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Design of Wearable Agricultural Solar-powered Sprayer for Remote Areas

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Abstract

Solar Energy is the present and the future for Egypt. In remote areas, spraying pesticides is done by hand work and fuel sprayers. Solar-Powered Sprayer (SPS) is an innovative product developed for agricultural applications, which utilizes the solar energy as a fuel to be used for spraying the pesticides, Fungicides and Fertilizers. The solar energy is stored in the Lead Acid batter which powers DC pump and LED and the pump is used for extracting the atmospheric air with solute flow to the hose to the nozzle. In the nozzle, both the solute and pressurized air are mixed for spaying. LED Lamp is powered by the stored energy for nightly use for near lighting. The conventional sprayers cost EGP 3,500, but the developed Solar-Powered one costs only EGP 1,100[2]. This Proposed model presents an efficient and economical way of spraying pesticides, Fungicides and Fertilizers and this model .is more reliable and durable for the future

Keywords: *Solar Panel, Battery, Photovoltaic, Agriculture, Pesticide, Spraying*

1. Introduction

Energy is the most essential of all resources. All the energy we use on Earth comes from fission or fusion of atomic nuclei or from energy stored in the Earth. The problem with both fission and fusion is that they have dangerous radioactivity and side effects [3]. Therefore, most of the generation of energy in our modern industrialized society is strongly depending on very limited non-renewable resources, particularly fossil fuels. As the world's energy demand rises and resources become rare, Searching for alternative energy resources has become an important issue for our time. Also rapid growth in energy consumption is the major necessary over the past few years. The energy reserve is limited and is not sufficient to meet the growth in energy demands. Though the fossil fuels are currently available in large quantities, they eventually will finish and on the other hand, the use of fossil fuels leads to environmental worries such as global warming and Climate change. This sounds a serious issue and requires important attention. To deal this issue, renewable energy sources like solar, wind, biomass and fuel cells are the only alternatives remain

Agriculture is very important for the human needs, ensuring food production, and ecosystems, as well as for social and economic development and for sustainable cities. Energy is the most essential of all resources. All the energy we use on Earth comes from fission or fusion of atomic nuclei, or from energy stored in the Earth. The problem with both fission and fusion is that they have dangerous radioactivity and side effects [3]. Therefore, most of the generation of energy in our case industrialized society strongly depends on very limited non-renewable resources, especially fossil fuel. As the world's energy demand rises and resources become rare, the search for alternative energy resources has become an important issue for this century

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among the different clean energy technologies, the most effective and peaceful energy source is solar energy. The use of new efficient photovoltaic solar cells (PVSCs) has emerged as an alternative measure of renewable green power, energy conservation and demand-side management. Owing to their high initial cost, PVSCs have not yet been fully an attractive alternative for electricity users who are able to buy cheaper electrical power from the utility grid. However, they can be used extensively for water pumping and air conditioning in remote and rural areas, where [utility power is not available or is too expensive to transport [4 The previous inventions small scale solar sprayers are used on mechanical hand spraying or using the fossil fuels (petro – Gasoline – Kerosene) to spray the solute. The main disadvantage of Mechanical Hand Sprayer is the effort which is used for increase the pressure inside the tank which causes damage in the mechanical hand in the sprayer and the main disadvantage of fossil fuels sprayer is the exhaust gases which affect dangerously the human-being's health, the fossil fuel also adds more weight to it, the exhausting noise and vibration from the fossil fuel engine which harm human's ear, the operating cost and durability. As this solar-powered sprayer is powered by photovoltaic solar cells there is no need for the users to use fossil fuels for spraying or increasing their effort by pushing the mechanical hand. This paper will be the permanent solution for this issue and will be more efficient one.

2. Background and Inventions

Recently, research work was focused on developing the smart agricultural sprayers for small-scale application, which does not have any serious effects on the users. Earliest work from the history clearly says that there has been a remarkable increase in the development for new technique in agricultural sprayer for small-scale application. Initially the powder pest was sprayed by the users with their bare hand. After that, hand sprayer or mechanical sprayer was introduced in early 1960's. In early 1980's Power sprayer came in the market, as an evolutionary version of hand sprayer. Power sprayer is powered by either petrol/kerosene, which drives the DC pump for spraying the solute. For a litre of Petrol 0.78 Acre of land can be covered and in a litre of kerosene 0.50 Acre of land can be covered [5], [8], [18].

