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Method and arrangement for operating a pump

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(57) ABSTRACT

A method of operating a pump system, the pump system including a pump arranged to be rotated with an AC motor, an inverter, the output of which is electrically connected to the AC motor and a photovoltaic panel system electrically connected to feed DC power to an inverter. The method includes setting a voltage limit (Vboost), determining continuously voltage obtained from the photovoltaic panel system, when the determined voltage of the photovoltaic panel system is below the set voltage limit, controlling the output frequency of the inverter such that the ratio between output voltage of the inverter and the output frequency is substantially constant, and when the determined voltage of the photovoltaic panel system exceeds the voltage limit (Vboost), controlling the output frequency of the inverter for keeping the voltage of the photovoltaic panel system substantially at the voltage limit.

(Figure 1)

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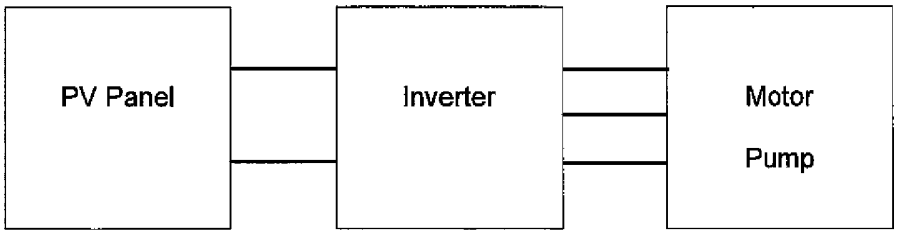

FIG 1

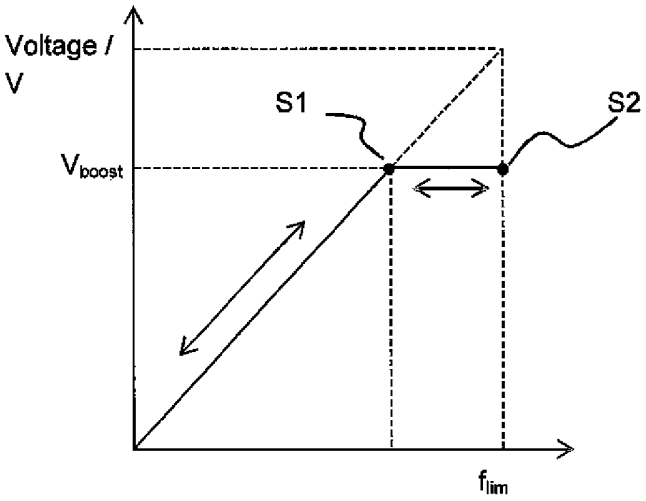

FIG 2

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METHOD AND ARRANGEMENT FOR OPERATING A PUMP

FIELD OF THE INVENTION

The present invention relates to pumping systems, and more particularly to pumping systems employing solar power.

BACKGROUND OF THE INVENTION

Photovoltaic panels or photovoltaic panel systems are largely employed in generation of electricity. Conventional way of using a photovoltaic panel is to charge a battery with the panel, and use the energy from the battery for electrical supply. The energy from the battery is well-regulated, i.e. the voltage available from a battery is known and substantially constant DC voltage.

The charging of the battery can be carried out efficiently using a charging controller having a maximum power point tracker (MPPT). MPPTs are used for driving the charging controller to the operating point in which maximum amount of power can be extracted from the panel.

If the energy from the panel system is used in driving a motor load, a motor controller is further needed. Motor controller can be, for example an inverter that produces alternating voltage from the DC voltage source. The alternating voltage can be employed to drive an alternating current motor, such as an induction motor. One typical use of alternating motors is to use them for rotating pumps in pumping applications.

When the solar panel system or photovoltaic panel system is used solely for pump applications, then the above described typical way of providing alternating voltage to a pump is quite complicated and requires multiple of electrical components. The number of required components makes the structure expensive and also vulnerable.

BRIEF DESCRIPTION OF THE INVENTION

The present invention is aimed at providing a method and/or arrangement for operating a pump.

