Standalone solar-powered ultraviolet mobile disinfectant: Bringing solar energy in the global fight against COVID-19

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Abstract

As the first initiative of its kind in Algeria, here is presented a solar-powered mobile "Ultraviolet Germicidal Irradiation" disinfection unit (UVGI) based on a special germicidal ultraviolet-C (UVC) radiator. The system was designed to disinfect several objects such as: medical tools, reusable masks, face-shields, gloves, phones, laptops, keys, money and many other portable devices that need to be disinfected/sterilized. It offers the advantage of complete autonomy through the built-in photovoltaic (PV) system that includes a solar panel, a gel battery, a charge controller and a power inverter. The system provides an extra 220V-50Hz outlet with 375VA maximum power to be used when energy is needed. The system is easily scalable to generate higher ultraviolet dosages by adding more UVC lamps. The chemical-free germicidal UVC sanitizing method employed by this device effectively disactivates a very wide range of microorganisms (microbes, bacteria and fungi and viruses including the actual SARS-CoV-2 that causes COVID-19 respiratory disease) and it has several advantages in comparison to chemical-based sanitizing methods. The total cost to make this open source device is below 1000 € and is easily customizable and scalable. This device is an open source, secure and fast equipment for objects and surface disinfection. The device will be fully automated by adding PIR sensors or remote control after further funding will be received.

Keywords: *Solar energy, photovoltaics, UVGI, UVC, COVID-19, coronavirus, SARS-CoV-2*

I. Introduction

The global struggle and fight against the actual pandemic caused by the rapid spread of the SARS-COV-2 coronavirus that causes COVID-19 disease is endorsed by every possible scientific, medical and technical advance humanity have ever achieved. Governments worldwide are counting on both prevention and treatment aspects in order to slow the spread of the coronavirus on one hand, and on the other hand, funds and subsidies from private and public sectors are mobilized to support the revived research and development in the quest for an effective vaccine that could save us from such a virulent pandemic. For example, artificial intelligence is exploited to predict and simulate every possible chemical formula that can be used to reach the vaccine through self-learning algorithms and virtual experimentation. Recently a chemical that can slowdown the spread of the coronavirus has been discovered by AI and reported [1] [2]. Robotics abilities are exploited to execute some tasks that require remote and distant operations such as delivery of medical tools and drugs within hospitals and cleaning some infected sites among many

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other tasks in the same objective [3]. Many university groups and scientific clubs in Algeria are fabricating face-shields, masks, hand sanitizers, disinfection corridors, and many other equipment that are distributed to the hospitals in order to help the medical staff to fight the pandemic. For example, the "WE ALGERIANS" initiative has already delivered thousands of face masks and shields to hospitals and many of its sub-teams are fabricating medical ventilators. 3D-printers as another example have allowed the innovation of many devices such as artificial respirators and ventilators, flexible face shields, reusable masks and other devices. During this week, the Algerian government has issued new laws and directives imposing wearing masks for all citizens, as a consequence, shortages of this medical masks are likely predicted, therefore, our device will help solving this problem where using a chemical-free sterilizing process would be beneficial to quickly sterilize these masks within seconds while avoiding the use of wet chemical disinfectants that may cause skin irritations and allergies. Many other reusable devices will as well need such a quick and safe physical sterilization.