In the year of 2010, electric power sprayer introduced. However, from the legacy was mentioned above, can be revealed that none of them is sustainable. In case of hand sprayer, the solute sprayed over the land by the raw hand, pest spraying leads to affect the farmer's health condition. It is worse either by intake of it or by the wounds in their hand. At the same time, hand sprayer farmers should use their fingers in the nozzle to produce the pressure, this leads to create severe hand pain. While considering the power sprayers the weight of the system, operational cost and contamination are major drawbacks. Also the vibration and over weight of the system harm the spinal cord of farmers. To handle those all above mentioned, we designed and implemented agricultural solar-powered sprayer. As it uses the solar power as its main power source, no fossil fuel is needed, no manual pressure is needed and it does not harm users at all. Table 1 shows a comparison of the various types of sprayers.

Table 1. Comparison between the various types of solar sprayers:

	Manual	Fossil Fuel	Solar Power
	No Power Needed	Large Tank	Clean, Sustainable
	Low Cost	Long Continuous	High Pressure
	Common	Spraying	Silent Spraying for Poultry
		High Pressure	Wearable
		Mass Usage	Useful for
			Remote areas
			Nightly-Work
			Zero Operating Cost
			Useful for UPS
Pros			Handy cost
	Low Pressure	Low durability	Absence of Awareness
	Need continuous	Pollution	Wrong treatment and

Cons	pressurizing		Maintenance
	Easy damage in Components	High operating costs	
	Low durability	High cost	
	No Nightly-Work	Need to Fuel Continuously	
	Cannot spray high objects	Large Size and Weight	

3. Characteristics of PV Panel

The solar cell is the basic unit of the photovoltaic panel (PVP). It is the responsible part of transforming the sun photon's energy directly into electrical energy by photovoltaic effect.[10] Nowadays, there are various types of solar cells made with different characteristics are available in the market. These models have varying electrical and physical characteristics depending on the manufacturer. The most commonly used element in the fabrication of solar cell is silicon. [1]

3.1 Solar cell characteristics

The solar cell is simply a diode with large-area forward biased with a photovoltage. The photovoltage is created from the dissociation of electron-hole pairs created by incident photons within the built in field of junction or diode. PV cell is made of semiconducting materials such as silicon that can convert sunlight directly into electrical power and it is usually covered with anti-reflective materials so that it absorbs the maximum amount of light energy. When sunlight strikes the cell, it liberates electrons within the material which then produce DC current. When light becomes incident on a photovoltaic cell without voltage bias (i.e., short-circuit), it creates electron-hole pairs absorbing photons [1] which create a short circuit current (Isc) proportional to the incident light. When both light and voltage bias (i.e., a load connected) are available, the photovoltaic cell current I is the difference between the short circuit current and the dark current ID. This is shown in the equivalent circuit in Fig.1 where the shunt resistance is usually very high and the series resistance is small.

The operating current of the solar cell is given by

$$I_{diode} = I_o(e^{(qV/KT)} - 1) \quad [1]$$

$$J_{pv} = J_{sc} - J_{diode} \quad [2]$$

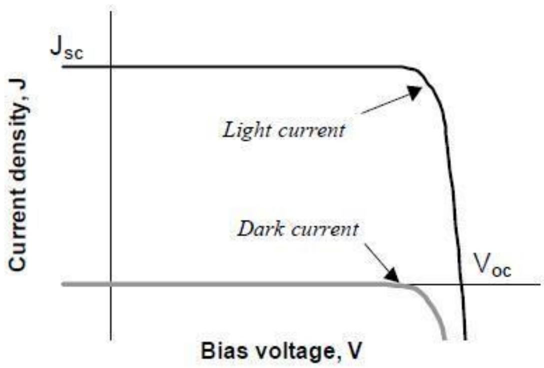

Figure 1. The effect of light on the current-voltage characteristics of a p-*n* junction