The invention is based on the idea of using the available DC voltage from the photovoltaic panel system directly at the input of the inverter, and controlling the output frequency of the inverter based on the available DC voltage.

Once the DC voltage reaches a set voltage as per V/f ratio, the output frequency is increased, the voltage is controlled to be substantially at the limit value by changing the output frequency of the inverter.

An advantage of the method and arrangement is that a simple structure is obtained and the properties of the photovoltaic panel system are still fully utilized. In

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the arrangement, the output of a photovoltaic panel system is directly connected to the input of an inverter, and the inverter is further connected to feed an AC motor. The motor is driven with an alternating voltage and the frequency. The voltage/frequency ratio depends on the voltage obtained from the photovoltaic panel system. Once the voltage from the panel system exceeds available limit, then the operation of the pump drive is continued by increasing the output frequency and keeping the voltage substantially constant. The frequency can be increased as the photovoltaic panels are essentially current sources and are able to produce current for operating the motor even when the voltage of the panels has not increased to the rated voltage. The photovoltaic panel can deliver maximum power when the voltage has reached to maximum limit and photovoltaic panel has current capacity available. The solar pump drive will settle at maximum power point, deviating from standard voltage / frequency curve by increasing frequency – keeping voltage constant and drawing more current from the photovoltaic panels.

With the foregoing in view, the invention in one aspect resides broadly in a method of operating a pump system, the pump system including a pump arranged to be rotated with an AC motor, an inverter, the output of which is electrically connected to the AC motor and a photovoltaic panel system electrically connected to feed DC power to an inverter, the method including:

setting a voltage limit (Vboost),

determining continuously voltage obtained from the photovoltaic panel system,

when the determined voltage of the photovoltaic panel system is below the set voltage limit, controlling the output frequency of the inverter such that the ratio between output voltage of the inverter and the output frequency is substantially constant, and

when the determined voltage of the photovoltaic panel system exceeds the voltage limit (Vboost), controlling the output frequency of the inverter for keeping the voltage of the photovoltaic panel system substantially at the voltage limit.

In another aspect the invention resides broadly in a pump arrangement including a pump arranged to be rotated with an AC motor, an inverter, the output of which is electrically connected to the AC motor and a photovoltaic panel system electrically connected to feed DC power to an inverter, wherein the arrangement includes means for setting a voltage limit (Vboost), means for determining continuously voltage obtained from the photovoltaic panel system, means for controlling the output frequency of the inverter such that the ratio between output voltage of the inverter and the output frequency is substantially constant, when the determined voltage of the photovoltaic panel system is below the set voltage limit, and means for controlling the output frequency of the inverter for keeping the voltage of the photovoltaic panel system substantially at the voltage limit, when the

determined voltage of the photovoltaic panel system exceeds the voltage limit (Vboost).

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which

Figure 1 shows a schematic block diagram of the arrangement of the invention, and

Figure 2 shows a V/f-curve and operation points.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows how a photovoltaic panel system is connected to the input of an inverter. As known, photovoltaic panels produce DC voltage and this DC voltage is directly used by the inverter. An inverter produces alternating voltage from the inputted DC voltage. Typical way of producing AC voltage is to use pulse width modulation (PWM) in which positive and negative DC voltage are alternately connected at the output. When the durations of positive and negative pulses are altered for each output phase, an alternating voltage with a desired frequency can be obtained at the output of the inverter.

According to the invention, an AC motor is connected at the output of the inverter and a pump is mechanically connected to the AC motor. The rotation of the motor drives the pump and carries out pumping operation. In the example of Figure 1, the inverter produces a three-phase output voltage for a three-phase motor.

According to the invention, the control of the output frequency of the inverter is carried out on the basis of the inputted voltage when the voltage is below a set limit. When the voltage is below the set limit Vboost, the ratio between the output voltage of the inverter and output frequency of the inverter is kept substantially constant as shown in Figure 2. The constant ratio between the output voltage and output frequency (constant Volts / Hertz; V/f) is generally known in the art of motor control. This control method keeps the torque of the motor constant, and in known method, the control is applied throughout the speed range up to nominal speed of the motor. In a typical case the full nominal voltage is available, and depending on the required rotational speed, the inverter is modulated in such a manner, that suitable voltage is outputted from the inverter so that the V/f ratio is constant.