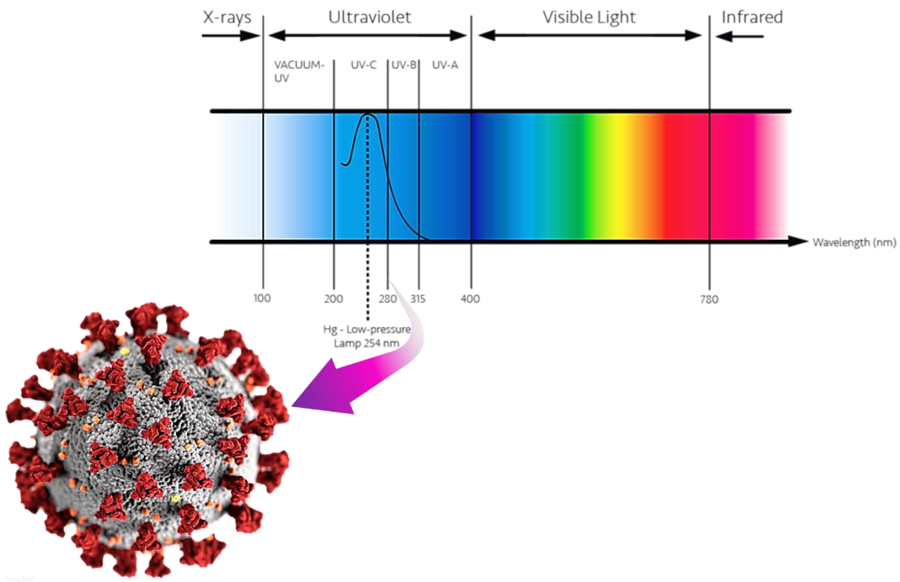

Figure.1. electromagnetic spectrum showing the UVC range and the appropriate wavelength of 254nm that is able to disactivate the actual SARS-COV-2 coronavirus.

Ultraviolet germicidal irradiation (UVGI) is a well-known chemical-free disinfection process, often defined as the use of the third ultraviolet range, namely UVC (which have wavelength within the germicidal range (λ=200–280 nm)) for air and surfaces disinfection, see Fig.1. UVC radiation has the power to disactivate microorganisms such as microbes, bacteria, fungi and viruses (including the actual SARS-CoV-2 responsible of COVID-19) by causing DNA damage and preventing their replication [4]. Historically, the term 'UVGI' was originally coined by the International Commission on Illumination (CIE) and adopted later by the Centers for Disease Control (CDC), and this term distinguishes disinfection applications from the nongermicidal UVA wavelengths of black lights and suntan lamps (320–400 nm). UVGI is also used to distinguish air and surface disinfection applications from those in water. The full history and timeline of UVGI development has been detailed by Wladyslaw Kowalski [4]. Recently, several studies have shown that UVC can disactivate coronaviruses, including severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV). It was also reported in a recent study that the actual SARS-CoV-2 was effectively disactivated by higher doses of UVC [5, 6]. In this work, we have designed and fabricated a mobile stand-alone photovoltaic system that carries one 36W UVC disinfection lamp which will be delivered to a local hospital as a prototype. The device joints the advantages of using abundant solar energy and UVGI disinfection capabilities. The system provides an extra amount of electrical power that can for example charge other mobile devices or supply other disinfection corridors that spray special chemicals often placed at the entrance of hospitals or medical care houses, or where electricity is not all the time available (cases of far sites, emergency or blackout).

II. Hardware description

The stand-alone photovoltaic system includes a 160Wp polycrystalline silicon solar panel (JONSOL, Germany), a PWM charge controller with 10A nominal current (STECA, Germany), a solar power inverter with 12V input voltage and 220V-50Hz output pure sinewave signal with a nominal power of 375VA (VICTRON Energy, The Netherlands). The battery is a sealed Gel-VRLA (valve regulated lead acid) type with 12V voltage and 100Ah capacity (1200Wh energy) (JARRET, China). The solar panel support is 23° inclined, the whole frame consists of PV panel support and the back part includes small room for the battery and the inverter to be included in, this cavity is well aired as the bottom consists of a solid stainless-steel fence, the upper part integrates a cavity that contains the UVC radiator. The charge controller is fixed on the outer side of the box in order to allow constant monitoring of the battery level and the charging flow status. An extra AC waterproof outlet is fixed beneath the charge controller that provides extra power from the inverter. The UVC radiator is simply controlled by switch fixed on the outer right side of the device. This will be developed in the future and replaced by a PIR detector to allow a fully automatic well-timed control. For security a DC switch is placed between the solar panel and the charge controller, and an AC switch is placed between the power inverter and the devices it supplies (radiator and the outlet). The inverter has its own protective DC fuse. The construction of the device is somehow simple and includes two main steps: metallic scaffolding construction and electrical assembly.