Under darkness, the solar cell is not an active device. It works primarily as a diode. Externally, the solar cell is an energy receiver that does not produce either a current or a voltage. Under this condition: if the solar cell is connected to an external supply, theory shows that the voltage and current are related by the diode equation given by

$$I_d = I_o[\, e(qV/KT) -1] \quad [3]$$

$$I_L = I_{sc} - I_o\,(e(qV/KT) - 1) - I_{sh} \quad [4].$$

Where, I_{sc} is the photocurrent in Amperes, I_L is the output current of solar cell in Amperes I_{sh} is the shunt branch current in Amperes, I_d is the diode current in Amperes, I_o is the saturation current in Amperes q is the electric charge in Coulombs, K is the Boltzmann's constant in Joules/ Kelvin T is the junction temperature in Kelvin.

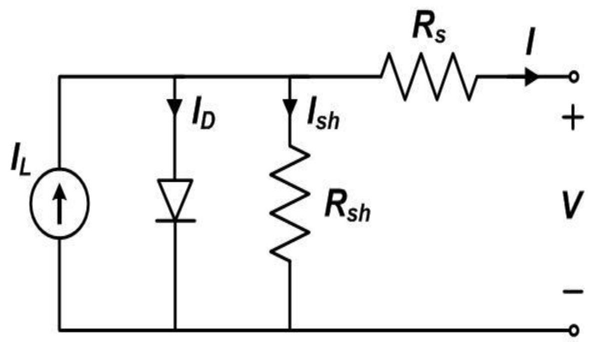

Figure 2. Solar cell circuit model

3.2 Electrical characteristics of Solar cell

The short-circuit current (I_{sh}) occurs on a point of the curve where the voltage is zero, $V = 0$, $I_{sh} = I_L$. Note that I_{sh} is directly proportional to the available sunlight and at this point, the output power of the solar cell is zero. The open circuit voltage (V_{oc}) occurs on a point of the curve where the current is zero. The maximum power output occurs at point 'P_{mpp}' on the curve shown in Figure 2. The point

'P_{mpp}' is usually referred to as the "knee" of the I-V curve

$$V_{oc} = \frac{nKT}{q}\ln(\frac{I_L}{I_o} + 1) \qquad [5]$$

$$V_{mp} = V_{oc} - \frac{nkT}{q}\ln\left(\frac{Vmp}{\frac{nkT}{q}} + 1\right)V_{mp} = V_{oc} - \frac{nkT}{q}\ln\left(\frac{Vmp}{\frac{nkT}{q}} + 1\right) \qquad [6]$$

For example, if $n = 1.3$ and $V_{oc} = 600$ mV, as for a typical silicon cell, V_{mp} is about 93 mV smaller than Voc.

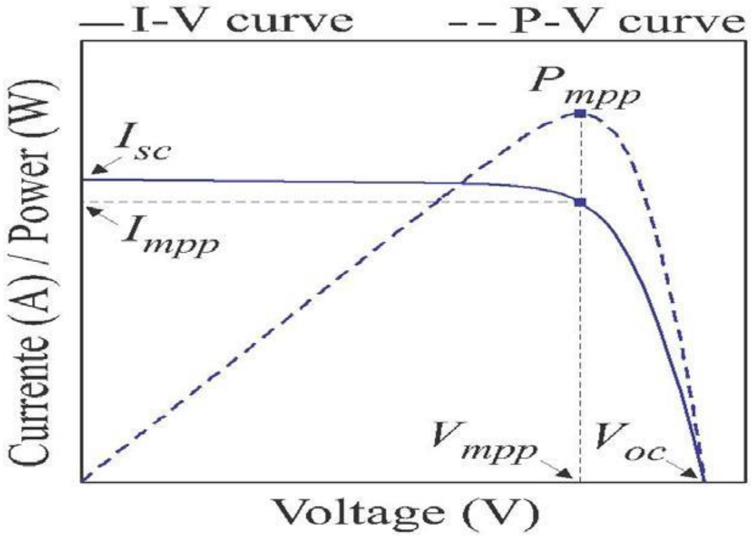

Figure 3. Typical representation of an I-V curve, showing short-circuit current (I^{scsc}) and open-circuit voltage (V^{ococ}) points, as well as the maximum power point (V^{mpmp}, I^{mpmp}).