As mentioned, in the present invention, the output frequency of the inverter is determined based on the available voltage from the photovoltaic panel system, and the idea is to use all the energy available for the pumping process. In the invention, a voltage limit Vboost is set. When the DC output voltage from the panel system exceeds the set DC voltage limit in the controller, the operation is continued by increasing the output frequency of the inverter and keeping output voltage supplied

to the motor substantially constant. The output voltage of the inverter and the obtained DC voltage from the panel depend on each other, and for simplicity Figure 2 shows the inverter output voltage. In Figure 2, operation point S1 shows a point in which the operation in the constant V/f mode is discontinued. The output voltage of the inverter is kept substantially constant until voltage reach the point S2.

The increase of the output frequency leads to increase in power demand of the motor. As known the required power is the product of the required torque and the rotational speed. In a pump application the torque will change with the square of the rotational speed. When the output frequency of the inverter, i.e. the rotational speed of the pump, is increased, the required torque of the motor increases with the square of the speed change. The operation point of the motor is no longer in the constant V/f operation point. The required torque is produced by increasing the current supply to the motor from the photovoltaic panel system. Photovoltaic panels are in essence current sources and current from the panel is proportional to the radiation received by the panel.

For keeping the power balance between input and output of the inverter, the generated power needs to match the used power. If the voltage of the input to the inverter is substantially constant, then the power change needs to be compensated by changing current. As mentioned above, the increase of rotational speed of the pump requires change of torque. The torque needs to be produced with the supplied current from the panel. If the available power from the panel system is exceeded, the voltage of the panel will collapse. Thus by changing the output frequency, while monitoring the voltage at the output of the panel system, pump output can be kept at a maximum level. When the frequency is increased and the voltage is not collapsing, the PV-panel is able to provide the required amount of current. If the measured voltage starts to go down, the output frequency of the inverter is reduced thereby reducing the amount of current drawn from the panel.

The output frequency of the inverter is preferably limited to the nominal value of the controlled motor. In such a case the increase in voltage reduces the current from the panel system. The operation point of the inverter varies between operation points S1 and S2 shown in Figure 2 when the voltage is substantially constant.

According to an embodiment of the invention, when the output voltage from the panel system exceeds the available limit, the output frequency of the inverter controlled to be higher by multiplying the output frequency reference by a constant factor. This increase of output frequency increases the required power and thereby the current drawn from the panel system.

In another embodiment, a controller is used for changing the output frequency of the inverter depending upon the available DC voltage and for keeping the V/f ratio constant. In this embodiment the controller follow the V/f ratio below the Vboost. Above the Vboost curve the controller will not follow the V/f curve. The controller will

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increase the frequency, even if the voltage is constant. Thus controller utilizes the maximum available current in the PV cell. Once the voltage falls below this Vboost then the controller once again follow the V/f curve. This will ensure that there is limited impact the PV cell when there is sudden decrease in the DC voltage.

In the present invention, the properties of a photovoltaic panel system are utilized fully even if the voltage of the photovoltaic panel does not reach its maximum value.

The arrangement of the invention includes a pump arranged to be rotated with an induction motor, an inverter, the output of which is electrically connected to the induction motor and a photovoltaic panel system electrically connected to feed DC power to an inverter. The induction motor is a three-phase motor. Further, the arrangement includes means for setting a voltage limit Vboost and means for determining continuously voltage obtained from the photovoltaic panel system. The means for setting the voltage limit can be for example arranged in the inverter as a programmable setting and the value is stored in the inverter. Similarly, the means for determining the voltage obtained from the panel system is incorporated as a measurement in the inverter. The inverter continuously measures the input voltage.

The arrangement further includes means for controlling the output frequency of the inverter such that the ratio between output voltage of the inverter and the output frequency is substantially constant, when the determined voltage of the photovoltaic panel system is below the set voltage limit. Preferably the inverter includes a control scheme which produces maximal output voltage from the input DC voltage and changes the output frequency of the voltage according to the level of the output voltage.