III. Configuration and setup

III.1. The UVC radiator

Here, we have used a commercial UV-C radiator that contains built-in power supply (ballast) which have a programmable timer in order to set the required disinfection time, and one quartz low-pressure mercury lamp to produce UV-C radiation (Germany). Figure.2 shows the actual used radiator. This tube provides 36W of power and can be acquired separately in the case of replacement or can be used in other devices as well. The radiator is built as one stainless steel case that have a door used to protect the lamp after usage. Two ways to fix the UVC radiator into the scaffolding can be used, the first one is to have it attached to the facing wall where the UV rays are emitted to the outside. The second one (which we adopted) is to attach the radiator into the upper side of the UVC box in a way to have the UV rays emitted towards the bottom plate, this is way safer and well adapted to attack the treated surface directly.

Figure.2. The used UV radiator having a 36W quartz UVC lamp, a manually programmable and on/off switch.

III.2. The photovoltaic system

The UVC lamp has 36W nominal power, if we assume around 8 operation hours per day that means that the required energy is E_{tot}= 36 x 8 = 288 Wh. The battery of 100Ah capacity delivers E_{batt}=12V x 100Ah= 1200Wh of energy which is largely sufficient for UVGI disinfection for several hours (at least 30h) without recharging. However, the system has been sized to deliver an extra amount of energy when needed. The VRLA-Gel battery will be not deeply discharged. With a 160Wp panel, to recharge a completely empty battery around 8 hours are needed (160 Wp x 8h =1280 Wh), if the battery is partially discharged, let's say 50%, then only four hours are sufficient to full charging. The metallic frame of the device is designed in such a way that the solar panel is inclined by 23° deg, and that is not an ideal tilting angel for the southern part of Algeria (Laghouat city) which has 33° deg of latitude angle, however, since the system is mobile, sun can be tracked

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manually, the design will be improved in the next design. The framework is built with 2mm thick steel and painted with a special anti-rust paint to resist against corrosion and humidity, then a colorful paint was applied. Trolley wheels are soldered to allow the mobility of the device. Figure.3 illustrates the simplified wiring diagram of the device.

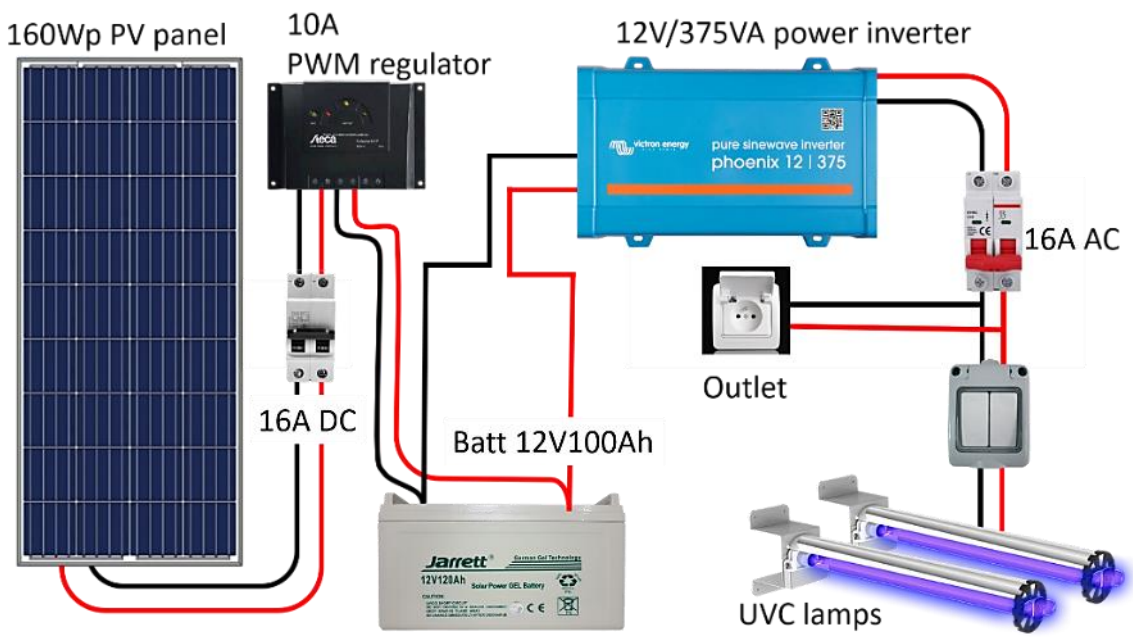

Figure.3. simplified wiring diagram of the Pv-powered UVD disinfection device. Between the UVC radiator and the inverted, PIR sensors or remote controllers will be added later.