The power output at the maximum power point under standard test conditions (STC) (1000W/m2) is known as the ‘peak power' of the cell. Hence photovoltaic panels are usually rated in terms of their peak watts (Wp).

The *fill factor* (*FF*), is a measure of the cell quality and series resistance of a cell. It is defined as

$$FF = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}} \quad [7]$$

$$P_{mp} = V_{oc} I_{sc} FF \quad [8]$$

PV cells are combined to make panel that is covered with glass or clear plastic. Panels can be tied together to make an array that is sized for a specific application. The produced power varies with sun radiation and cells' temperature. If the latter is held constant, this power variation results in a variable current at a fixed voltage. Increasing (decreasing) temperature significantly reduces (increases) PV array's voltage and slightly increases (decreases) current that leads to reduce (increase) the generated power.

The temperature dependency of *Voc* for silicon is approximated as shown in Figure 4:

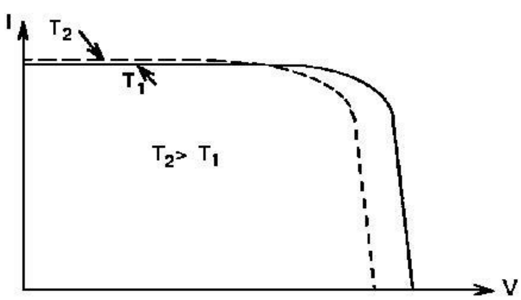

Figure 4. Representation of variance of current and voltage with variance of temperature

This paper is composed of six parts, which include:

1) Solar panel is comprised of PV cells. PV cells are made of semiconducting materials that can convert sunlight directly into electricity. When sunlight strikes the cells, it excites and liberates .electrons within the material which then move to produce a DC current.

2) Solar photovoltaic system are able to produce electricity only when the sunlight is available, therefore stand-alone systems obviously need some type of backup storage which makes them available through the night or bad weather conditions or a certain number of autonomy days for indoors use. Among many backup storage technologies, the lead-acid battery is the most suitable battery for this application because it is relatively inexpensive, produced in high capacity, variable discharging rate and widely available. As well as the control of the operating load voltage is in battery's output voltage's range, so that load receives voltages within its own range of permeability [6], [16], the starting torque in the DC motor is high, but this motor reduces it [5], [7].

3) The pump runs directly from the battery with DC current so that the inverter is not needed, the pump is attached to anti-vibration mounting for backbone's safety. This type of design is to allow the sprayer to stand upright on the ground. This pump is able to spray liquid from 0.3 litres to 3 litres per minute with the help of the nozzle. An on/off tap is also attached to the delivery tube. Starting torque is high in Dc motor and this will give a good starting pressure. [12], [18]

4) Mini inverter for small home uses, its power is 100w for lighting and small applications. It gives the consumer a small UPS for home's usage in electricity cutout time for remote areas and a solar-powered sprayer in spraying time.

5) Charge controller for safety and securing a long life time for the battery, it maintains optimal generated power from sun radiation and differentiate with MPPT technology between current and voltage to achieve the maximum output power, it gives a larger output power for cold climate use.

6) Liquid tank is used to store the solute in liquid form. Intake is given from the top of the tank and outlet is taken from bottom of the tank that insures a good pressure for the user.