Further, the arrangement includes means for controlling the output frequency of the inverter for keeping the voltage of the photovoltaic panel system substantially at the voltage limit, when the determined voltage of the photovoltaic panel system exceeds the voltage limit Vboost. The controller is preferably implemented in the inverter.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of operating a pump system, the pump system including a pump arranged to be rotated with an AC motor, an inverter, the output of which is electrically connected to the AC motor and a photovoltaic panel system electrically connected to feed DC power to an inverter, the method including:

setting a voltage limit (Vboost),

determining continuously voltage obtained from the photovoltaic panel system,

when the determined voltage of the photovoltaic panel system is below the set voltage limit, controlling the output frequency of the inverter such that the ratio between output voltage of the inverter and the output frequency is substantially constant, and

when the determined voltage of the photovoltaic panel system exceeds the voltage limit (Vboost), controlling the output frequency of the inverter for keeping the voltage of the photovoltaic panel system substantially at the voltage limit.

2. A method according to claim 1, including:

setting a frequency limit (flimit), and

limiting the output frequency of the inverter to the frequency limit.

3. A method according to claim 1 or 2, wherein when the determined voltage of the photovoltaic panel system is above the set limit, the method includes:

controlling the voltage of the photovoltaic panel system by changing the output frequency of the inverter.

4. A method according to claim 1, characterized including:

providing a frequency reference for the inverter output frequency,

multiplying the frequency reference with a constant factor when the determined voltage of the photovoltaic system exceeds the set limit, and

controlling the inverter with the multiplied frequency reference.

5. A pump arrangement including a pump arranged to be rotated with an AC motor, an inverter, the output of which is electrically connected to the AC motor and a photovoltaic panel system electrically connected to feed DC power to an inverter, wherein the arrangement includes means for setting a voltage limit (Vboost), means for determining continuously voltage obtained from the photovoltaic panel system, means for controlling the output frequency of the inverter such that the ratio between output voltage of the inverter and the output frequency is substantially constant, when the determined voltage of the photovoltaic panel system is below the set

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voltage limit, and means for controlling the output frequency of the inverter for keeping the voltage of the photovoltaic panel system substantially at the voltage limit, when the determined voltage of the photovoltaic panel system exceeds the voltage limit (Vboost).

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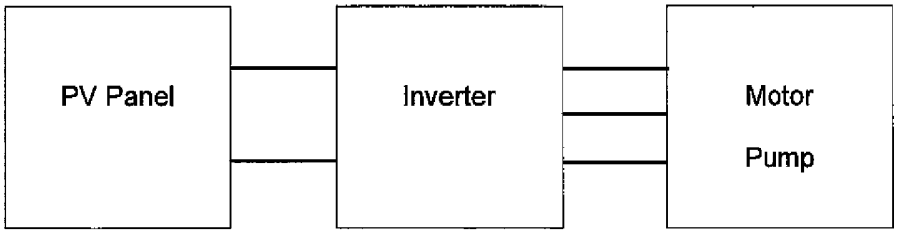

FIG 1

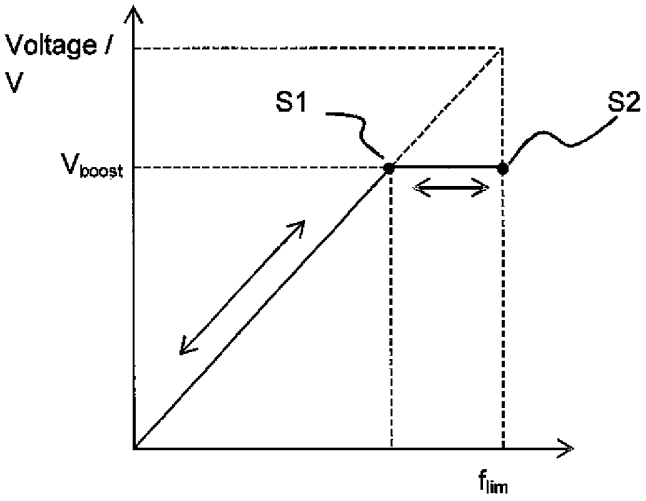

FIG 2