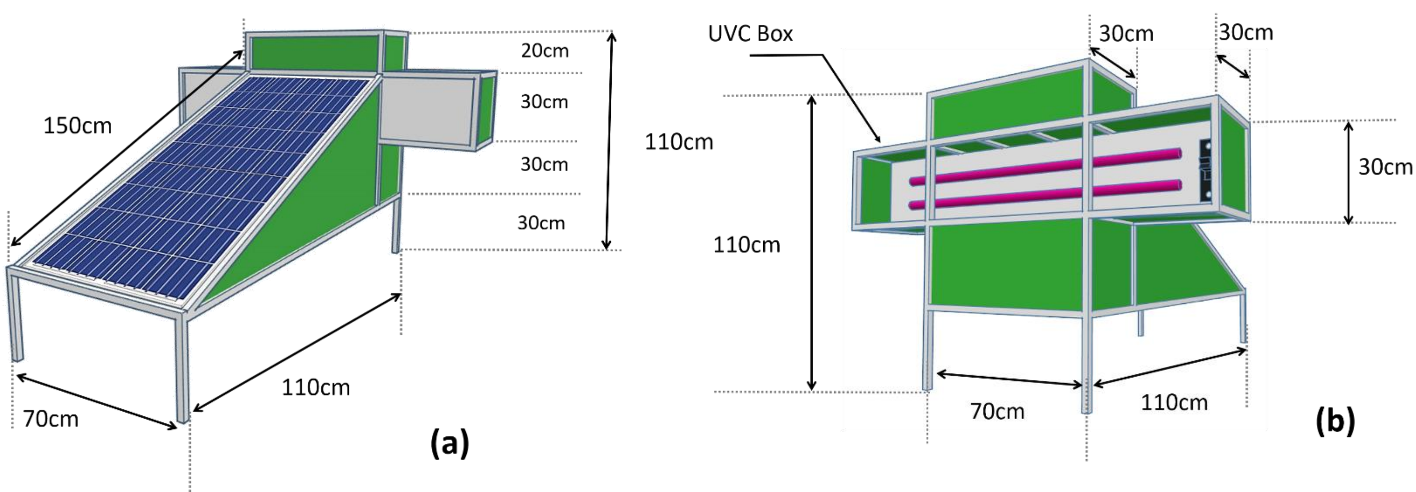

Figure.4. 3D models view of the attended finished product. Tolley wheels are soldered afterwards under the four stands of the scaffold to allow the mobility.

Figure.5. Unfinished product under construction. The final prototype will be ready next weeks and the manuscript will be updated accordingly.

IV. Operation

The mobile device was tested to disinfect several objects such as face shields and masks, smartphones and medical tools. The operation is made easy by a simple On/Off switch for several seconds according to recommendations by. Figures.4(a) and 4(b) illustrate the 3-d model of the unit along two different view angles with the respective dimensions. Figure.5 shows the unfinished system that is still under construction (will be updated later). The charge and discharge cycles were perfectly working the extra outlet was tested by plugging a powerful LED floodlight of 300W plus charging a smartphone with 18W fast charger.

V. Conclusion

In this work, a standalone PV-powered UVC disinfectant device was conceived and constructed in the aim of bringing solar photovoltaic energy into the fight against COVID-19 pandemic. Our device is simple to build and easily movable, it can be used for hospitals entrances (indoor and outdoor), it can also be used in other places as needed to provide concise and efficient chemical-free disinfection. The device will be further developed by an automatic control of the UVC lamps through PIR sensors, and should be further supplied with microcontrollers to allow remote Wi-Fi or Bluetooth monitoring and control. We hope that this work will contribute to the global fight against COVID-19 by at least the available knowledge and materials.

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