IV. STRUCTURAL BLOCK

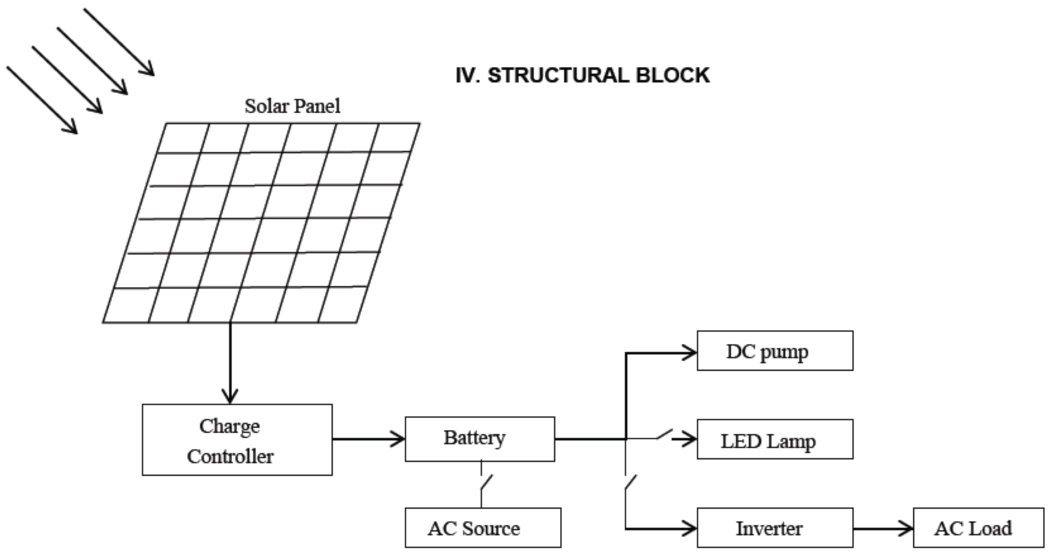

Figure 5: Structural Block of Proposed System

5. Hardware Components

Solar panel is 20W (17.2 Volt, 1.16 Amps). The characteristics of the 20 W solar photovoltaic panel is given in Table 2:

Table 2: Characteristics of the 20 W solar photovoltaic panel

Pmax	20W
Voc	21.6V
Vmp	17.2V
Isc	1.31A
Imp	1.16A
No. of Cells	36
Operating Temperature	40C to 80C-

Charge controller has ratings 5A 12/24V, takes the solar panel's output and regulates it to the battery.
The regulated power is stored in the lead-acid battery, which is 12V and 10Ah. It is charged from solar panel at day and charge from AC source with adaptor 12V 1A at night.

Light Emitter Diode (LED) Lamp is 12V, 200mA and 200 Lumens for close lighting. It is connected to the battery and turned on at night by the user.

The inverter is 100W and connected to the battery through on/off switch, it is normally off and when the users is need an electricity backup system for their home, they switch it on.

The liquid tank that contains the solute is 47 cm in length, 35 cm in width, 10 cm in thickness and 16 Litres in volume. It has a belt for wearing on the back. The characteristics of the DC pump is given in Table 3.

Table 2: Characteristics of the DC Pump

Rated Voltage	12V
Rated Current	1A
Pressure	3Bar
Noise	20dB
Operating Temperature	20C to 80C-
Voltage Range	3V to 14

6. Operation of Proposed System

In this proposed system, the sunrays are directly received by the solar panel, which has the ability to convert the light into electric power. The output power of the panel is given to solar charge controller which has maximum power point tracking technique to control the voltage and the current to obtain the battery's charging voltage to prevent the battery from over charging and also increase the battery's life time then, it is sent the lead- acid battery. The battery stores the energy and supplies to the sprayer (for day/night times also). The output of the battery is given to the DC pump, the pump pulls the liquid from the tank and pressurizes it with 3 bar to the nozzle through hose. The designed solar-powered sprayer has the ability to spray the solute up to 4 meters above the ground.

6.1 Features of the proposed model

- The operation and maintenance cost of solar-powered sprayer is negligible compared to the other models

- Useful for agricultural sector in remote areas and poultry sector without any need of another power source
- Silent Spraying for Poultry
- Environmentally friendly
- Wearable
- Useful uninterrupted power system (UPS)
- Effective and economic use of electricity and water
- Highly reliable
- Durable
- Simple to install

7. Conclusions

This developed model has smaller weight, negligible harm to users and a capability of working day and night times. It can be used as an uninterrupted power system (UPS) during electricity's cutout time and it is charged from AC source at night with adaptor. It is a forward step to endow rural agricultural areas. The main advantage of this developed system is, it does not affect user's health by any ways and also it is friendly to ecological system. By increasing the investments in clean and renewable energy sources, we can build a pure and secure future for the world.

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