claimed in Claim 1, in which the morning threshold is used to trigger the resetting of the counter to zero before triggering the operation of the voltage-frequency converter.

3. A method as claimed in Claim 1 or 2, in which the evening threshold is used to trigger the counter to printout the accumulated value therein after the voltage-frequency converter has been switched off.

4. A device for measuring the solar energy received at a particular place, comprising a pick-up which is arranged to receive solar energy and supply an electric signal corresponding to the intensity of that received energy, a converting circuit connected to receive said corresponding signal and convert it into a representative frequency signal, a threshold circuit connected to receive said corresponding signal and arranged to provide a dawn signal corresponding to a morning threshold of energy intensity falling on said pick-up and a dusk signal corresponding to an evening threshold of energy intensity falling on said pick-up and a counter circuit connected to said converting circuit and to said threshold circuit to count under the control of threshold circuit the cycles of said representative frequency signal, between the occurrence of said dawn and dusk signals.

5. A device as claimed in Claim 4, in which said converting circuit comprises a voltage controlled-frequency oscillator.

6. A device as claimed in claim 5, in which the ratio of the frequency produced by said oscillator to the voltage applied to it is subjected so that the frequency is 1 Hz when the solar energy intensity received at ground level is 1 $W/m^2$.

7. A device as claimed in Claim 4, 5 or 6, including a frequency divider interposed between said converter and said counter circuit for dividing the frequency by 3 600 so that each counting unit represents 1 $Wh/m^2$.

8. A device as claimed in Claim 4, 5, 6 or 7 including a printer connected to said counter and to said threshold circuit, the printer being adapted to record the contents of the counter and being actuated by the dusk signal.

9. A device as claimed in any one of Claims 4 to 8, in which said threshold circuit is arranged so that the morning and the evening threshold are independently adjustable.

10. A device as claimed in any one of Claims 4 to 9, in which said threshold circuit provides said dawn signal when the solar energy intensity falling on said pick-up passes through a value chosen from the range 15 - 20 $W/m^2$.

11. A device as claimed in any one of Claims 4 to 10, in which said threshold circuit provides said dusk signal when the solar energy intensity falling on said pick-up passes through a value of approx. 5 $W/m^2$.

12. A method of measuring the solar energy received at a place substantially as herein described with reference to the accompanying drawings.

13. A device for measuring the solar energy received at a place substantially as herein described with reference to the accompanying drawings.

KILBURN & STRODE,
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Agents for the Applicants.

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1589114 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

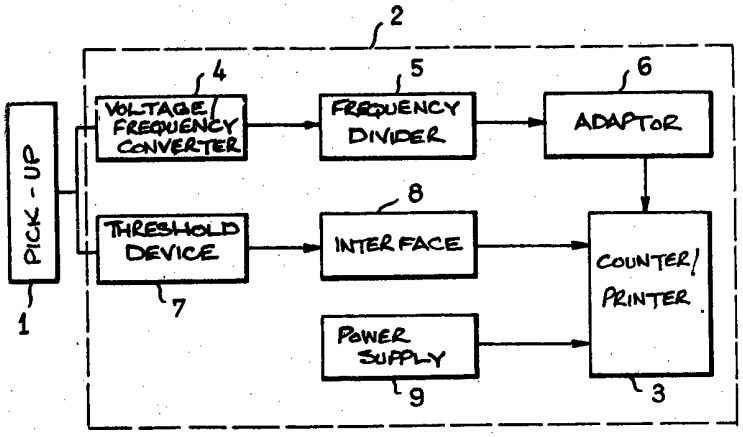


FIG_1

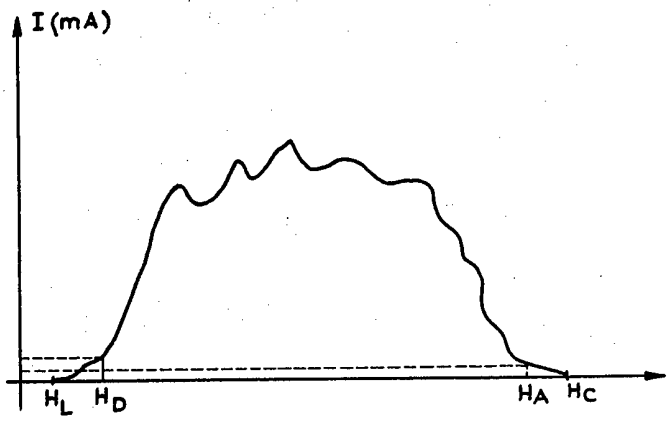


FIG_4

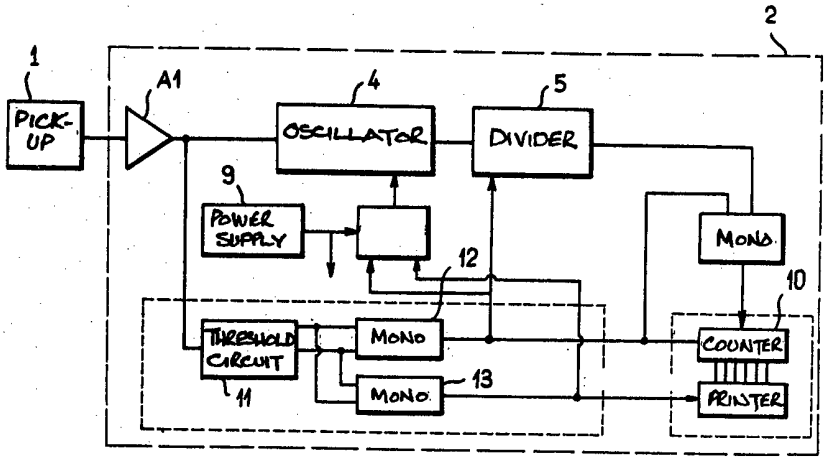
2
1
PICK-UP
A1
4
OSCILLATOR
5
DIVIDER
9
POWER SUPPLY
MONO
12
10
THRESHOLD CIRCUIT
11
MONO
13
COUNTER
PRINTER

FIG_2

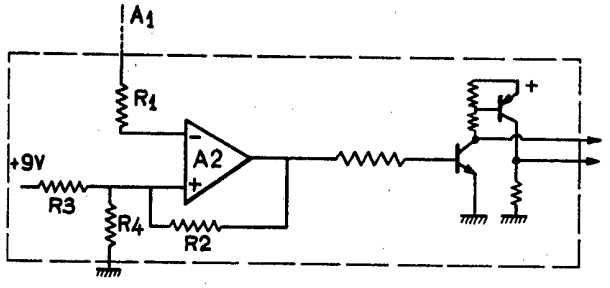
A1
R1
+9V
R3
R4
R2
A2

FIG_3